# **KORESPONDENSI PAPER**

JUDUL: Anthropometry indicators that are most related to metabolic profiles in female college students

JURNAL : Food Research

Status : Jurnal Internasional Terindeks Scopus SJR 0,233

# **AKTIFITAS KORESPONDENSI**

No	Aktifitas	Tanggal	Halaman
1.	Submit article	1-9 April 2021	1-30
2.	Review dan Revisi Artikel	8 April 2021	31-147
3.	Accepted	27 September 2021	148
4	Copyediting dan galleyproof	2 Mei 2022 - 18 Mei 2022	149-245
5.	Article Published	22 Mei 2022	246

# Submit article

kepada Food 👻

Manuscript Submission 🏓

\$ @ C

📼 Kam, 1 Apr 2021, 13.48 🟠 🕤 🚦

Dear Editorial Board Food Research

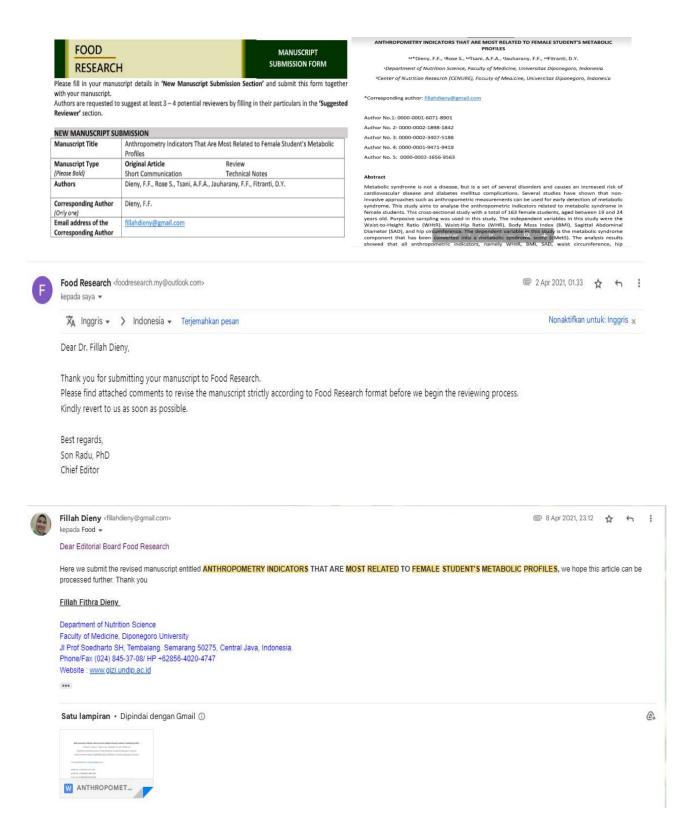
Fillah Dieny <fillahdieny@gmail.com>

Here we submit the manuscript with the title ANTHROPOMETRY INDICATORS THAT ARE MOST RELATED TO FEMALE STUDENT'S METABOLIC PROFILES, we hope this article can be processed further. Thank you

# Fillah Fithra Dieny

Department of Nutrition Science Faculty of Medicine, Diponegoro University JI Prof Soedharto SH, Tembalang, Semarang 50275, Central Java, Indonesia. Phone/Fax (024) 845-37-08/ HP +62856-4020-4747 Website: <u>www.ojcl.undip.ac.id</u>





Manuscript ID: FR-2021-250 🔉 Kotak Masuk x	× ¢	3 0	
Food Research <foodresearch.my@outbok.com> kepada saya ↓</foodresearch.my@outbok.com>	@ 9 Apr 2021, 16.19 ★ ←	n :	
🕱 Inggris 🔹 🗲 Indonesia 👻 Terjemahkan pesan	Nonaktifkan untuk: Ingg	Nonaktifkan untuk: Inggris 🗶	
Dear Dr. Fillah Fithra Dienv.			

This message is to acknowledge receipt of the above manuscript that you submitted via email to Food Research. Your manuscript has been successfully checked-in. Please refer to the assigned manuscript ID number in any correspondence with the Food Research Editorial Office or with the editor.

Your paper will be reviewed by three or more reviewers assigned by the Food Research editorial board and final decision made by the editor will be informed by email in due course. Reviewers' suggestions and editor's comments will be then made available via email attached file. You can monitor the review process for your paper by emailing us on the "Status of my manuscript".

If your manuscript is accepted for publication, Food Research editorial office will contact you for the production of your manuscript.

Thank you very much for submitting your manuscript to Food Research.

Sincerely,



9<sup>th</sup> April 2021

Authors: Dieny, F.F., Rose S., Tsani, A.F.A., Jauharany, F.F. and Fitranti, D.Y.

Manuscript title: Anthropometry indicators that are most related to female student's metabolic profiles

Manuscript ID: FR-2021-250

Dear Dr. Fillah Fithra Dieny,

This message is to acknowledge receipt of the above manuscript that you submitted via email to Food Research. Your manuscript has been successfully checked-in. Please refer to the assigned manuscript ID number in any correspondence with the Food Research Editorial Office or with the editor.

Your paper will be reviewed by three or more reviewers assigned by the Food Research editorial board and final decision made by the editor will be informed by email in due course. Reviewers' suggestions and editor's comments will be then made available via email attached file. You can monitor the review process for your paper by emailing us on the "Status of my manuscript".

If your manuscript is accepted for publication, Food Research editorial office will contact you for the production of your manuscript.

Thank you very much for submitting your manuscript to Food Research.

Sincerely,

Son Radu, Ph.D. Chief Editor Email: foodresearch.my@outlook.com

# 1 Anthropometric Profile and Its Correlation to Insulin Resistance in Female Students with Obesity

# 2 Abstract

The prevalence of obesity in adolescent girls is increasing each year. Several anthropometric 3 measurements can be used to detect the incidence of insulin resistance. This study aims to observe the 4 5 correlation of anthropometric profiles with insulin resistance in adolescent girls with obesity. This was an observational study with a total of 120 female students of Universitas Diponegoro (Undip), aged 6 7 between 18 and 21 years old, who have waist circumference >80 cm. They were chosen by a simple 8 random sampling technique. Anthropometric profile data taken was has consisted of waist 9 circumference, hip circumference, waist-hip circumference ratio (WHR), waist-to-height ratio (WHtR), 10 neck circumference, wrist waist circumference, thigh circumference, and 2D:4D digit ratio. Insulin 11 resistance data was determined using the Homeostasis Model Assessment-Insulin Resistance (HOMA-IR.). Bivariate analysis was completed with the Spearman Rank test. There was 83.3% of subjects who 12 13 experienced insulin resistance. High WHtR was found in 98.3% of total subjects as many as 90.8% of 14 subjects were at risk based on WHR values. Based on 2D:4D ratio digits, neck circumference, wrist 15 circumference <50% of subjects were found as at risk. There was no correlation between waist 16 circumference, WHR, wrist circumference, 2D:4D digit ratio with HOMA-IR (p>0.05). However, there was 17 a positive correlation between WHtR, neck circumference, and thigh circumference with HOMA-IR 18 (p<0.05) Anthropometric profiles such as WHtR, neck circumference, and thigh circumference were 19 correlation correlated of insulin resistance in female adolescent with obesity. 20

21 Keywords: Adolescent; Anthropometric Indicator; Insulin Resistance; Obesity.

# 22

# 23 1. Introduction

24 Nutritional status in adolescents is very important since adolescence is a transition period from children to adulthood. This transition causes biological, psychological and cognitive changes that 25 26 influence their nutritional status (Brown et al., 2011). However, nutritional status problems in 27 adolescents are still fairly high, including obesity. The Prevalence of central obesity 15 years 28 adolescents and older has increased from 26.6% in 2013 to 31% in 2018 (Badan Penelitian dan 29 Pengembangan Kesehatan, 2018). Obesity incidence will later be associated with degenerative 30 diseases. Women is are at higher risk of suffering from degenerative disease, while Indonesian Basic 31 Health Research 2018 results reports the prevalence of stroke, diabetes mellitus, heart disease, and 32 hypertension is found higher in women than men (Badan Penelitian dan Pengembangan Kesehatan, 33 2018). Indonesian Basic Health Research 2018 results also states state that women and people live 34 in urban areas of all ages have high prevalence of diabetes mellitus (Badan Penelitian dan 35 Pengembangan Kesehatan, 2018).

Type 2 diabetes mellitus is caused by insulin resistance, a condition in which patient's body is unable to absorb glucose (Srikanthan et al., 2016). Study in Semarang City showed that 96.1% of adolescents experienced insulin resistance which was measured by Homeostasis Insulin Resistance Assessment Model (HOMA-IR) (Nuraini et al., 2017). HOMA-IR is a formula for calculating insulin Commented [A1]: Edit all those marked in RED to follow Food Research format revised

Formatted: Highlight

Formatted: Highlight

Commented [A2]: What are the conclusions of this study?

Commented [A3R2]: Anthropometric profiles such as WHtR, neck circumference, and thigh circumference were correlated of insulin resistance in female adolescent with obesity.

$\langle 1 \rangle$	
1//)	Commented [A4]: a simple
<u>,    )</u>	Commented [A5R4]: revised
1/1/	Commented [A6]: has consisted
, \\\	Commented [A7R6]: revised
(\ \)	Commented [A8]:
	Commented [A9R8]: revised
	Commented [A10]: who experienced
	Commented [A11R10]: revised
$\sum$	Formatted: Highlight
$\langle \rangle \rangle$	Commented [A12]: correlated
	Commented [A13R12]: revised
	Formatted: Highlight
Ì	Commented [A14]: revised
	Commented [A15]: childhood
	Commented [A16R15]: revised
$\square$	Formatted: Highlight
	<b>Commented [A17]:</b> overview of problems associated with metabolic disease in this age group. prevalence of central obesity in the age group over 15 years
(11)	Commented [A18]: The prevalence
	Commented [A19R18]: revised
///	Formatted: Highlight
$\langle \langle \rangle \rangle$	Commented [A20]: are

# Commented [A21R20]: revised Commented [A22]: state Commented [A23R22]: revised

Formatted: Highlight

. [1]

resistance based on fasting blood sugar and insulin levels. Its measurement is simple, inexpensive,often used and has been validated by the clamp method (Sumarni, 2017).

One factor causing insulin resistance is central or abdominal obesity as abdominal fat is more actively undergoing lipolysis (Sumarni, 2017). Recently, several measurements of the body's anthropometric profile that can describe the incidence of central obesity are reported, where the measurements are done easily. Central obesity in adolescents can be described generally using measurements of waist circumference and hip waist circumference ratio (WHR). Some studies also mention that waist circumference and WHR have a significant correlation with insulin resistance (Sumarni, 2017).

49

50

51 52

53

54

55 56

57

58

59

60

61 62

63 64

65 66

67 68

69

70

In addition to waist circumference and WHR, other anthropometric profile measurements are also progressively more used, namely Waist-to-Height Ratio (WHtR). WHtR describes central obesity in adolescents with more accurate results than Body Mass Index (BMI) (Ashwell & Gibson, 2016; Saraswati & and Sulchan, 2016; Yang et al., 2017). Study in Mexico demonstrates WHtR as a better tool in identifying cardiometabolic obesity in adolescents used to predict hypertension and insulin resistance (Rodea-Montero et al., 2014). Other studies conducted in Semarang also showed the correlation between WHtR and increasing insulin resistance (Asnelviana et al., 2017).

Wrist circumference can also be utilized as <u>the indicator</u>. Studies conducted in late adolescents in Indonesia, show wrist circumference as one of the anthropometric measurements that can predict obesity and insulin resistance in late adolescents. Wrist circumference reflects bone in the wrist area as well as peripheral fat distribution and metabolism thus it can measure one's body frame and bone size easily (Fitriyanti, Tjahjono, et al., 2019).

Another measurement of anthropometric profiles that can be used to predict metabolic syndrome in adolescents is the measurement of neck circumference. <u>Some studiesy show correlation</u> between neck circumference with insulin resistance (Liang et al., 2014; Saneei et al., 2019). Neck circumference can represent upper-body subcutaneous adipose tissue that plays a role in predicting insulin resistance and type 2 diabetes (Saneei et al., 2019).

In addition, measurement of thigh circumference can also predict metabolic syndrome in adolescents since it reflects central adiposity (Bando et al., 2017). Results of a study conducted in Korea show that thigh circumference is positively related to insulin resistance (Park et al., 2012). Several studies also explain that thigh circumference is a good indicator in determining type 2 diabetes mellitus 2 (Jung et al., 2013; Ting et al., 2018).

71 Recently, it has been reported that there are other anthropometric measurements as indicators in predicting metabolic syndrome disease, namely The Ratio of Second to Fourth Digit Length (2D:4D) 72 73 (Endang Purwaningsih, 2016). The Ratio of the length of the index finger and ring finger (2D:4D) can describe the exposure to the hormone estrogen and prenatal testosterone. A study has shown that 74 75 a low digit ratio is associated with high testosterone levels in men, while a high digit ratio is 76 associated with low testosterone levels in women (Kumar et al., 2016). The size of digit ratio occurs 77 since the end of the first trimester of fetal development (Oyeyemi et al., 2014). Inappropriate 78 exposure of to -androgen hormone can cause Polycystic Ovary Syndrome (PCOS), causing infertility 79 in premenopausal women. Women who experience PCOS often have metabolic diseases such as hypertension and insulin resistance (White et al., 2017). The Study states that digit ratio is correlated 80

	Formatted: Highlight
/	Commented [A24]: Do not use & in your manuscript.
	Commented [A25R24]: revised
	Formatted: Strikethrough, Highlight
	Formatted: Highlight
	Formatted: Highlight
X	Formatted: Highlight
l	Commented [A26]: the correlation
l	Commented [A27R26]: revised
	Formatted: Highlight
1	Formatted: Highlight
1	Formatted: Highlight
1	Commented [A28]: the indicator.
	Commented [A29R28]: revised
	Formatted: Highlight
ľ	Formatted: Highlight
)	Formatted: Highlight
	Formatted: Highlight
1	Commented [A30]: studies
	Commented [A31R30]: revised
	Formatted: Highlight
J	Formatted: Highlight
J	Formatted: Highlight
	Formatted: Highlight
1	Formatted: Highlight
Ą	Commented [A32]: The ratio
4	Commented [A33R32]: revised
Ą	Commented [A34]: A low
1	Commented [A35R34]: revised
1	Commented [A36]: A high
	Commented [A37R36]: Revised
1	Commented [A38]: to
1	Commented [A39R38]: revised
1	Commented [A40]: REVISED
-	Formatted: Highlight

81 with obesity, which is a risk factor for metabolic disease (Gölge et al., 2016). There aren't many 82 studies showing the relationship between digit ratio with insulin resistance.

In this study, we want to find out the portrayal and correlation of anthropometric profiles (waist
 circumference, WHR, WHtR, wrist circumference, neck circumference, thigh circumference, and
 second to fourth digit ratio) and insulin resistance in female adolescents with obesity.

# 86 2. Materials and methods

2.1 Design, location, and time

This is an observational study and <u>is</u> included within the scope of community nutrition science. This research conducted in Universitas Diponegoro Semarang, Indonesia at 10 Faculties in from June until August 2019. There were 1,260 female students who participated in <u>a</u> screening program. The entire study was approved by the Health Study Ethics Committee (KEPK) Faculty of Medicine, Universitas Diponegoro/Central General Hospital dr. Kariadi No. 373/EC/KEPK/FK UNDIP/VIII/2019.

# 2.2 Samplings

Subjects of this study were 120 students from Universitas Diponegoro who were selected through simple random sampling, according to the following inclusion criteria: aged 18-21 years old, had 80 cm or more waist circumference, had intact fingers on both hands, were not currently consuming drugs that could affect the blood glucose and insulin levels, were willing to do fasting for at least 8 hours, did not smoke and/or consume alcohol, were not sick or in the care of a doctor, did not do heavy physical activity or exercise, were not pregnant and breastfeeding, were willing to be the subject of study by filling out informed consent. The exclusion criteria in this study were subject's withdrawal from the study. The subject moved to another university, and the subject's passed away within study period.

### 2.<mark>3 Data collected</mark>

Independent variables in this study were the anthropometric profile consisted of waist circumference, waist-hip circumference ratio (WHR), Waist-Height Ratio (WHtR), neck circumference, wrist circumference, thigh circumference, and the ratio of index finger length and ring finger (2D:4D). The dependent variable in this study was insulin resistance.

Waist circumference data was were obtained from waist circumference measurements measured at the midpoint between the iliac crest and costal margins (lower ribs) using a medical measuring tape with 0.1 cm precision/ Subjects used minimal clothing (Yang et al., 2017). Subjects were considered at risk when waist circumference was 80 cm or more (Saklayen, 2018).

115WHR data was obtained from the waist circumference to hip circumference ratio.116Measurement of pelvic circumference was done by medical measuring tape with 0.1 cm precision.117The Pelvic circumference is measured by determining the widest points on the buttock (Fitriyanti,118Tjahjono, et al., 2019). Subjects are categorized as risky when WHR was more than 0.85 (Saklayen,1192018).

120Data on the ratio of waist circumference and height (WHtR) was obtained from121measurements of height and waist circumference of the subject. Height was measured using a122microtoise with 0.01 cm precision. The subject stands without using footwear and accessories123above the head. Subjects were considered at risk when WHtR was 0.5 or more (Zhang et al., 2016).

Commented [A41]: Is included

Commented [A43]: a screening Formatted: Strikethrough	1	Commented [A42]: from
	1	Commented [A43]: a screening
	ĺ	Formatted: Strikethrough
Formatted: Strikethrough	ĺ	Formatted: Strikethrough

Commented [A44]: The subject's	
Commented [A45R44]: revised	
Commented [A46]: the subject's	
Commented [A47R46]: revised	
Commented [A48]: The subject	
Commented [A49R48]: revised	
Commented [A50]: the	
Commented [A51R50]: revised	
Commented [A52]: the subject	
Commented [A53R52]: revised	
Commented [A54]: The subjects	
Commented [A55R54]: revised	
Commented [A56]: By whom was data collected?	
<b>Commented [A57R56]:</b> how to measure each data has been described in the research method. Anthropometric data were taken directly by researchers, laboratory data were taken by laboratory workers	
Commented [A58]: the ratio	
Commented [A59R58]: revised	
Commented [A60]: were	
Commented [AC1DC0], revised	
Commented [A61R60]: revised	
Formatted: Strikethrough	
Formatted: Strikethrough	

124	Neck circumference was measured by medical measuring tape with 0.1 cm precision. Its
125	measurements in women was were done by subject's upright head position and were forward.
126	facing eyes, and then horizontally measured just below the protruding larynx.

127 Wrist circumference da ta was were measured using medical measuring tape with 0.1 cm 128 precision. Its measurement was done by placing the medical measuring tape horizontally on the 129 distal side of the ulna protrusion, around the wrist. Wrist circumference measurement results was 130 were divided into 3 categories: small if subjects whose height less than 155 cm had wrist circumference less than14 cm, subjects whose height 155-163 cm had wrist circumference 15.2 131 132 cm, subjects whose height more than 163 cm had wrist circumference less than 15.9 cm; 133 moderate if subjects whose height less than 155 cm had wrist circumference 14-14.6 cm, subjects 134 whose height 155-163 cm had wrist circumference 15.2-15.9 cm, subjects whose height more 135 than 163 cm had wrist circumference 15.9-16.5 cm; large if subjects whose height less than 155 136 cm had wrist circumference more 14.6 cm, subjects whose height 155-163 cm had wrist 137 circumference more than 15.9 cm, subjects had height more than 163 cm have wrist 138 circumference more than 16.5 cm (Nabila et al., 2018).

139Thigh circumference was measured by a medical measuring tape. Subjects were standing and140wearing as little few clothes as possible. Thigh circumference was measured 10 cm above the141upper right patella. After that certain point was marked, the tape is placed horizontally and142encircles the thigh (Bando et al., 2017).

143 2D:4D ratio digit data is measured by a caliper with 0.001 mm precision. Measurements were 144 made with the position of the palm of the hand open (Wu et al., 2013). The length of the index 145 finger or second finger is the length of finger measured from the midpoint of the second 146 metacarpophalangeal joint and the most distal point of the second finger. The length of the ring 147 finger or the fourth finger is the length of the finger measured from the midpoint of the fourth 148 metacarpophalangeal joint and the most distal point of the fourth finger. 2D:4D ratio digit data 149 was obtained from the length of the second finger divided by the length of the fourth finger. The 150 ratio digits were <mark>consideres</mark>considered high when the result shows more than 0.9811 for the right 151 hand and more than 0.9821 for the left hand (Balci et al., 2018).

152Insulin resistance data was determined using HOMA-IR values. Measurement of Homeostasis153Insulin Resistance Assessment Model (HOMA-IR) based on fasting blood glucose and fasting154insulin level with the following formula (Nuraini et al., 2017):

$$\frac{Fasting \ Insulin \ \left(\frac{mU}{L}\right) x \ Fasting \ Blood \ Glucose \ \left(\frac{mmol}{L}\right)}{22.5}$$

Threshold of HOMA-IR value for adolescents is less than 1,65 (Nuraini et al., 2017). This blood sampling was in collaboration with Sarana Medika laboratory.

159 2.4 Data analysis

155

156 157

158

160

161

162

163

164

165

Data normality test was performed through Kolmogrov-Smirnov test. We used univariate analysis to describe each variable. <mark>Bivariate analysis was completed by Spearman Rank test</mark>. Bivariate analysis was performed to see whether there was a correlation between anthropometric profiles and insulin resistance.

3. Results and discussion

Commented [A64]: were
Commented [A65]: were
Formatted: Strikethrough
Formatted: Strikethrough
Commented [A66]: forward-facing
Commented [A67]: were
Formatted: Strikethrough
Formatted: Strikethrough
Commented [A68]: were
Formatted: Strikethrough
Formatted: Strikethrough

Commented [A69]: few
Formatted: Strikethrough
Commented [A70]: the tape
Commented [A71]: the index

Commented [A72]: considered

Commented [A73]: shows

Formatted: Highlight

Commented [A74]: Results

**Commented [A75]:** What about confounding variables in this study?

Formatted: Justified, Indent: Left: 0.3", First line: 0.3"

\_\_\_\_\_Table 1 described the anthropometric profile of the subjects. The median body weight 166 3. 167 was 66.6 kg. The median waist circumference and pelvic circumference were 85.75 cm and 103.5 cm, respectively, while the median WHR was 0.84  $\pm$  0.23. Based on table 1, the median neck 168 169 circumference, wrist circumference, WHtR was 32.5 cm, 15 cm, and 0.55 cm, respectively. The 170 characteristic of the subjects could also be seen in table 2. Table 2 showed that all subjects (100%) 171 had less than 80 cm waist circumference which meant they were at risk of developing metabolic 172 syndrome. Another anthropometric profile showed that 98.3% of subjects (n=118) had high WHtR 173 values. Based on WHR, as many as 90.8% of the subjects (n=108) were at risk. A total of 83.3% 174 subjects (n=100) also experienced insulin resistance as seen from the HOMA-IR value >1.65. 175 However, anthropometric profiles, specifically neck circumference, wrist circumference, 2D:4D digit 176 ratio of right hand; 2D:4D digit ratio of left hand, showed that less than 50% of subjects are at risk 177 (10.8%; 21.7%; 39.2%; 44.2% respectively).

178 The correlation of anthropometric profile and insulin resistance incidence determined by 179 HOMA-IR was shown in Table 3. Anthropometric profiles having a significant correlation with HOMA-180 IR were neck circumference (r=0.271; p=0.003), WHtR (r=0.33; p <0.001) and thigh circumference 181 (r=0.224; p=0.014). Based on the analysis, higher the value of the neck circumference, thigh 182 circumference, and WHtR, higher the HOMA-IR score. Table 3 also showed that waist circumference 183 had no correlation with HOMA-IR (r=0.151; p=0.1). There was also no correlation between wrist 184 circumference and HOMA-IR (r=0.12; p=0.19). In addition, there was no correlation between WHR 185 and HOMA-IR in the study subjects (r=-0.019; p=0.836). Based on the analysis, other anthropometric profiles having no correlation with HOMA-IR were 2D:4D right hand digit ratios (r=0.139; p=0.129) 186 and 2D:4D left hand digit ratios (r=0.169; p=0.065). 187

# 4. Discussion

188 189

190

191

192

193

194

195

196

Late adolescents, especially women, have the risk of experiencing metabolic syndrome. Based on this study results, 83.3% of subjects experience insulin resistance determined by HOMA-IR. Since 2007, the Genome Wide Association Studies (GWAS) have identified around 88 loci associated with the risk of developing type 2 diabetes mellitus where most of the loci are related to insulin secretion and pancreatic beta cell function, causing insulin resistance associated with obesity (A. E. Brown & and Walker, 2016). Study conducted in Semarang City also showed that 96.1% of subjects experienced insulin resistance determined by HOMA-IR (Nuraini et al., 2017).

197More than 50% of subjects of this study have high WHtR and WHR values.The Study conducted198in Jepara shows that 26.94% of adolescents experience abdominal obesity as seen from WHtR values199of above 0.45 (Azizah & and Sulchan, 2016). Other study conducted at the Faculty of Medicine200Universitas Riau demonstrates that 44.1% students experience central obesity as seen in the ratio201waist-hip circumference (Jannah et al., 2015). For women of reproductive age, fat storage is202centralized in certain areas to protect important reproductive organs. This increases the risk of high203WHR in women (Jannah et al., 2015).

204Based on the analysis, neck circumferencehas a correlation correlates with Homeostasis Model205Assessment for Insulin Resistance (HOMA-IR), where the greater the neck circumference of the206subject, the higher HOMA-IR value. A Study in China shows that neck circumference has a significant207correlation with insulin resistance assessed by HOMA-IR (Liang et al., 2014). Previous case studies in208Public Senior High School 2 Semarang and Public Junior High School 9 Semarang also stated that neck209circumference has a significant correlation with fasting blood sugar (Mayasari & Wirawanni, 2014).

Commented [A76]: of subjects

Commented [A77]: of the subjects

Formatted: Strikethrough
Commented [A78]: Do not use & in your manuscript.

Commented [A79]: The study

Commented [A80]: Do not use & in your manuscript.

Formatted: Strikethrough

1	Commented [A81]: correlates
1	Formatted: Strikethrough
1	Commented [A82]: The neck
1	Commented [A83]: A study
-	Commented [A84]: A significant

210Neck circumference is an easy anthropometric measurement. It can reflect the central obesity211index and is associated with several cardiovascular risk factors such as dyslipidemia, hypertension,212hyperuricemia, and insulin resistance. It is also considered an estimation of upper-body213subcutaneous adipose tissue which plays a role in predicting insulin resistance and type-2 diabetes214(Nabila et al., 2018). The Rrelease of excess free fatty acids associated with upper\_body215subcutaneous fat, explicitly the neck, can be one mechanism to explain the correlation between neck216circumference and insulin resistance (Ebbert & and Jensen, 2013).

217 Lipolytic function and releasing rate of free fatty acids in upper body subcutaneous fat is found 218 higher than lower body subcutaneous fat. Excessive free fatty acids in muscles and other tissues 219 induce the body to use more free fatty acids as energy. They will also inhibit glucose oxidation, 220 causing insulin resistance (Ebbert & and Jensen, 2013). Increased free fatty acids also play a role in 221 increasing VLDL production and inhibition of insulin clearance which induces insulin resistance. In 222 addition, neck circumference is also positively correlated with A total fat body and visceral fat which 223 are related to biological parameters of insulin resistance. Two perivascular ectopic fat depots are also 224 found in the neck region. Adipokine secretion, such as leptin, adiponectin, and interleukin-6, from 225 perivascular ectopic fat deposit ts-causes metabolic dysfunction including insulin resistance (Saneei 226 et al., 2019).

Subjects with large neck circumferences have a greater risk for obesity (Saneei et al., 2019).
 Subcutaneous fat has a major role in the association of insulin resistance and obesity (Sri Yuliani et al., 2017). Insulin resistance is an important complication of obesity which causes hyperglycemia and impaired glycemic parameters (Saneei et al., 2019).

231Waist to Height Ratio (WHtR) is a good predictor in determining insulin resistance in the232individual with obesity (Jamar et al., 2017). Based on the analysis, WHtR has a correlation with233HOMA-IR, where the greater the WHtR score, the greater the value of HOMA-IR. A study conducted234in Australia on the correlation of WHtR and metabolic syndrome in adolescents and children with235obesity, results in a correlation between WHtR and HOMA-IR (Nambiar et al., 2013). Other studies236conducted in Korea also find that high WHtR values in obese adolescents would affect the incidence237of insulin resistance measured by HOMA-IR (Lim et al., 2015).

238 WHtR plays a role in measuring central obesity which is often associated with metabolic 239 disorders. An lincrease in fat tissue will promote increase in adipokine secretion. This can increase 240 insulin resistance. The most important adipokines is TNF- $\alpha$  which plays a role in inducing insulin 241 resistance through glucose transporter 4 (GLUT-4) and increasing the release of free fatty acids. 242 Increased transfer of free fatty acids to muscles results in increased intracellular fatty acid 243 metabolites such as diacylglycerol, ceramide, and acetyl-CoA. These metabolites will activate the 244 serine pathway or threonine kinase that reduces the ability to activate insulin receptors. Hence, it 245 can cause insulin resistance when occurs in the long termas it can damage visceral adipocyte  $\beta$  cells 246 (Asnelviana et al., 2017).

Based on the statistical test results, we find a correlation between thigh circumference and insulin resistance as measured by HOMA-IR. This finding is in line with <u>the</u> study conducted in Korea which shows the result that thigh circumference is positively related to HOMA-IR. The greater the thigh circumference, the greater the risk of insulin resistance (Park et al., 2012). Other <u>another</u>-study in Korea explains that the measurement of thigh circumference is an indicator of diabetes marker (Jung et al., 2013). <u>The</u> Study conducted in Taiwan also shows the left thigh circumference is a significant predictor of determining type 2 diabetes mellitus 2 (Ting et al., 2018). Large thigh

### Commented [A85]: The central

Commented [A86]: The release
Commented [A87]: Upper-body
Commented [A88]: Do not use & in your manuscript.
Formatted: Strikethrough
Commented [A89]: Do not use & in your manuscript.
Formatted: Strikethrough
Commented [A90]: A total
Commented [A91]:

	Commented [A92]: The individual
	Commented [A93]: Results
	Commented [A94]: An increase
	Commented [A95]: adipokines
	Commented [A96]: term
	Commented [A97]: the study
_	Commented [A98]: another
	Commented [A99]: The study

254 circumference not only indicates greater muscle mass, but also an increase in femoral subcutaneous 255 fat mass. Lower muscle mass and subcutaneous fat in the thigh are associated with insulin resistance 256 which results in hyperglycemia and diabetes (Ting et al., 2018). Subcutaneous fat in the thighs is a 257 metabolism of circulating fatty acids that are circulating because there is a difference in lipolysis 258 activity between subcutaneous fat in the abdomen and thighs. Subcutaneous fat in the thigh is 259 wasting the metabolism of circulatory fatty acids as there is a difference between lypolyisis activity 260 of abdominal and thigh subcutaneous fat. Subcutaneous fat of the thigh tends to take fatty acids 261 from the bloodstream, thus preventing the liver, pancreas, and ectopic fat such as the muscles from 262 being exposed to high fatty acids (Nugraha et al., 2019).

263Based on the study analysis, no correlation is found between neither waist circumference nor264waist-hip circumference ratio with insulin resistance. This finding is contradictory to a study265conducted on adolescents in Korea which shows the results that waist circumference and waist-hip266circumference ratio have a significant correlation to HOMA-IR (Lim et al., 2015). Waist circumference267and waist-hip circumference ratio can be used as a screening tool to detect the incidence of268abdominal obesity which can cause metabolic disorders such as insulin resistance (Fitriyanti, Sulchan,269et al., 2019).b

270 However, a study conducted in Manado about the correlation of waist circumference and blood 271 sugar levels shows no correlation between waist circumference and blood sugar levels among 272 teachers at the Middle School and High School Eben Haezar Christian Manado. Other study held in 273 Ngawi also shows no correlation between waist circumference and blood sugar levels in early 274 adulthood (Manungkalit et al., 2015). Several other studies, including a study conducted at the Pusti 275 Pidie Health Center, show no correlation between waist circumference ratio pelvis and blood sugar 276 among Community Health Center's employees (Mulyani & and Rita, 2016). The study states that the 277 ratio of waist-hip circumference is not an extremely decisive factor in increasing blood sugar levels 278 as many other factors influence the increase in blood sugar levels. Therefore other anthropometric 279 measurements need to be carried out (Mulyani & Rita, 2016).

280 Wrist circumference is a strong predictor of diabetes (Jahangiri Noudeh et al., 2013). Wrist 281 circumference is an easily measured anthropometric parameter that can determine body frame and 282 bone size. Increased bone mass will also be associated with hyperinsulinemia (Fitriyanti, Tjahjono, et al., 2019). However, in this study, wrist circumference has no correlation does not correlate with 283 284 HOMA-IR. Inconsistent with the study conducted by Kusmiyati et al. in 18 years old adolescents, 285 which demonstrates a correlation between wrist circumference and fasting insulin and HOMA-IR in 286 both male and female adolescents (Fitriyanti, Tjahjono, et al., 2019). However, the study conducted 287 by Rumaisha et al. about the correlation of wrist circumference and the blood glucose level among 288 obese women shows no correlation between wrist circumference with fasting blood glucose. Other 289 another study conducted at Public Senior High School 6 Semarang also results in no correlation 290 between wrist circumference with fasting blood glucose levels (Arifin & and Panunggal, 2014). 291 Factors influencing HOMA-IR values were fasting blood glucose and fasting insulin levels, where 292 higher glucose levels fasting blood means higher the HOMA-IR value in the subject (Mitrea et al., 293 2013)

294The Second to Fourth Digit Ratio (2D:4D) can be used to evaluate prenatal androgen exposure295in the postpartum period. The Homeobox genes, HoxA and HoxB, are responsible for urogenital296differentiation, prenatal androgen synthesis and fingers development. In animals, prenatal and297neonatal androgenic exposure can increase adiposity, insulin resistance, and changes in adipose

Commented [A104]: a significant
Commented [A105]: the correlation
Commented [A106]: Do not use & in your manuscript.
Formatted: Strikethrough
Commented [A107]: Therefore

Commented [A100]: The thigh

Commented [A102]: lipolysis

Commented [A103]: a study

Commented [A101]: the metabolism

Commented [A108]: Does not correlate
Formatted: Strikethrough
Commented [A109]: The study
Commented [A110]: Another

Formatted: Strikethrough
Formatted: Strikethrough
Commented [A111]: Do not use & in your manuscript.
Formatted: Strikethrough

<b>Commented [A112]:</b> Do not use & in your manuscript.	
Commented [A113]: androgen	

10

298 tissue lipolysis later in adulthood (Yildiz et al., 2015). However, based on this study analysis, the 299 Second to Fourth Digit Ratio (2D:4D) of the right and left hand is not related to HOMA-IR or insulin 300 resistance incidence. This finding is supported by study conducted in Turkey, on the correlation 301 between Second to Fourth Digit Ratio (2D:4D) and metabolic syndrome. It shows that Sthe second to 302 Fourth Digit Ratio (2D:4D) is not related to insulin resistance or the incidence of diabetes mellitus in 303 the subject. Researchers state that no available study that reports Second to Fourth Digit Ratio 304 (2D:4D) as a predictor of androgen exposure and explains its correlation with metabolic syndrome 305 (Yildiz et al., 2015). Other studies conducted by Abdullahi Yusuf Asuku et al. regarding the correlation 306 of Second to Fourth Digit Ratio (2D:4D) and metabolic syndrome indicators in Nigeria shows the 307 results that Second to Fourth Digit Ratio (2D:4D) of the right and left hand has no correlation with 308 fasting blood sugar levels in the subjects (Asuku et al., 2017). Researchers explain the absence of 309 correlation between Second to Fourth Digit Ratio (2D:4D) and metabolic syndrome indicators is 310 caused by the small number of subjects, i.e. 465 subjects, meanwhile this study includes only 120 311 subjects. This might be there reason of for no association found between the second to Fourth Digit 312 Ratio (2D:4D) and the incidence of insulin resistance.

313

#### 314 Conflict of interest - Disclose any potential conflict of interest appropriately.

- 315 The authors declare no conflict of interest.
- 316
- 317 Acknowledgments

#### 318 This research was funded by the "Hibah Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) 2019, The

- Ministry of Research, Technology and Higher Education, Indonesia". 319
- 320
- 321

Commented [A114]: the second

Commented [A115]: a predictor

Commented [A116]: the small
Commented [A117]: for
Commented [A118]: the second
Formatted: Strikethrough

Formatted: Strikethrough

Commented [A119]:

### Commented [A120]: doi links have all been completed

Brown, A. E., & Walker, M. (2016). Genetics of Insulin Resistance and the Metabolic Syndrome. <i>Current</i>	
Cardiology Reports, 18. https://doi.org/10.1007/s11886-016-0755-4	
Brown, J. E., Janet, I., Krinke, B., Lechtenberg, E., & Murtaugh, M. (2011). Nutrition: Through the Life Cycle	
(Instructor's 4th Edition). (4th ed.). Wadsworth Cengage Learning.	
Ebbert, J. O., & Jensen, M. D. (2013). Fat depots, free fatty acids, and dyslipidemia. Nutrients, 5(2), 498-	
508. https://doi.org/10.3390/nu5020498	
Endang Purwaningsih. (2016). Insidensi panjang jari telunjuk terhadap jari manis (rasio 2D: 4D) pada	
mahasiswa Fakultas Kedokteran Universitas YARSI Angkatan 2013-2014. Jurnal Kedokteran YARSI,	
24(1), 001–008. https://doi.org/10.33476/jky.v24i1.134	
Fitriyanti, A. R., Sulchan, M., Tjahjono, K., & Sunarto, S. (2019). Prediction of insulin resistance in late	
adolescent based on anthropometric index. Jurnal Gizi Dan Pangan, 14(2), 53–60.	
https://doi.org/10.25182/jgp.2019.14.2.53-60	
Fitriyanti, A. R., Tjahjono, K., Sulchan, M., & Sunarto, S. (2019). Sensitivitas dan spesifisitas lingkar	
pergelangan tangan sebagai prediktor obesitas dan resistensi insulin pada remaja akhir. Jurnal	
Gizi Indonesia (The Indonesian Journal of Nutrition), 7(2), 121–126.	
https://doi.org/10.14710/jgi.7.2.121-126 Gölge, U. H., Sivasli, Z., Pazarc, Ö., Göksel, F., Kaymaz, B., & Kuloğlu, H. E. (2016). Relationship Between	
Second to Fourth Digit Ratios and Obesity, Muscle Mass. Journal of Clinical and Analytical	
Medicine, 6. https://doi.org/10.4328/JCAM.3846	
Jahangiri Noudeh, Y., Hadaegh, F., Vatankhah, N., Momenan, A. A., Saadat, N., Khalili, D., & Azizi, F. (2013).	
Wrist Circumference as a Novel Predictor of Diabetes and Prediabetes: Results of Cross-Sectional	
and 8.8-Year Follow-up Studies. The Journal of Clinical Endocrinology & Metabolism, 98(2), 777–	
784. https://doi.org/10.1210/jc.2012-2416	

322

323

324

325

326

327

328

329

330

331

332

333

334

335

336

337

338

339

340

341

342

343

344

345

346

347

348

349

350

351

352

353

354

355

356

357

358

359

360

361

362

363

364

365

366

367

368

369

References

Nigeria.

Pedesaan

diabetes

Journal

https://doi.org/10.4103/jeca.jeca\_24\_17

Jepara.

mellitus

https://doi.org/10.15761/IOD.1000183

https://doi.org/10.14710/jnc.v5i2.16362

Kementerian Kesehatan Republik Indonesia.

Arifin, R., & Panunggal, B. (2014). Hubungan Lingkar Pergelangan Tangan dengan Kadar Glukosa Darah

Ashwell, M., & Gibson, S. (2016). Waist-to-height ratio as an indicator of 'early health risk': Simpler and

Asnelviana, H., Sulchan, M., & Panunggal, B. (2017). Kejadian Resistensi Insulin pada Anak Obesitas Usia

Asuku, A., Danborno, B., Akuyam, S., Timbuak, J., & Adamu, L. (2017). Relationship of second-to-fourth

Azizah, A. N., & Sulchan, M. (2016). Kadar C-Reactive Protein (CRP) pada Remaja Putri Stunted Obesity di

Badan Penelitian dan Pengembangan Kesehatan. (2018). Riset Kesehatan Dasar 2018 (RISKESDAS 2018).

Balci, R. S., Acikgöz, A. K., Göker, P., & Bozkir, M. G. (2018). The Relationship of Finger Length Ratios

Bando, H., Kato, Y., Sakamoto, K., Ogawa, T., Bando, M., & Yonei, Y. (2017). Investigation for waist

Integrative

of Morphology, 36(1), 310-318. https://doi.org/10.4067/S0717-95022018000100310

(2D:4D) with Quantitative, Verbal Talent and Anthropometric Parameters. International Journal

circumference (WC), waist-to-height ratio (WHtR) and thigh-to-waist ratio (TWaR) in type 2

of

9-12 Tahun di Kota Semarang. Journal of Nutrition College, 6(4), 391–395.

Experimental

Journal

(T2DM).

982–987. https://doi.org/10.14710/jnc.v3i4.6922

of

e010159. https://doi.org/10.1136/bmjopen-2015-010159

pada Remaja Putri Usia 15-18 Tahun di SMA Negeri 6 Semarang. Journal of Nutrition College, 3(4),

more predictive than using a 'matrix' based on BMI and waist circumference. BMJ Open, 6(3),

digit ratio with metabolic syndrome indices and serum biomarkers in Hausa ethnic group of Kano,

and

Nutrition

Clinical

Obesity

Anatomy,

College,

and

16(2),

5(2),

Diabetes,

103.

71-76.

3(4).

- 370 Jamar, G., Almeida, F. R. de, Gagliardi, A., Sobral, M. R., Ping, C. T., Sperandio, E., Romiti, M., Arantes, R., 371 & Dourado, V. Z. (2017). Evaluation of waist-to-height ratio as a predictor of insulin resistance in 372 non-diabetic obese individuals. A cross-sectional study. Sao Paulo Medical Journal = Revista 373 Paulista De Medicina, 135(5), 462–468. https://doi.org/10.1590/1516-3180.2016.0358280417
- 374 Jannah, W., Bebasari, E., & Ernalia, Y. (2015). Profil Status Gizi Mahasiswa Fakultas Kedokteran Universitas 375 Riau Angkatan 2012 dan 2013 Berdasarkan Indeks Massa Tubuh, Waist Hip Ratio, dan Lingkar 376 Pinggang. Jurnal Online Mahasiswa (JOM) Bidang Kedokteran, 2(1), 1–7.
- 377 Jung, K. J., Kimm, H., Yun, J. E., & Jee, S. H. (2013). Thigh Circumference and Diabetes: Obesity as a Potential 378 Effect Modifier. Journal of Epidemiology, 23(5), 329-336. 379 https://doi.org/10.2188/jea.JE20120174
- 380 Kumar, N., Sallehuddin, M. A. B., Syed, S. M. F. B., Idris, M. H. B., Jamba, T. A., S, S. R., Patil, J., & Aithal, A. 381 (2016). The Ratio of Second to Fourth Digit Length (2D:4D) and Heart Disease. Bangladesh Journal 382 of Medical Science, 15(4), 529-532. https://doi.org/10.3329/bjms.v15i4.23958
- 383 Liang, J., Teng, F., Liu, X., Zou, C., Wang, Y., Dou, L., Sun, Z., & Qi, L. (2014). Synergistic effects of neck 384 circumference and metabolic risk factors on insulin resistance: The Cardiometabolic Risk in 385 Chinese (CRC) studv. Diabetology & Metabolic Syndrome, 6(1), 116. 386 https://doi.org/10.1186/1758-5996-6-116
- 387 Lim, S. M., Choi, D. P., Rhee, Y., & Kim, H. C. (2015). Association between Obesity Indices and Insulin 388 Resistance among Healthy Korean Adolescents: The JS High School Study. PloS One, 10(5), 389 e0125238. https://doi.org/10.1371/journal.pone.0125238
- 390 Manungkalit, M., Kusnanto, & Ana Dyah Ayu Purbosari. (2015). Hubungan Lingkar Pinggang dengan Faktor 391 Risiko Diabetes Mellitus (Tekanan Darah, Kadar Gula Darah, dan Indeks Massa Tubuh) pada Usia 392 Dewasa Awal di Wilayah KEcamatan Gerih Kabupaten Ngawi. Jurnal NERS Lentera, 3(1), 10.
- 393 Mayasari, N., & Wirawanni, Y. (2014). Hubungan Lingkar LEher dan Lingkar Pinggang dengan Kadar 394 Glukosa Darah Puasa Orang Dewasa: Studi Kasus di SMA Negeri 2 Semarang dan SMP Negeri 9 395 Semarang. Journal of Nutrition College, 3(4), 473-481. https://doi.org/10.14710/jnc.v3i4.6829
- 396 Mitrea, A., Soare, A., Popa, S. G., Tudor, M. N., Mota, M., & Pozzilli, P. (2013). Wrist Circumference: An 397 Independent Predictor of Both Insulin Resistance and Chronic Kidney Disease in An Elderly 398 Population. Romanian Journal of Diabetes Nutrition and Metabolic Diseases, 20(3), 323–329.
- 399 Mulyani, N. S., & Rita, N. (2016). Hubungan Rasio Lingkar Pinggang Pinggul (RLPP) dengan Kadar Gula 400 Darah pada Pegawai di Puskesmas Sakti Pidie. AcTion: Aceh Nutrition Journal, 1(2), 94-98. 401 https://doi.org/10.30867/action.v1i2.17
- 402 Nabila, R., Widyastuti, N., & Murbawani, E. A. (2018). Hubungan Lingkar Pergelangan Tangan dengan 403 Kadar Glukosa Darah Wanita Obesitas Usia 40-55 Tahun. Journal of Nutrition College, 7(2), 92–99.
- Nambiar, S., Truby, H., Davies, P. S. W., & Baxter, K. (2013). Use of the waist-height ratio to predict 404 405 metabolic syndrome in obese children and adolescents. Journal of Paediatrics and Child Health, 406 49(4), E281-287. https://doi.org/10.1111/jpc.12147
- 407 Nugraha, P. G., Candra, A., Murbawani, E. A., & Ardiaria, M. (2019). Hubungan antara Lingkar Paha dan 408 Lingkar Panggul dengan Sindroma Metabolik. DIPONEGORO MEDICAL JOURNAL (JURNAL KEDOKTERAN DIPONEGORO), 8(4), 1217-1224. 409
- Nuraini, I. S., Sulchan, M., & Dieny, F. F. (2017). Resistensi insulin pada remaja stunted obesity usia 15-18 410 411 tahun di Kota Semarang. Journal of Nutrition College, 6(2), 164-171. 412 https://doi.org/10.14710/jnc.v6i2.16906
- 413 Oyeyemi, B. F., Iyiola, O. A., Oyeyemi, A. W., Oricha, K. A., Anifowoshe, A. T., & Alamukii, N. A. (2014). 414 Sexual dimorphism in ratio of second and fourth digits and its relationship with metabolic syndrome indices and cardiovascular risk factors. Journal of Research in Medical Sciences : The 415 416 Official Journal of Isfahan University of Medical Sciences, 19(3), 234–239.

- Park, J. S., Cho, M. H., Ahn, C. W., Kim, K. R., & Huh, K. B. (2012). The association of insulin resistance and
   carotid atherosclerosis with thigh and calf circumference in patients with type 2 diabetes.
   *Cardiovascular Diabetology*, *11*, 62. https://doi.org/10.1186/1475-2840-11-62
- Rodea-Montero, E. R., Evia-Viscarra, M. L., & Apolinar-Jiménez, E. (2014). Waist-to-Height Ratio Is a Better
   Anthropometric Index than Waist Circumference and BMI in Predicting Metabolic Syndrome
   among Obese Mexican Adolescents. *International Journal of Endocrinology*, 2014, 1–9.
   https://doi.org/10.1155/2014/195407
- Saklayen, M. G. (2018). The Global Epidemic of the Metabolic Syndrome. *Current Hypertension Reports*,
   20(2). https://doi.org/10.1007/s11906-018-0812-z
- Saneei, P., Shahdadian, F., Moradi, S., Ghavami, A., Mohammadi, H., & Rouhani, M. H. (2019). Neck
   circumference in relation to glycemic parameters: A systematic review and meta-analysis of
   observational studies. *Diabetology & Metabolic Syndrome*, 11(1), 50.
   https://doi.org/10.1186/s13098-019-0445-7
- Saraswati, A. T., & Sulchan, M. (2016). Kejadian Sindrom metabolik pada Remaja Putri Stunted Obesity di
   Pedesaan Jepara. Journal of Nutrition College, 5(3), 192–197.
   https://doi.org/10.14710/jnc.v5i3.16399
- Sri Yuliani, N. N., Subagio, H. W., & Murbawani, E. A. (2017). Korelasi Lingkar Leher dengan Persentase
   Lemak Tubuh pada Obesitas. *Diponegoro Journal of Nutrition and Health*, 5(3), 195815.
- Srikanthan, K., Feyh, A., Visweshwar, H., Shapiro, J. I., & Sodhi, K. (2016). Systematic Review of Metabolic
  Syndrome Biomarkers: A Panel for Early Detection, Management, and Risk Stratification in the
  West Virginian Population. *International Journal of Medical Sciences*, *13*(1), 25–38.
  https://doi.org/10.7150/ijms.13800
- Sumarni, S. (2017). Hubungan antara Lingkar Pinggang dan Derajat Lemak Viseral dengan Resistensi
   INsulin pada Dewasa Obes. *Healthy Tadulako Journal (Jurnal Kesehatan Tadulako)*, 3(1), 15–21.
- Ting, M.-K., Liao, P.-J., Wu, I.-W., Chen, S.-W., Yang, N.-I., Lin, T.-Y., & Hsu, K.-H. (2018). Predicting Type 2
   Diabetes Mellitus Occurrence Using Three-Dimensional Anthropometric Body Surface Scanning
   Measurements: A Prospective Cohort Study. *Journal of Diabetes Research, 2018*, 1–10.
   https://doi.org/10.1155/2018/6742384
- White, M., Jarrett, T., & Komar, C. (2017). Correlation between Digit Length Ratios and Risk Factors
  Associated with Metabolic Syndrome. *Journal of Metabolic Syndrome*, 06(01).
  https://doi.org/10.4172/2167-0943.1000221
- Wu, X., Yang, D., Chai, W., Jin, M., Zhou, X., Peng, L., & Zhao, Y. (2013). The Ratio of Second to Fourth Digit
   Length (2D:4D) and Coronary Artery Disease in a Han Chinese Population. *International Journal of Medical Sciences*, 10(11), 1584–1588. https://doi.org/10.7150/ijms.6360
- Yang, H., Xin, Z., Feng, J.-P., & Yang, J.-K. (2017). Waist-to-height ratio is better than body mass index and
   waist circumference as a screening criterion for metabolic syndrome in Han Chinese adults:
   *Medicine*, 96(39), e8192. https://doi.org/10.1097/MD.0000000008192
- Yildiz, P., Yildiz, M., Yildirim, A., Gucenmez, S., Donderici, O., & Serter, R. (2015). The 2nd to 4th Digit
   Length Difference and Ratio as Predictors of Hyperandrogenism and Metabolic Syndrome in
   Females. KONURALP TIP DERGISI, 7, 45–49.
- Zhang, Y.-X., Wang, Z.-X., Chu, Z.-H., & Zhao, J.-S. (2016). Profiles of body mass index and the nutritional
   status among children and adolescents categorized by waist-to-height ratio cut-offs. *International Journal of Cardiology*, 223, 529–533. https://doi.org/10.1016/j.ijcard.2016.07.303
- 460 461 462
- 463

# Tables and Figures – 1 PAGE 1 TABLE/FIGURE. PLACE ALL TABLES AND FIGURES AT THE END OF THE MANUSCRIPT BODY AFTER THE REFERENCES

# 

# Table 1. Characteristic of Subjects.

Variable	Median	Minimum	Maximum
Body weight (kg)	66.6	47.8	107.4
Body height (cm)	157.4	100.5	171.4
Waist circumference (cm)	85.75	80.5	114
Hip circumference (cm)	103.5	30	170
Neck circumference (cm)	32.5	14.5	39
Wrist circumference (cm)	15	13.5	17.5
Thigh circumference (cm)	57.4	31	78.4
Waist Height to Ratio (WHtR)	0.55	0.49	0.95
Waist-hip circumference ratio	0.84	0.6	3.33
(WHR)			
2D:4D digit ratio of the right hand	0.98	0.84	1.09
2D:4D digit ratio of the left hand	0.99	0.52	0.6
HOMA-IR	2.33	0.54	18.32

# Table 2. Frequency Distribution.

Category	n	%
Waist circumference		
At risk >80 cm	120	100
Neck circumference		
At risk ≥35.5 cm	13	10.8
Under risk <35.5 cm	107	89.2
Wrist circumference		
At risk ≥16 cm	26	21.7
Under risk <16 cm	94	78.3
Waist Height to Ratio (WHtR)		
At risk ≥0.5	118	98.3
Under risk <0.5	2	1.7
Waist-hip circumference ratio (WHR)		
At risk ≥0.8	109	90.8
Under risk <0.8	11	9.2
2D:4D digit ratio of the right hand		
At risk	47	39.2
Under risk	73	60.8
2D:4D digit ratio of the left hand		
At risk	53	44.2
Under risk	67	55.8
HOMA-IR		
Normal	20	16.7
Resistance	100	83.3

Tabel 3. Correlation of Anthropometric Profile and HOMA-IR.

Variable	r	р
Waist circumference (cm)	0.151	0.1
Neck circumference (cm)	0.271	0.003*
Wrist circumference (cm)	0.12	0.19
Thigh circumference (cm)	0.224	0.014*
Waist Height to Ratio (WHtR)	0.33	< 0.001*
Waist-hip circumference ratio (WHR)	-0.019	0.836
2D:4D digit ratio of the right hand	0.139	0.129
2D:4D digit ratio of the left hand	0.169	0.065
Correlation test: Rank-Spearman	*Significant (p<0.05)	

Page 1: [1] Commented [A21R20]

Author

revised

1	Anthropometry indicators that are most related to female student's metabolic profiles	Commented [acer1]: lowercase
2	<sup>1,2</sup> *Dieny, F.F., <sup>1</sup> Rose S., <sup>1,2</sup> Tsani, A.F.A., <sup>1</sup> Jauharany, F.F. and <sup>1,2</sup> Fitranti, D.Y.	Commented [A2R1]: revised
3	<sup>1</sup> Department of Nutrition Science, Faculty of Medicine, Universitas Diponegoro, Indonesia	
4	<sup>2</sup> Center of Nutrition Research (CENURE), Faculty of Medicine, Universitas Diponegoro, Indonesia	
5		
6	*Corresponding author: <u>fillahdieny@gmail.com</u>	
7		
8	Author No.1: 0000-0001-6071-8901	
9	Author No. 2: 0000-0002-1898-1842	
10	Author No. 3: 0000-0002-3407-5188	
11	Author No. 4: 0000-0001-9471-9419	
12	Author No. 5: 0000-0002-1656-9563	
13		
14	Abstract	

15 Metabolic syndrome is not a disease, but is a set of several disorders and causes an increased risk of 16 cardiovascular disease and diabetes mellitus complications. Several studies have shown that non-invasive 17 approaches such as anthropometric measurements can be used for early detection of metabolic 18 syndrome. This study aims to analyse the anthropometric indicators related to metabolic syndrome in 19 female students. This cross-sectional study with a total of 163 female students, aged between 19 and 24 20 years old. Purposive sampling was used in this study. The independent variables in this study were the 21 Waist-to-Height Ratio (WHtR), Waist-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal 22 Diameter (SAD), and hip circumference. The dependent variable in this study is the metabolic syndrome 23 component that has been converted into a metabolic syndrome score (cMetS). The analysis results 24 showed that all anthropometric indicators, namely WHtR, BMI, SAD, waist circumference, hip 25 circumference and WHR have a strong positive relationship with the metabolic syndrome score (p<0.001). 26 BMI was the anthropometric indicator that is most associated with the metabolic profiles, such as systolic 27 blood pressure (p<0.001), blood sugar (p<0.05), and HDL (p<0.001). Waist circumference was the 28 anthropometric indicator that is most associated with triglycerides and metabolic syndrome score 29 (p<0.001). Metabolic syndrome in female students in Semarang can be identified using anthropometric 30 measurements, one of which is BMI and WHR which are very easy to measure and efficient. In addition, 31 the use of cMetS in the metabolic assessment of a person was found to be more effective.

32 Keywords: Adolescent; Anthropometric Indicator; Female; Metabolic Profile; Metabolic Syndrome.

- 33
- 34

# 35 1. Introduction

Metabolic syndrome is a set of body metabolic disorders such as dyslipidaemia, hyperglycaemia,
 hypertension, and central obesity (Srikanthan *et al.*, 2016; Devi *et al.*, 2017; Christijani, 2019).
 Metabolic syndrome is not a disease, but is a set of several disorders and causes an increased risk of
 cardiovascular disease and diabetes mellitus complications. Some epidemiological studies have
 shown that metabolic syndrome doubles the risk of cardiovascular diseases (Sri Rahayu and Maulina,
 2017).

42 Several studies found that the prevalence of metabolic syndrome keeps increasing every year. A 43 study in China shows the prevalence of metabolic syndrome in adults was 24.2% (Li et al., 2018). 44 Another study indicated that the prevalence of metabolic syndrome in Indonesia was 21.66% 45 (Herningtyas and Ng, 2019). In recent studies metabolic syndrome can be assessed using the 46 continuous value of metabolic syndrome (cMets) or the metabolic syndrome score recommended by 47 the American Diabetic Association of Diabetes. The metabolic syndrome score is a z-score resulting 48 from the assessment of all components of the metabolic syndrome (Pratiwi, et al., 2017). The 49 advantages of using cMetS are (1) reducing dichotomization factors because cardiovascular disease 50 is a progression of several components of the metabolic syndrome, (2) cMetS is more sensitive and 51 less error-prone than categoric metabolic syndrome assessments, (3) increasing the statistical power 52 (Okosun, Lyn, et al., 2010).

53 Central obesity is one of the components of metabolic syndrome parameters. Central obesity is associated with increased blood pressure, serum triglycerides, decreased HDL, and glucose 54 55 intolerance. Based on the National Basic Health Research (Riskesdas) in 2018, the prevalence of 56 obesity in adults was 21.8%, and the prevalence of central obesity at age of more than 15 years 57 increased from 26.6% in 2013 to 31% in 2018 (Badan Penelitian dan Pengembangan Kesehatan, 58 2018). Obesity is closely related to degenerative diseases. The Riskesdas 2018 showed that the 59 prevalence of stroke, diabetes mellitus, heart disease, and hypertension is higher in women than 60 men.

61 Several studies have shown that non-invasive approaches such as anthropometric measurements can be used for early detection of metabolic syndrome (Pratiwi, et al., 2017). Anthropometric 62 63 measurements are described as the measurements of body dimensions and body composition to 64 assess nutritional status. The advantages of anthropometric measurements are relatively fast and 65 easy, as it can be performed using portable and calibrated instruments with standardized methods 66 (Rokhmah, et al., 2015). Some anthropometric measurements that can be used for early detection 67 of metabolic syndrome are Waist-to-Height Ratio (WHtR), waist-to-hip ratio (WHR), hip circumference, Body Mass Index (BMI), Sagital Abdominal Diameter (SAD). 68

69 One of the anthropometric measurements which can be a parameter for central obesity is the 70 ratio of waist circumference to height (WHtR). The instruments used in the measurement are 71 microtoise and measuring tape so that it takes longer time. Studies on waist circumference have been 72 shown to have a strong correlation with abdominal fat deposits (Zhou et al., 2014). The distribution 73 of abdominal adipose tissue (central obesity) in adults is associated with a component of the 74 metabolic syndrome (Rodea-Montero, et al., 2014). A study on adult subjects has shown that people 75 who have the same waist circumference but are shorter in height have a greater risk of developing 76 metabolic syndrome than taller people (Zhou et al., 2014). Therefore, WHtR can be used as a simple

Commented [A3]: revised

Commented [A4]: revised

Commented [A5]: revised

and effective anthropometric index to identify the metabolic risk associated with obesity (Rodea Montero, *et al.*, 2014).

79 The waist-to-hip ratio (WHR) is a measurement that may indicate central obesity (Karimah, 2018). 80 The higher the WHR value, the higher the risk level for several metabolic diseases. The waist-to-hip ratio is calculated by dividing the measurement of the waist circumference by the circumference of 81 82 the hip. The cut-off points for WHR are  $\geq$ 1.0 for men and  $\geq$ 0.85 for women (Rokhmah, et al., 2015). 83 Individuals with a high waist and hip circumference will also have a higher distribution of fat in their 84 abdominal area. Irregular fats distribution in the abdominal area indirectly causes higher triglyceride 85 levels circulating in the blood, which will affect blood pressure (Sumardiyono et al., 2018). WHR measurement is more sensitive in assessing the distribution of fat in the body, especially in the 86 87 abdominal. This measurement is three times better than BMI in reflecting the presence of harmful 88 fats in the abdominal. Measurement of waist circumference is performed by determining the lower 89 part of arcus costae and crista iliaca (Sri Rahayu and Maulina, 2017).

Body Mass Index (BMI) is a practical and easy measurement to perform, but it cannot distinguish
 between fat mass, bone mass and muscle mass. BMI is calculated as body weight (kg) / height
 squared (m<sup>2</sup>) (Okura *et al.*, 2018). BMI can be used as the first measurement before any other
 anthropometric measurements.

94 Sagittal Abdominal Diameter (SAD) or the height of the abdomen while the subjects are in lying 95 position. This anthropometric measurement has not been widely used to measure fat tissue in the 96 abdominal area. SAD measurements using computed tomography or magnetic resonance imaging, 97 and are associated with components of metabolic syndrome. The measurements of SAD are taken 98 when the subject is lying down on the examination table with naked upper body. SAD is related to 99 central obesity in individuals with obese and normal nutritional status. Furthermore, SAD is 100 associated with diabetes mellitus and a predictor of cardiovascular disease incidence, even when SAD 101 is measured in standing position (Pajunen et al., 2013). Based on the abovementioned problems, our 102 study aims to analyse the anthropometric indicators related to metabolic syndrome in female 103 students.

# 104

106

107

108

109

110

# 105 2. Materials and methods

2.1 Design, location, and time

The scope of this study is community nutrition with a cross-sectional study design. Anthropometric and biochemical data were collected at the Cito Laboratory, Banyumanik Semarang with health protocols applied. The study started from March to July 2020.

# 111 2.2 Samplings

This study was conducted during the SARS-CoV-2 outbreak, which later was named COVID-19 by the WHO, so the registration for study participants was done online. The inclusion criteria were female students aged 19-24, resided in Semarang, willing to be a study participant and willing to follow a series of study instructions. Subjects were asked to fill in personal data using a Google form; and eligible subjects will be contacted by the researchers to plan a direct meeting. Purposive sampling was used in this study and the total number of subjects required was 163. Commented [A6]: revised

Commented [A7]: revised

Commented [A8]: revised

Commented [A9]: revised

## 119 2.3 Data collected

120 The independent variables in this study were the Waist-to-Height Ratio (WHtR), Waist-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference. 121 Bodyweight was measured using a digital scale to the nearest 0.01 kg, height was measured using a 122 123 microtoise to the nearest 0.1 cm, waist circumference and hip circumference was measured using a 124 measuring tape (Medline) to the nearest 1 mm and abdominal height was measured using the 125 Abawerk Schaffenburg abdominal calliper to the nearest 1 mm. SAD measurements were performed 126 with the subject in a supine position on a flat surface with both knees forming an angle of 90° (Firouzi 127 et al., 2018).

128The cut-off point used in this study refers to previous studies because it had been adjusted for the129Asian race (Rose *et al.*, 2020). Each anthropometric measurement is stated as "at risk" if the130individuals have  $\geq 0.50$  for WHR (Zhang *et al.*, 2016),  $\geq 0.85$  for WHR (Rokhmah, *et al.*, 2015), > 19.3131cm for (Dieny *et al.*, 2020), and have the normal to overweight BMI (18.5 - 25 kg/m<sup>2</sup>) or obese BMOI132( $\geq 25.0$  kg/m<sup>2</sup>) (Susetyowati, 2016).

133 The dependent variable in this study is the metabolic syndrome component that has been 134 converted into a metabolic syndrome score (cMetS) with the cut-off point on cMetS> 2.21 (Rose et 135 al., 2020). The guidelines for metabolic syndrome in this study are taken from the National 136 Cholesterol Education Program-Adult Treatment Panel (NCEP-ATP III) 2005 which has been 137 frequently used in Indonesia. There are 5 parameters to assess metabolic syndrome: (1) fasting blood 138 glucose levels ≥110 mg/dL, (2) triglyceride levels ≥150 mg/dL (3) HDL cholesterol levels <50 mg/dL, 139 (4) central obesity in women with waist circumference ≥80 cm, and (5) systolic and diastolic blood 140 pressures ≥130 mmHg and ≥85 mmHg, respectively (Soewondo et al., 2010). The calculation of the metabolic syndrome score (cMetS) was done in the following steps: (1) after measuring all 141 142 parameters of the metabolic syndrome, standardisation was carried out to obtain a Z-score; (2) the 143 blood pressure must be converted into Mean Arterial Blood (MAP) by dividing the difference 144 between systolic and diastolic blood pressure by three and summed with the diastolic blood pressure; (3) the HDL cholesterol standardisation results were multiplied by (-1) because the 145 146 parameter was inversely related to the risk of metabolic syndrome; (4) All Z-scores were added to 147 obtain the cMetS values; (5) The final step was to compare the cMetS values with the cut-off point 148 <mark>of ≥2,</mark>21 <mark>(Eisenmann *et al.,* 2010; Okosun, Boltri*, et al.,* 2010; Rose *et al.,* 2020). The subjects were</mark> 149 instructed to do fasting for at least 8 hours; only drinking water was permitted.

150 Other than the cMetS score, metabolic syndrome risk can also be assessed from the classification 151 of metabolic types. This classification combines the internal and external signs of the body such as 152 biochemical parameters, the ratio of subcutaneous fat to abdominal fat, and blood pressure (Prybyla 153 O, 2020). The main phenotypes that reflect the possible combination of metabolic profile and the 154 degree of obesity are metabolic healthy obese weight, metabolic healthy normal weight, metabolic 155 unhealthy normal weight, and metabolic unhealthy normal weight.

### 2.4 Data analysis

Statistical analyses were performed using SPSS Statistical software. This study has received an ethical clearance issued by the Medical/Health Research Bioethics Commission, Faculty of Medicine, Sultan Agung Islamic University Semarang with Number No.296 /IX /2020 /Bioethical Commission.

160 161 162

156 157

158

159

Commented [A10]: revised

Commented [A11]: revised

Commented [A12]: revised

# 163 3. Results and discussion/Results

The subject characteristics measured in female student aged 19-24 years include age, anthropometric indicators, and metabolic syndromes. Table 1 shows the characteristics of the study subjects. The mean of WHtR value in this study was 0.51. Meanwhile, the mean of WHR was 0.80; the mean of BMI was 24.04 kg/m<sup>2</sup>; the mean of SAD was 16.79 cm; and the mean of waist circumference was 79.44 cm.

169 Table 2 shows various nutritional status of the subjects based on BMI. We found that 43.6% of the 170 subjects had normal BMI, 17.2% were overweight and 35.6% were obese. Based on the WHtR 171 anthropometric indicator, 72.4% of subjects were at risk of having obesity; based on WHR, 22.1% had 172 central obesity; based on BMI, 35.6% were obese; based on SAD 12.3% of the subjects were at risk; and based on waist circumference 55.2% had central obesity. According to the metabolic profile that 173 174 was assessed, 16.6% had high FBG levels, 8.6% had hypertriglycerides, 17.2% had low HDL, 16.6% had 175 high systolic blood pressure, and 21.5% had high diastolic blood pressure. In addition, we found 33.1% 176 of the subjects had high metabolic syndrome (cMetS) scores. This proportion was similar to the 177 assessment based on the metabolic type of unhealthy subjects (subjects who had  $\geq$  3 risk factors of 178 the metabolic profile), which was 33.7%. Moreover, two subjects had five risk factors: abdominal 179 obesity, hypertension, hyperglycaemia, hypertriglycerides, and low HDL.

180 If we are considering metabolic type based on nutritional status (subjects with non-obese BMI 181 (<25kg/m<sup>2</sup>) with metabolic healthy and metabolic unhealthy and subjects with obese BMI (> 25kg/m<sup>2</sup>) 182 with metabolic healthy and metabolic unhealthy), subjects are categorised as metabolic unhealthy (experiencing metabolic syndrome) if they fulfil ≥ 3 risk factors including high waist circumference, 183 184 blood pressure, GDP and triglyceride levels, and low HDL levels. Based on these criteria, we found that 185 10.4% of the subjects had metabolic unhealthy normal weight (MUNW) and 23.3% of the subjects had 186 metabolic unhealthy obesity weight (MUOW). In non-obese subjects, 54% of them were metabolic 187 healthy.

188 Table 3 and Table 4 show the results of statistical analyses on anthropometric indicators related 189 to the metabolic syndromes. Table 3 shows the bivariate statistical analysis using the Pearson 190 correlation test. The analysis results showed that all anthropometric indicators, namely WHtR, BMI, SAD, waist circumference, hip circumference and WHR have a strong positive relationship with the 191 192 metabolic syndrome score (p<0.001), which means that the higher the anthropometric value, the 193 higher the metabolic syndrome score. In addition, the analysis on the relationship between 194 anthropometric indicators and each metabolic profile revealed that almost all of the independent 195 variables (WHtR, waist and hip circumference, WHR, BMI, and SAD) were associated with each 196 metabolic profile, such as baseline systolic pressure, diastolic blood pressure, triglyceride levels, blood 197 sugar levels, and HDL. Only WHR that was not associated with diastolic blood pressure (p>0.005).

Table 4 shows the results of the analysis using multiple linear regression to determine anthropometric indicators that are most associated with each metabolic profile and metabolic syndrome score.

The results showed that BMI was the anthropometric indicator that is most associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood sugar (p<0.05), and HDL (p <0.001). In addition, waist circumference was the anthropometric indicator that is most associated with triglycerides and metabolic syndrome score (p<0.001). Based on the Adjusted R2 value on the metabolic syndrome score, we found that 37.5% of the metabolic syndrome score was related to anthropometric indicators, such as WHtR, waist and hip circumference, WHR, BMI, and SAD. The rest
 may be influenced by other variables that are not included in this study.

# 209 4. Discussion

208

210 The objective of this study was to determine the anthropometric indicators associated with 211 metabolic syndromes in female students. The study included 163 female students aged 19-24 years. 212 The students are in their late adolescents who begin to have an independent life. Inappropriate and 213 unhealthy eating behaviours will have an impact on the student's nutritional status. Excessive 214 nutritional status and obesity will affect student's body metabolism. Based on the study results, 215 33.1% of the subjects had a high metabolic syndrome (cMetS) score. In line with the previous study 216 conducted in 2019 on 18-to-21-year-old students at Diponegoro University, 20% of the subjects had 217 high cMetS (Rose et al., 2020). Meanwhile, a study conducted by Pratiwi et al in 2017 using secondary 218 data from the National Basic Health Research 2013 found that 19.98% of adolescents aged 15-24 219 years had high cMetS (Pratiwi, et al., 2017). Therefore, we conclude that there is a trend of Metabolic 220 Syndrome Score (cMetS) among young women in Semarang.

221 The assessment of metabolic syndrome using a continuous type (scoring) rather than using a 222 dichotomy or binary ("yes" and "no") is recommended (Christijani, 2019). An adolescent can be 223 diagnosed with metabolic syndrome if their Metabolic Syndrome Score (cMetS) >2.21 (Pratiwi, et al., 224 2017). Anthropometric indicators used in this study are Waist and Height Ratio (WHtR), Waist-to-Hip 225 Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and Waist Circumference. 226 Based on the correlation analyses, all anthropometric indicators have a significant positive 227 relationship with the Metabolic Syndrome Score (cMetS). Furthermore, the multivariate analyses show that the anthropometric indicators of BMI and RLPP are strongly associated with cMetS. 228

229 According to the metabolic type, most of the subjects (54%) in this study had metabolic healthy 230 normal weight (MHNW) metabolic type. In this type, the individuals have a normal BMI and does not 231 show any metabolic risk. Our study also shows that 10.4% of the subjects were classified as metabolic 232 unhealthy normal weight (MUNW). The subjects' BMI in this category is in the normal range but has 233 a high percentage of body fat that makes them at high risk of developing metabolic disorders (Eckel 234 et al., 2015; Suliga et al., 2015). Several recent cohort studies have shown a greater risk of type II 235 diabetes mellitus in individuals with MUNW compared to individuals with MHNW (Ärnlöv et al., 2011; 236 Hadaegh et al., 2011; Aung et al., 2014; Jung et al., 2014; Hinnouho et al., 2015). Other studies have 237 shown that women with the MUNW type have a long-term impact of an increased risk of 238 cardiovascular diseases such as higher blood pressure, triglyceride and glucose levels as well as lower 239 levels of adiponectin, HDL, and LDL compared to women with the MHNW type (Kim et al., 2013)

240In our study, 23.3% of the subjects belonged to the Metabolic Unhealthy Obese Weight (MUOW)241type. Subjects with this metabolic type have an obese BMI and have a high risk of developing242metabolic disorders. A study conducted in Japan on 29,564 subjects showed that individuals with243MUOW had a greater risk of developing type II diabetes mellitus compared to individuals with MHOW244(Heianza et al., 2015).

245 We also found that 12.3% of the subjects were categorized as metabolic healthy obese weight 246 (MHOW). Individuals in this metabolic type have an obese BMI but do not show any metabolic risks. 247 Given the impact of obesity in relation to the risk of metabolic diseases, various studies have been 248 conducted to examine the long-term effects of MHOW. Individuals with MHOW had a different fat 249 distribution pattern (less ectopic and visceral fat), and lower inflammatory markers (Samocha-Bonet Commented [A13]: revised

Commented [A14]: revised

Commented [A15]: revised

Commented [A16]: revised

et al., 2014). Other studies also have shown that women with MHOW had lower blood pressure, 251 triglyceride levels, and glucose levels, but higher levels of HDL, adiponectin, and LDL compared to women with MUNW (Kim et al., 2013). This condition was associated with good diet quality in 252 253 individuals with MHOW. Based on National Health and Nutrition Examination Surveys (NHANES) 254 data, Camhi et al examined the quality of diet in obese subjects, and found that adolescents and adult 255 women with the MHOW metabolic type had higher diet quality scores due to high intake of fruit, 256 whole grains, meat, and nuts (Camhi et al., 2015). The correlation test results indicated that all anthropometric indicators had a positive 257 258 relationship with the metabolic syndrome scores with p <0.001. Meanwhile, the regression analyses 259 show that BMI and WHR were inversely related to cMetS. This is in line with research conducted by Lindy et al, who stated that an increase in the WHR value could be associated with the risk of 260 261

metabolic syndrome in children and adolescents in Florida (Moore et al., 2015). A study conducted 262 by Al-Bachir and Bakir stated that there was a strong relationship between overweight and obese adolescents with metabolic syndrome (Al-Bachir and Bakir, 2017). Furthermore, a study conducted 263 264 by Adrian et al on 15-year-old adolescents in South Africa found that central obesity as measured by 265 the hip circumference could lead to an increased risk of cardiovascular diseases and death. Therefore, 266 hip circumference and waist circumference can be used to predict the risk of cardiovascular diseases 267 and death in the future (Cameron et al., 2012).

268 Body Mass Index (BMI) is the most widely used indicator of measurement in epidemiological 269 studies and is used as a substitute for evaluating body composition. However, BMI cannot distinguish 270 fat from fat mass and lean mass, and it fails to show the presence of adipose and body fat distribution 271 (Ofer et al., 2019; Leone et al., 2020). However, the BMI cut-offs for metabolic syndrome has not yet 272 been determined (Ofer et al., 2019). Obesity in adolescents is generally assessed using a BMI of ≥25.0 273 kg/m<sup>2</sup>. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m<sup>2</sup>) and 274 obesity (≥25.0 kg/m<sup>2</sup>), and we found that 35.6% of the subjects were obese. The finding is in line with 275 the research conducted by Sophia et al on the subject of students at Universitas Diponegoro aged 276 18-21 years. They found that 40% of their study population had obesity level I and 36.3% had obesity 277 level II (Rose et al., 2020).

278 Abdominal obesity is often assessed to determine a metabolic syndrome in people. One of the 279 indicators used to measure abdominal obesity is the Waist-to-Hip Ratio (WHR) which is calculated by 280 dividing the waist circumference and the hip circumference. Measurement of waist circumference is 281 more sensitive in assessing the distribution of body fat in the abdominal wall, which is also a 282 component in the metabolic syndrome. The limit of the WHR value for female is  $\geq$  0.85 (Rokhmah, et 283 al., 2015). This study shows that every 1% increase in the WHR value will increase the cMetS value 284 by 10.411. Hip circumference is also an indicator that has a strong correlation with cMetS, but many 285 studies have used it as a ratio along with waist circumference for assessing a person's central obesity 286 status. 287

#### 288 5. Conclusion

289 Metabolic syndrome in female students in Semarang can be identified using anthropometric 290 measurements, one of which is BMI and WHR which are very easy to measure and efficient. In 291 addition, the use of cMetS in the metabolic assessment of a person was found to be more effective.

292

250

Commented [A17]: revised Commented [A18]: revised Commented [A19]: revised Commented [A20]: revised Commented [A21]: revised Commented [A22]: revised Commented [A23]: revised

# 293 Conflict of interest - Disclose any potential conflict of interest appropriately.

294 The authors declare no conflict of interest.

### 295 Acknowledgments

296 The authors would like to thank all the subjects who participated in this study. We would also like

- 297 to express our gratitude to The Ministry of Research, Technology and Higher Education, Indonesia"
- 298 was funded by the "Hibah Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) 2019.

### 299

# 300 References

Al-Bachir, M. and Bakir, M. A. (2017). Predictive value of body mass index to metabolic syndrome risk
 factors in Syrian adolescents. *Journal of Medical Case Reports*, 11(1). doi: 10.1186/s13256-017-1315 2.

- Ärnlöv, J., Sundström, J., Ingelsson, E., Lind, L. (2011). Impact of BMI and the metabolic syndrome on the
   risk of diabetes in middle-aged men. *Diabetes Care*, 34(1), pp. 61–65. doi: 10.2337/dc10-0955.
- Aung, K. K., Lorenzo, C., Hinojosa, M. A., Haffner, S. M. (2014). Risk of developing diabetes and
   cardiovascular disease in metabolically unhealthy normal-weight and metabolically healthy obese
   individuals. *Journal of Clinical Endocrinology and Metabolism*, 99(2), pp. 462–468. doi:
   10.1210/jc.2013-2832.
- Badan Penelitian dan Pengembangan Kesehatan. (2018). *Riset Kesehatan Dasar (RISKESDAS) 2018.* Jakarta, Indonesia.
- Cameron, A. J., Magliano, D. J., Shaw, J. E., Zimmet, P. Z., Carstensen, B., Alberti, K. G. M. M., Tuomilehto,
  J., Barr, E. L. M., Pauvaday, V. K., Kowlessur, S., Söderberg, S. (2012). The influence of hip circumference
  on the relationship between abdominal obesity and mortality. *International Journal of Epidemiology*,
  41(2), pp. 484–494. doi: 10.1093/ije/dyr198.
- Camhi, S. M., Whitney Evans, E., Hayman, L. L., Lichtenstein, A. H., Must, A. (2015). Healthy eating index
   and metabolically healthy obesity in U.S. adolescents and adults. *Preventive Medicine*, 77, pp. 23–27.
   doi: 10.1016/j.ypmed.2015.04.023.
- Christijani, R. (2019). Determination of Diagnosis of Metabolic Syndrome based on Assessment of
   Metabolic Syndrome and NCEP ATP-III Score in Adolescent. *The Journal of Nutrition and Food Research*,
   42(1), pp. 21–28. doi: 10.22435/pgm.v42i1.2418.
- Devi, R., Manhas, S., Prasad, S., Sharma, S., Bhaskar, N., Mahajan, S. (2017). Short Review of Metabolic
   Syndrome. *International Journal of Research & Review*, 4(2), p. 29.
- Dieny, F. F., Setyaningsih, R. F., Fitranti, D. Y., Jauharany, F. F., Putra, Y. D., Tsani, A. F. A. (2020). Abdominal
   diameter profiles have relationship with insulin resistance in obese female adolescents. *Electronic Journal of General Medicine*, 17(5), p. em219. doi: 10.29333/ejgm/7882.
- 327 Eckel, N., Mühlenbruch, K., Meidtner, K., Boeing, H., Stefan, N., Schulze, M. B. (2015). Characterization of 328 metabolically unhealthy normal-weight individuals: Risk factors and their associations with type 2 and 329 diabetes. Metabolism: Clinical Experimental, 64(8), 862-871. doi: pp. 330 10.1016/j.metabol.2015.03.009.
- Eisenmann, J. C., Laurson, K. R., Dubose, K. D., Smith, B. K., Donnelly, J. E. (2010). Construct validity of a
   continuous metabolic syndrome score in children. *Diabetology and Metabolic Syndrome*, 2(1). doi:
   10.1186/1758-5996-2-8.
- Firouzi, S. A., Tucker, L. A., LeCheminant, J. D., Bailey, B. W. (2018). Sagittal abdominal diameter, waist
   circumference, and BMI as predictors of multiple measures of glucose metabolism: An NHANES
- investigation of US adults. *Journal of Diabetes Research*, 2018, pp. 1–14. doi: 10.1155/2018/3604108.

### Commented [A24]: revised

- Hadaegh, F., Bozorgmanesh, M., Safarkhani, M., Khalili, D., Azizi, F. (2011). Predictability of body mass
   index for diabetes: Affected by the presence of metabolic syndrome?. *BMC Public Health*, 11(1), p. 383.
   doi: 10.1186/1471-2458-11-383.
- Heianza, Y., Kato, K., Kodama, S., Ohara, N., Suzuki, A., Tanaka, S., Hanyu, O., Sato, K., Sone, H. (2015). Risk
  of the development of Type 2 diabetes in relation to overall obesity, abdominal obesity and the
  clustering of metabolic abnormalities in Japanese individuals: Does metabolically healthy overweight
  really exist? The Niigata Wellness Study. *Diabetic Medicine*, 32(5), pp. 665–672. doi:
  10.1111/dme.12646.
- Herningtyas, E. H. and Ng, T. S. (2019). Prevalence and distribution of metabolic syndrome and its
  components among provinces and ethnic groups in Indonesia. *BMC Public Health*, 19(1), p. 377. doi:
  10.1186/s12889-019-6711-7.
- Hinnouho, G. M., Czernichow, S., Dugravot, A., Nabi, H., Brunner, E. J., Kivimaki, M., Singh-Manoux, A.
  (2015). Metabolically healthy obesity and the risk of cardiovascular disease and type 2 diabetes: The
  Whitehall II cohort study. *European Heart Journal*, 36(9), pp. 551–559. doi: 10.1093/eurheartj/ehu123.
- Jung, H. S., Chang, Y., Eun, Y. K., Kim, C. W., Choi, E. S., Kwon, M. J., Cho, J., Zhang, Y., Rampal, S., Zhao, D.,
  Soo, K. H., Shin, H., Guallar, E., Ryu, S. (2014). Impact of body mass index, metabolic health and weight
  change on incident diabetes in a Korean population. *Obesity*, 22(8), pp. 1880–1887. doi:
  10.1002/oby.20751.
- Karimah, M. (2018). Rasio Lingkar Pinggal-panggul Memiliki Hubungan Paling Kuat dengan Kadar Glukosa
   Darah'. Jurnal Berkala Epidemiologi, 6(3), pp. 219–226.
- Kim, M., Paik, J. K., Kang, R., Kim, S. Y., Lee, S. H., Lee, J. H. (2013). Increased oxidative stress in normal weight postmenopausal women with metabolic syndrome compared with metabolically healthy
   overweight/obese individuals. *Metabolism: Clinical and Experimental*, 62(4), pp. 554–560. doi:
   10.1016/j.metabol.2012.10.006.
- Leone, A. *et al.* (2020). Evaluation of different adiposity indices and association with metabolic syndrome
   risk in obese children: Is there a winner?. *International Journal of Molecular Sciences*, 21(11), p. 4083.
   doi: 10.3390/ijms21114083.
- Li, Y. *et al.* (2018). Metabolic syndrome prevalence and its risk factors among adults in China: A nationally
   representative cross-sectional study. *PLoS ONE*, 13(6), p. e0199293. doi:
   10.1371/journal.pone.0199293.
- Moore, L. M. *et al.* (2015). Analysis of Pediatric Waist to Hip Ratio Relationship to Metabolic Syndrome
   Markers. *Journal of Pediatric Health Care*, 29(4), pp. 319–324. doi: 10.1016/j.pedhc.2014.12.003.
- Ofer, K. *et al.* (2019). Normal body mass index (BMI) can rule out metabolic syndrome: An Israeli cohort
   study. *Medicine*, 98(9), p. e14712. doi: 10.1097/MD.00000000014712.
- Okosun, I. S., Boltri, J. M., *et al.* (2010). Continuous metabolic syndrome risk score, body mass index
   percentile, and leisure time physical activity in American children. *Journal of Clinical Hypertension*,
   12(8), pp. 636–644. doi: 10.1111/j.1751-7176.2010.00338.x.
- Okosun, I. S., Lyn, R., *et al.* (2010). Validity of a Continuous Metabolic Risk Score as an Index for Modeling
   Metabolic Syndrome in Adolescents. *Annals of Epidemiology*, 20(11), pp. 843–851. doi:
   10.1016/j.annepidem.2010.08.001.
- Okura, T. *et al.* (2018). Body mass index ≥23 is a risk factor for insulin resistance and diabetes in Japanese
   people: A brief report. *PLOS ONE*. Edited by P. Bjornstad, 13(7), p. e0201052. doi:
   10.1371/journal.pone.0201052.
- Pajunen, P. *et al.* (2013). Sagittal abdominal diameter as a new predictor for incident diabetes. *Diabetes Care*, 36(2), pp. 283–288. doi: 10.2337/dc11-2451.
- Pratiwi, Z. A., Hasanbasri, M. and Huriyati, E. (2017). Penentuan titik potong skor sindroma metabolik
   remaja dan penilaian validitas diagnostik parameter antropometri: analisis Riskesdas 2013. Jurnal Gizi
- 384 *Klinik Indonesia*, 14(2), p. 80. doi: 10.22146/ijcn.25590.

- Prybyla, O. (2020). Metabolic phenotyping: is it so important?. Journal of Cognitive Neuropsychology.
   iMedPub., 4(1), 1-3.
- Rodea-Montero, E. R., Evia-Viscarra, M. L. and Apolinar-Jiménez, E. (2014). Waist-to-height ratio is a better
   anthropometric index than waist circumference and BMI in predicting metabolic syndrome among
   obese mexican adolescents. *International Journal of Endocrinology*, 2014, 195407. doi:
   10.1155/2014/195407.
- Rokhmah, F. D., Handayani, D. and Al-Rasyid, H. (2015). Korelasi lingkar pinggang dan rasio lingkar
   pinggang-panggul terhadap kadar glukosa plasma menggunakan tes toleransi glukosa oral. *Jurnal Gizi Klinik Indonesia*, 12(1), pp. 28–35. doi: 10.22146/ijcn.22425.
- Rose, S., Dieny, F. F., Nuryanto, N., Tsani, A. F. A. (2020). The correlation between waist-to-height ratio
   (wHtR) and second to fourth digit ratio (2D:4D) with an increase in metabolic syndrome scores in obese
   adolescent girls. *Electronic Journal of General Medicine*, 17(3), p. em211. doi: 10.29333/ejgm/7872.
- Samocha-Bonet, D., Dixit, V. D., Kahn, C. R., Leibel, R. L., Lin, X., Nieuwdorp, M., Pietiläinen, K. H., RabasaLhoret, R., Roden, M., Scherer, P. E., Klein, S., Ravussin, E. (2014). Metabolically healthy and unhealthy
  obese The 2013 stock conference report. *Obesity Reviews*, 15(9), pp. 697–708. doi:
  10.1111/obr.12199.
- Soewondo, P., Purnamasari, D., Oemardi, M., Waspadji, S., Soegondo, S. (2010). Prevalence of Metabolic
   Syndrome Using NCEP/ATP III Criteria in Jakarta, Indonesia: The Jakarta Primary Non-communicable
   Disease Risk Factors Surveillance 2006. *Acta Med Indones.*, 42(4), pp. 199–203.
- Sri Rahayu, M. and Maulina, M. (2017). Hubungan Rasio Lingkar Pinggang dan Lingkar Pinggul dengan
   Penyakit Jantung Koroner. *Jurnal Aceh Medika*, 1(1), pp. 1–10. Available at:
   www.jurnal.abulyatama.ac.id/acehmedika (Accessed: 8 April 2021).
- Srikanthan, K., Feyh, A., Visweshwar, H., Shapiro, J. I., Sodhi, K.(2016). Systematic review of metabolic
  syndrome biomarkers: A panel for early detection, management, and risk stratification in the West
  Virginian population. *International Journal of Medical Sciences*, 13(1), pp. 25–38. doi:
  10.7150/ijms.13800.
- Suliga, E., Kozieł, D., Cieśla, E., Głuszek, S. (2015). Association between dietary patterns and metabolic
   syndrome in individuals with normal weight: A cross-sectional study. *Nutrition Journal*, 14(1), p. 55.
   doi: 10.1186/s12937-015-0045-9.
- Sumardiyono, S., Pamungkasari, E. P., Mahendra, A. G., Utomo, O. S., Mahajana, D., Cahyadi, W. R., Ulfia,
  M. (2018). Hubungan Lingkar Pinggang dan Lingkar Panggul dengan Tekanan Darah pada Pasien
  Program Pengelolaan Penyakit Kronis (Prolanis). *Smart Medical Journal*, 1(1), p. 26. doi:
  10.13057/smj.v1i1.24504.

418 Susetyowati, S. (2016). Gizi Remaja, in *Ilmu Gizi: Teori dan Aplikasi*. Jakarta, Indonesia: EGC, pp. 160–164.

Zhang, Y. X., Wang, Z. X., Chu, Z. H., Zhao, J. S. (2016). Profiles of body mass index and the nutritional
 status among children and adolescents categorized by waist-to-height ratio cut-offs. *International Journal of Cardiology*, 223, pp. 529–533. doi: 10.1016/j.ijcard.2016.07.303.

Zhou, D., Yang, M., Yuan, Z. P., Zhang, D. D., Liang, L., Wang, C. L., Zhang, S., Zhu, H. H., Lai, M. D., Zhu, Y.
M. (2014) . Waist-to-Height Ratio: A simple, effective and practical screening tool for childhood obesity
and metabolic syndrome. *Preventive Medicine*, 67, pp. 35–40. doi: 10.1016/j.ypmed.2014.06.025.

# 426 Tables and Figures – 1 PAGE 1 TABLE/FIGURE. PLACE ALL TABLES AND FIGURES AT THE END OF THE 427 MANUSCRIPT BODY AFTER THE REFERENCES

428

425

Table 1. Minimum, Maximum, Average and Standard Deviation

Variabel	Minimum	Maximum	Mean	SD
Anthropometric Indicators				
WHtR (rasio)	0.37	0.71	0.51	0.07

RLPP (rasio)	0.67	0.96	0.80	0.06	
BMI (kg/m²)	15.81	39.30	24.04	4.72	
Sagital Abdominal Diameter (cm)	11.35	25.50	16.79	2.42	
Hip Circumference (cm)	80.60	138.45	98.96	9.30	
Waist Circumference (cm)	58.00	112.10	79.44	10.78	
Metabolic Profiles					
Blood Glucose Levels (mg/dL)	66.00	110.00	92.00	7.59	
Trygliceride Levels (mg/dL)	29.00	309.00	88.35	44.68	
Cholesterol Levels HDL (mg/dL)	36.00	109.00	61.73	26.43	
Sistolic Blood Pressure (mmHg)	84.00	144.00	114.63	11.13	
Diastolic Blood Pressure (mmHg)	55.00	178.00	82.40	55.52	
cMetS (Score of Metabolic Syndrome)	-7.10	<u>11.93</u>	0.01	2.90	

429 430 **Commented [acer25]:** If these are decimal points, revise ALL '," to "." Use standardized value

haracteristics	n	%	
nthropometric			
Body Mass Index (BMI)			
Underweight (< 18.5 kg/m <sup>2</sup> )	6	<mark>3.</mark> 7	
Normal (18.5 – 22.9 kg/m <sup>2</sup> )	71	43.6	Commented [acer26]: revise
Overweight (23-24.9 kg/m <sup>2</sup> )	28	<mark>17.2</mark>	Commenter Incorport Comme
Obese ( $\geq 25.0$ kg/m <sup>2</sup> )	58	<mark>35.6</mark>	
Waist Height Ratio (WHtR)			
Normal (<0.50)	45	<mark>27.6</mark>	
Risk (≥0.50)	118	<mark>72.4</mark>	
Waist Hip Ratio			
Normal (<0.85)	127	77.9	
Central Obesity (≥0.85)	36	<mark>22.1</mark>	
Sagital Abdominal Diameter (SAD)			
Normal (≤19.3 cm)	143	<mark>87.7</mark>	
Risk (>19.3 cm)	20	12.3	
Wait Circumference	20	12.9	
Normal (<80 cm)	73	<mark>44.8</mark>	
Obese (≤80 cm)	90	55.2	
Metabolic Profiles	50	<mark></mark>	
Blood Glucose Levels			
Normal (<110 mg/dL)	136	<mark>83.4</mark>	
High (≥110 mg/dL)	27	16.6	
Triglycerides	27	10.0	
Normal (<150 mg/dL)	149	<mark>914</mark>	
High (≥150 mg/dL)	145	8.6	
Cholesterol HDL	14	0.0	
Normal (≥150 mg/dL)	135	<mark>82.8</mark>	
Rendah (<150 mg/dL)	28	17.2	
Sistolic Blood Pressure	20	<u>-,,,</u>	
Normal (<130 mg/dL)	136	<mark>83.4</mark>	
High (≥130 mg/dL)	27	16.6	
Diastolic Blood Pressure	21	10.0	
Normal (<85 mg/dL)	128	<mark>78.5</mark>	
High (≥85 mg/dL)	35	21.5 21.5	
cMetS (Score of Metabolic Syndrome)	55	<b>21.J</b>	
Normal (<2.21)	109	<mark>66.9</mark>	
Risk ( $\geq 2.21$ )	109 54	33.1	
Tipe Metabolik	54	<mark></mark>	
Metabolic Unhealthy Normal Weight (MUNW)	17	<b>10.4</b>	
Metabolic Uniteditity Normal Weight (MHNW) Metabolic Healthy Normal Weight (MHNW)	88	10.4 54	
, 5, ,	00 38		
Metabolic Unhealthy Obese Weight (MUOW) Metabolic Healthy Obese Weight (MHOW)	38 20	23.3 12.3	

449	Table 3	3.The Rela	tionship b	oetween A	nthropor	netric Indi	cators and	d Metabolic	Profiles	(Blood Pre	essure,	
450			Triglyce	rides, Bloo	od Sugar,	HDL and I	metabolic	syndrome	scores)			Commented [A27]: revised
Variable	Sistolic	BP	Distolic	BP	TG		Blood G	lucose	HDL		cMetS	()
	r	р	r	р	r	р	r	р	r	р	r	p
WHtR	<mark>0.358</mark>	<mark>&lt;0.001</mark>	<mark>0.306</mark>	<mark>&lt;0.001</mark>	<mark>0.289</mark>	<mark>&lt;0.001</mark>	<mark>0.210</mark>	<mark>0.007</mark>	<mark>-0.266</mark>	<mark>0.001</mark>	<mark>0.599</mark>	<0.0 Commented [acer28]: revise
BMI	<mark>0.370</mark>	<mark>&lt;0.001</mark>	<mark>0.313</mark>	<mark>&lt;0.001</mark>	<mark>0.315</mark>	<mark>&lt;0.001</mark>	<mark>0.221</mark>	<mark>0.005</mark>	<mark>-0.292</mark>	<mark>&lt;0.001</mark>	<mark>0.600</mark>	<0.001
SAD	<mark>0.352</mark>	<mark>&lt;0.001</mark>	<mark>0.284</mark>	<mark>&lt;0.001</mark>	<mark>0.278</mark>	<mark>&lt;0.001</mark>	<mark>0.191</mark>	<mark>0.015</mark>	<mark>-0.264</mark>	<mark>0.001</mark>	<mark>0.575</mark>	<mark>&lt;0.001</mark>
WC	<mark>0.377</mark>	<mark>&lt;0.001</mark>	<mark>0.284</mark>	<mark>&lt;0.001</mark>	<mark>0.295</mark>	<mark>&lt;0.001</mark>	<mark>0.212</mark>	<mark>0.005</mark>	<mark>-0.243</mark>	<mark>0.002</mark>	<mark>0.616</mark>	<mark>&lt;0.001</mark>
HC	<mark>0.369</mark>	<mark>&lt;0.001</mark>	<mark>0.332</mark>	<mark>&lt;0.001</mark>	<mark>0.302</mark>	<mark>&lt;0.001</mark>	<mark>0.179</mark>	<mark>0.002</mark>	<mark>-0.273</mark>	<mark>&lt;0.001</mark>	<mark>0.581</mark>	<mark>&lt;0.001</mark>
WHR	<mark>0.244</mark>	<mark>0.002</mark>	<mark>0.128</mark>	<mark>0.104</mark>	<mark>0.194</mark>	<mark>0.013</mark>	<mark>0.172</mark>	<mark>0.028</mark>	<mark>-0.149</mark>	<mark>0.048</mark>	<mark>0.415</mark>	<mark>&lt;0.001</mark>
451												
452	Tab	le 4. Anthi	ropometr	ic indicato	rs most a	issociated	with meta	abolic comp	onents a	nd metab	olic	
453					syr	ndrome sc	ores					
	Va	riable		Sistolic I	BP							
				Konstan	ta US	Ca	<b>р1</b> <sup>ь</sup>	р2 <sup>с</sup>	ďĄ	djusted R	2	
	BN	11		<mark>91.759</mark>	<mark>0.9</mark>	<mark>)51</mark>	<mark>&lt;0.001</mark>	<mark>&lt;0.001</mark>	. <mark>0.</mark>	<mark>158</mark>		
				<mark>Blood G</mark>	lucose Le	vels						
				<mark>Konstan</mark>	ta <mark>US</mark>	<mark>C°</mark>	p1 <sup>b</sup>	<mark>p2<sup>c</sup></mark>	A	djusted R <sup>2</sup>		
	BN	11		<mark>83.454</mark>	<mark>0.3</mark>	<mark>55</mark>	<mark>0.005</mark>	<mark>&lt;0.001</mark>	. <mark>0.</mark>	<mark>043</mark>		
				HDL								
				<u>Konstan</u>	ta <mark>US</mark>	<u>C</u>	p1 <sup>b</sup>	<mark>p2°</mark>	A	djusted R <sup>2</sup>		
	BN	11		<mark>81.429</mark>	<mark>-0.</mark>	<mark>819</mark>	<mark>&lt;0.001</mark>	<mark>&lt;0.001</mark>	. <mark>0.</mark>	<mark>080</mark>		
				<b>Triglyce</b>	rides							
				Konstan	ta US	<mark>C°</mark>	<mark>р1<sup>ь</sup></mark>	p2 <sup>c</sup>	A	djusted R <sup>2</sup>		
	W	С		<mark>-6.614</mark>	1.1	. <mark>95</mark>	<0.001	<0.001	. <mark>0.</mark>	078		
				Score of	Metabo	lic Syndro	me					
				Konstan	ta <mark>US</mark>	<u>C°</u>	<mark>р1<sup>ь</sup></mark>	<mark>p2<sup>c</sup></mark>	A	djusted R <sup>2</sup>		
	W	С		<mark>-13.163</mark>	0.1	.66	<0.001	<0.001		375		

<sup>a</sup>Unstandardized Coefficient, <sup>b</sup>p-value, <sup>c</sup>p Uji F (ANOVA), <sup>d</sup>Koefisien Determinasi 

# PROSES REVIEW DAN REVISI

F	Food Research -{foodresearch.my@outlook.com> kepada saya -	@ 18 Mei 2021, 02.47	☆	¢	:
	🛪 Inggris 🗸 🖒 Indonesia 🖌 Terjemahkan pesan	Nonaktifkan u	untuk: In	nggris	×
	Dear Dr. Fillah Fithra Dieny,				
	Manuscript FR-2021-250 entitled " Anthropometry indicators that are most related to female student's metabolic profiles " which you submitted to Food comments of the reviewer(s) are included in the attached file.	Research, has been	revie	wed.	Гhe
	The reviewer(s) have recommended publication, but also suggest some revisions to your manuscript. Therefore, I invite you to respond to the revier manuscript. Once the revised manuscript is prepared, please send it back to me for further processing.	ewer(s)' comments a	and rev	vise y	our
	Because we are trying to facilitate timely publication of manuscripts submitted to Food Research, your revised manuscript should be submitted befor possible for you to submit your revision by this date, please let us know.	re or by 25th May <mark>20</mark>	)21. I	f it is	not
	Once again, thank you for submitting your manuscript to Food Research and I look forward to receiving your revised manuscript.				
	Sincerely,				
	Professor Dr. Son Radu Chief Editor, Food Research foodresearch.my@outlook.com				
0	From: Food Research < foodresearch.my@outlook.com>				
:	Sent: Friday, 9 April, 2021 5:19 PM				
	To: Fillah Dieny < <u>fillahdieny@gmail.com</u> >				
:	Subject: Manuscript ID: FR-2021-250				
	m				
	4 Lampiran • Dipindai dengan Gmail 🕢			Ŧ	<b>@</b> +
	Direction     Direction     Direction     Direction     Direction       Mathematical State     Mathematical State     Mathematical State     Mathematical State       Name     Name     Name     Mathematical State     Mathematical State       Name     Name     Name     Mathematical State     Mathematical State       Name     Name     Name     Name     Name     Name				
	W Evaluation Form     W Evaluation Form     W FR-2021-250.docx     W FR-2021-250 (1).d				
F	Food Research -{foodresearch.my@outlook.com> kepada saya ▼	12 Jun 2021, 12.52	☆	ţ	1
	🛪 Inggris 🔹 🗲 Indonesia 👻 Terjemahkan pesan	Nonaktifkan	untuk:	Inggris	x
	Dear Dr. Fillah Fithra Dieny,				
	As a gentle reminder, we are still awaiting your response on the revised manuscript. Please don't hesitate to inform us if you need more time doing so.				
	Best regards, Son Radu, PhD Cheif Editor				

	Fillah Dieny <fillahdieny@gmail.com> kepada Food •</fillahdieny@gmail.com>	@ 12 Jun 2021, 1	17.41	☆	÷
	Yes, I am working on it but I need more time, thank you 🙏				
	-				
	Satu lampiran • Dipindai dengan Gmail ()				
	Food Research				
	Q4 Food Science				
F	Food Research ≺foodresearch.my@outlook.com> kepada saya →	12 Jun 2021, 18.29	☆	¢	:
	🕱 Inggris 🗸 > Indonesia 🖌 Terjemahkan pesan	Nonaktifkan	untuk: I	nggris	×
	Dear Dr Fillah,				
	Thank you for informing us. We will wait for your manuscript.				
	Best regards,				
	Son Radu, PhD Chief Editor				
	Fillah Dieny ≺filahdieny⊛gmail.com> kepada Food ↓	@ 13 Jun 2021, 18.43	☆	÷	:
	Dear Editorial Board Food Research Here We send attached revised manuscript with the title Anthropometry indicators that are most related to metabolic profiles in female college students. We have	pe this article can be processed furthe	er. Than	k you	
	Fillah Fithra Dieny_				
	Department of Nutrition Science Faculty of Medicine, Diponegoro University				
	JI Prof Soedharto SH, Tembalang. Semarang 50275, Central Java, Indonesia. Phone/Fax (024) 845-37-08/ HP +62856-4020-4747				
	Website : www.gizi.undig.ac.id				
	Satu lampiran • Dipindai dengan Gmail 🛈				<b>@</b> .
	W FR-2021-250.docx				
F	Food Research -foodresearch.my@outbok.com> kepada saya →	@ 13 Jun 2021, 21.09 🕁 🕤	;		
	🕱 Inggris 🕶 🗲 Indonesia 🕶 Terjemahkan pesan	Nonaktifkan untuk: Inggris	s x		
	Dear Dr. Fillah,				
	Please revise the manuscript according to the comments attached and revert to us at your earliest convenience. Adhering to Food Research format is greatly appreciated.				

Best regards, Son Radu, PhD Chief Editor ÷

**@**+

Satu lampiran • Dipindai dengan Gmail 🛈	¢.
1 FR-2021-250.docx	
Food Research <foodresearch.my@outlook.com> kepada saya ▼</foodresearch.my@outlook.com>	@ 19 Jun 2021, 21.57 👷 🥱 🗄
🕱 Inggris 🗸 🖒 Indonesia 👻 Terjemahkan pesan	Nonaktifkan untuk: Inggris 🗙
Dear Dr. Fillah Fithra Dieny,	
Please find attached additional comments from a reviewer that just came in. We would advise to make necessary amendments with the consi manuscript.	ideration of their comments for better improvements on the
Best regards, Son Radu, PhD Chief Editor	
From: Food Research < <u>foodresearch.my@outlook.com</u> > Sent: Sunday, 13 June, 2021 10:09 PM To: Fillah Dieny < <u>fillahdieny@gmail.com</u> > ***	
2 Lampiran • Dipindai dengan Gmail 🛈	<u>*</u> @.
Mathematical Sector     Mathematical Sector       Math	
W Evaluation Form W FR-2021-250 (2).d	
Fillah Dieny <filahdieny@gmal.com>         kepada Food ↓</filahdieny@gmal.com>	@ 7 Jul 2021, 14.50 😒 🕤 🚦
Dear Editorial Board Food Research	
Well received with thanks.	
Here We send attached revised manuscript <mark>FR-2021-250</mark> entitled Anthropometry indicators that are most related to this article can be processed further. Thank you	metabolic profiles in female college students. We hope
<u>Fillah Fithra Dieny</u>	
Department of Nutrition Science Faculty of Medicine, Diponegoro University JI Prof Soedharto SH, Tembalang. Semarang 50275, Central Java, Indonesia.	
Phone/Fax (024) 845-37-08/ HP +62856-4020-4747 Website : <u>www.gizi.undip.ac.id</u>	

	Satu lampiran • Dipindai dengan Gmail ③				¢
F	Food Research -foodresearch.my@outlock.com> kepada saya -	@ 8 Jul 2021, 01.14	☆	¢	:
	🕱 Inggris 🗸 🗲 Indonesia 🗸 Terjemahkan pesan	Nonaktifkan	untuk:	Inggris	x
	Dear Dr. Fillah,				
	Please revise the references section according to the comments attached. Kindly adhere to Food Research format and revert to us at your earliest convenience.				
	Best regards, Son Radu, PhD Chief Editor				
	Fillah Dieny ⊲fillahdieny@gmail.com> kepada Food ↓	@ 8 Jul 2021, 09.36	☆	¢	:
	Dear Editorial Board Food Research				
	Well noted with thanks.				
	Here We send attached revised manuscript FR-2021-250 entitled Anthropometry indicators that are most related to metabolic profiles in fe	male college stude	nts. W	le hop	pe
	this article can be processed further. Thank you				
	Fillah Fithra Dieny_				
	Department of Nutrition Science Faculty of Medicine, Diponegoro University JI Prof Soedharto SH, Tembalang. Semarang 50275, Central Java, Indonesia. Phone/Fax (024) 845-37-08/ HP +62856-4020-4747 Website : <u>www.gizi.undip.ac.id</u>				
	lampiran • Dipindai dengan Gmail ③				¢
F	Food Research ⊲foodresearch.my@outlook.com> kepada saya ↓	8 Jul 2021, 1	5.59	☆	ť
	🕱 Inggris 🔹 🗲 Indonesia 👻 Terjemahkan pesan	Nonakt	fkan ur	ntuk: In	ggris
	Dear Dr Fillah Fithra Dieny,				
	Thank you for taking the time to revise the manuscript accordingly. We will contact you again for further processing.				
	Best regards, Son Radu, PhD Chief Editor				



# MANUSCRIPT EVALUATION FORM

Date	:	9 <sup>th</sup> April 2021
Manuscript ID	:	FR-2021-250
Please return by	:	9 <sup>th</sup> May 2021
Title of Manuscript	:	Anthropometry indicators that are most related to female student's metabolic profiles

- 1. IF YOU CANNOT REVIEW THIS MANUSCRIPT OR MEET THE DEADLINE, PLEASE INFORM US WITHOUT DELAY.
- 2. Your review should consider the article's scholarly merit including originality of the research issue and/or methodology, adequacy and rigor of the research methodology and techniques used, quality and rigor of data analysis, comprehensiveness of literature review, and the readability and presentation of the article. Please provide detailed and specific comments to all items. Also, where appropriate please provide suggestions for revision.

# COMMENT SHEET

Using item 2 in page 1 as a guideline, please indicate the reasons for your recommendations. Most author(s) will appreciate frankness, combined with a modicum of tact. Even if you recommend that the manuscript be accepted for publication, please provide some general comments to the author(s).

	Grade					
Evaluation Criteria	A (Excellent)	В	С	D	E (Worst)	
1. Appropriateness of Contents			V			
2. Originality of Topic		V				
3. Manuscript Format		V				
4. Research Methodology		V				
5. Data Analysis		V				
6. Relevance to the Journal			V			

# (REVIEWER'S SECTION)

# **REVIEWER'S COMMENTS/SUGGESTIONS**

# (AUTHOR'S SECTION)

AUTHOR'S ACTION/RESPONSE

\*NOTE FOR AUTHOR: Please state your response to the reviewer's comments/suggestion below

		the reviewer's comments/suggestion below
1.	TitleIt should reflect the articleGood, lowercase in title	Revised , already written in line 1-2
2.	Abstract Background, Aim, Methodology and Conclusion	
	No Clear enough	
3.	Keywords Min. 3 and Max. 6	
	No word "adolescent" in abstract so delete as a keyword	because female students is a late adolescents period
4.	Introduction Concise with sufficient background	
	Please revise from oldest to latest "et al" should be italicized , Apply to ALL citations	Revised , (Sri Rahayu and Maulina, 2017).
	Replace "&" with "and"Apply to alll	Revised to all
	Why use female student?	because female students (late adolescents period) are a group of women of reproductive age who are prone to nutritional problems which can later have an impact on the next life cycle
	Just first author surname Author <i>et al.,</i> year	(Eisenmann et al., 2010; Okosun, Boltri, et al., 2010; Rose et al., 2020).
5.	Research design/Methodology Clearly described and reproducible Revised base on review explain how to assess the metabolic syndrome score based on the components of the existing metabolic syndrome	The calculation of the metabolic syndrome score (cMetS) was done in the following steps: (1) after measuring all parameters of the metabolic syndrome, standardisation was carried out to obtain a Z-score; (2) the blood pressure must be converted into Mean Arterial Blood (MAP) by dividing the difference between systolic and diastolic blood pressure by three and summed with the diastolic blood pressure; (3) the HDL cholesterol standardisation results were multiplied by (-1) because the parameter was inversely related to the risk of metabolic syndrome; (4) All Z-scores were added to obtain the cMetS

		values; (5) The final step was to compare the cMetS values with the cut-off point of ≥2,21 Already written in lines 140-148
6.	Data Analysis Results well presented and discussed Revised base on review replace commas with periods in the numbers in the table	Revised in all tables, lines 433-453
7.	<b>Conclusion</b> A clear summary of the study Revised base on review	Metabolic syndrome in female students in Semarang can be identified using anthropometric measurements, one of which is BMI and WHR which are very easy to measure and efficient. In addition, the use of cMetS in the metabolic assessment of a person was found to be more effective.
8.	References References should follow the journal's format Revised base on review Replace ", &" with "and" Apply to ALL Volume must be un-italicized Lowercase If possible in English, Journal also in English, the Indonesian version may be removed	Revised, already written in all references revised Revised in line 319-321, Christijani, R. (2019). Determination of Diagnosis of Metabolic Syndrome based on Assessment of Metabolic Syndrome and NCEP ATP-III Score in Adolescent. The Journal of Nutrition and Food Research, 42(1), pp. 21–28. doi: 10.22435/pgm.v42i1.2418.
9.	English Proficiency Good	pp. 21–28. doi: 10.22433/pgm.v4211.2418.
	Additional comments/suggestions by the reviewer about the article Minor revision	

# **Overall Evaluation**

Please choose one.

Accept		Major Revision	
Minor Revision	V	Reject	

# Please return Manuscript and/or Review Comments to:

Food Research

Email: foodresearch.my@outlook.com



## MANUSCRIPT EVALUATION FORM

Date	:	9 <sup>th</sup> April 2021
Manuscript ID	: -	FR-2021-250
Please return by	: -	9 <sup>th</sup> May 2021
Title of Manuscript	:	Anthropometry indicators that are most related to female student's metabolic profiles

- 3. IF YOU CANNOT REVIEW THIS MANUSCRIPT OR MEET THE DEADLINE, PLEASE INFORM US WITHOUT DELAY.
- 4. Your review should consider the article's scholarly merit including originality of the research issue and/or methodology, adequacy and rigor of the research methodology and techniques used, quality and rigor of data analysis, comprehensiveness of literature review, and the readability and presentation of the article. Please provide detailed and specific comments to all items. Also, where appropriate please provide suggestions for revision.

## COMMENT SHEET

Using item 2 in page 1 as a guideline, please indicate the reasons for your recommendations. Most author(s) will appreciate frankness, combined with a modicum of tact. Even if you recommend that the manuscript be accepted for publication, please provide some general comments to the author(s).

Evaluation Criteria		Grade				
		A (Excellent)	В	С	D	E (Worst)
7. Appropriate	ness of Contents		v			
8. Originality of	f Topic		v			
9. Manuscript I	Format			v		
10. Researc	h Methodology		V			
11. Data Ar	nalysis		v			
12. Relevar	nce to the					
Journal		V				

# (REVIEWER'S SECTION) REVIEWER'S COMMENTS/SUGGESTIONS

(AUTHOR'S SECTION)

**AUTHOR'S ACTION/RESPONSE** 

\*NOTE FOR AUTHOR: Please state your response to the reviewer's comments/suggestion below

	comments/suggestion below
11. Title	Anthropometry indicators that are most related
It should reflect the article	to metabolic profiles in female college students
Consize and modify the sentence without using 'that are'. Specify the subjects. Is it in college students ?	
12. Abstract Background, Aim, Methodology and Conclusion Please highlight the gap. What is the difference between this research and the previous ?	Indonesia as a developing country cannot be separated from the existing nutritional problems in the world, including the incidence of obesity and metabolic syndrome. Several studies found that the prevalence of metabolic syndrome keeps increasing every year. A study in China showed the prevalence of metabolic syndrome in adults was 24.2% (Li et al., 2018). Another study indicated that the prevalence of metabolic syndrome in Indonesia was 21.66% (Herningtyas and Ng, 2019). In recent studies metabolic syndrome can be assessed using the continuous value of metabolic syndrome (cMets) or the metabolic syndrome score recommended by the American Diabetic Association of Diabetes. The metabolic syndrome score is a z-score resulting from the assessment of all components of the metabolic syndrome (Pratiwi, et al., 2017). The advantages of using cMetS are (1) reducing dichotomization factors because cardiovascular disease is a progression of several components of the metabolic syndrome, (2) cMetS is more sensitive and less error-prone than categoric metabolic syndrome assessments, (3) increasing the statistical power (Okosun, Lyn, et al., 2010). <b>Revised, already written in line 33-34</b>
can these results be generalized? ). Metabolic syndrome in female students in Semaran (line 18)	Metabolic syndrome in female college students

13.	Keywords	-
	Min. 3 and Max. 6	
14.	Introduction	Revised all
	Concise with sufficient background	
	Mention in what subjects. Several sentence	
	need to be modified	
15.	Research design/Methodology	SAD measurements were performed with the
	Clearly described and reproducible	subject in a supine position on a flat surface with
		both knees forming an angle of 90°
	Mention the technique how to perform SAD.	Anthropometric data were collected by trained
		enumerators. Revised, already written in line
		140-142
	State the type and the brand of digital scale	Weight and height data were obtained through
		direct measurements using a digital stamp scale
		GEA brand with an accuracy of 0.1 kg Revised,
		already written in line 135-137
	What is FBG? Line 163	Revised, Fasting blood glucose
16.	Data Analysis	All data were analyzed using computer
	Results well presented and discussed	programs and statistical analyses were
	Available in the article	performed using SPSS Statistical software
	Mention what statistical analysis in this	version 22. Univariate analysis was used to
	research	describe subjects characteristic. The distribution
		of data for normality was assessed using the
		Kolmogorov Smirnov test before statistical. The
		relationship of anthropometric indicators with
		metabolic profile (Blood Pressure, Triglycerides, Blood Sugar, HDL and metabolic syndrome
		scores) were determined using the Person
		correlation test. Furthermore, Anthropometric
		indicators that are most related to the metabolic
		component and metabolic syndrome score were
		analyzed using the Multiple Linear Regression
		test. Revised, already written in line 173-179
17.	Conclusion	Revised, already written in lines 233-268
	A clear summary of the study	
	can these results be generalized? You can add	
	the reason in the discussion section	
18.	References	Revised in all references based on review,
	References should follow the journal's format	already written in lines 311-417
	replace with 'and' a lot of the 'and' are missing	
	from the authors list.	
	Please include to the references below	

	Journal names should be written in full , Apply to all references	
19.	<b>English Proficiency</b> Several sentences need to be add with conjunction	Revised all, based on review
20.	Additional comments/suggestions by the reviewer about the article some writing of words in the table is wrong, check	Revised all, based on review

# **Overall Evaluation**

Please choose one.

Accept		Major Revision	
Minor Revision	v	Reject	

# Please return Manuscript and/or Review Comments to:

Food Research

Email: foodresearch.my@outlook.com



## MANUSCRIPT EVALUATION FORM

Date	:	9 <sup>th</sup> April 2021
Manuscript ID	: -	FR-2021-250
Please return by	: -	9 <sup>th</sup> May 2021
Title of Manuscript	:	Anthropometry indicators that are most related to female student's metabolic profiles

- 5. IF YOU CANNOT REVIEW THIS MANUSCRIPT OR MEET THE DEADLINE, PLEASE INFORM US WITHOUT DELAY.
- 6. Your review should consider the article's scholarly merit including originality of the research issue and/or methodology, adequacy and rigor of the research methodology and techniques used, quality and rigor of data analysis, comprehensiveness of literature review, and the readability and presentation of the article. Please provide detailed and specific comments to all items. Also, where appropriate please provide suggestions for revision.

## COMMENT SHEET

Using item 2 in page 1 as a guideline, please indicate the reasons for your recommendations. Most author(s) will appreciate frankness, combined with a modicum of tact. Even if you recommend that the manuscript be accepted for publication, please provide some general comments to the author(s).

		Grade				
	Evaluation Criteria	A (Excellent)	В	С	D	E (Worst)
13.	Appropriateness of					
Cor	ntents		N			
14.	Originality of Topic	$\checkmark$				
15.	Manuscript Format	$\checkmark$				
16.	Research Methodology	$\checkmark$				
17.	Data Analysis	$\checkmark$				
18.	Relevance to the	N				
Jou	irnal	N				

# (REVIEWER'S SECTION)

**REVIEWER'S COMMENTS/SUGGESTIONS** 

# (AUTHOR'S SECTION)

AUTHOR'S ACTION/RESPONSE

\*NOTE FOR AUTHOR: Please state your response to the reviewer's comments/suggestion below

		comments/suggestion below
21.	<b>Title</b> It should reflect the article	Good
22.	Abstract Background, Aim, Methodology and Conclusion No	Good
23.	<b>Keywords</b> <i>Min. 3 and Max. 6</i>	Good
24.	Introduction Concise with sufficient background Good If the main sentence in this paragraph is in this first sentence, make the other sentence to support the main. (line 32) In what subjects ? (line 34) Connect with the subjects taken in this research which is college female students (lines 51-52)	Indonesia as a developing country cannot be separated from the existing nutritional problems in the world, including the incidence of obesity and metabolic syndrome. Several studies found that the prevalence of metabolic syndrome keeps increasing every year. A study in China showed the prevalence of metabolic syndrome in adults was 24.2% (Li et al., 2018). Another study indicated that the prevalence of metabolic syndrome in Indonesia was 21.66% (Herningtyas and Ng, 2019). In recent studies metabolic syndrome can be assessed using the continuous value of metabolic syndrome (cMets) or the metabolic syndrome score recommended by the American Diabetic Association of Diabetes. ). Already written In lines 33-39 Several studies have shown that non-invasive approaches such as anthropometric measurements can be used for the early detection of metabolic syndrome (Pratiwi, <i>et al.</i> , 2017). Anthropometric measurements are described as the measurements of body dimensions and body composition to assess nutritional status. The advantages of anthropometric measurements are relatively fast and easy, as it can be performed using portable and calibrated instruments with standardized methods (Rokhmah, <i>et al.</i> , 2015).

	What is the differences or similarity between BMI and previous indicator ? What is the differences or similarity between SAD and previous indicator ? or what is the advantages of using SAD compare to other indicators etc	Some anthropometric measurements that can be used for early detection of metabolic syndrome are Waist-to-Height Ratio (WHR), waist-to-hip ratio (WHR), hip circumference, Body Mass Index (BMI), Sagital Abdominal Diameter (SAD). <b>Already written In lines 53-60</b> Body Mass Index (BMI) is a practical and easy measurement to perform, but it cannot distinguish between fat mass, bone mass and muscle mass. BMI is calculated as body weight (kg) / height squared (m <sup>2</sup> ) (Okura <i>et al.</i> , 2018). BMI can be used as the first measurement before any other anthropometric measurements. Sagittal Abdominal Diameter (SAD) or the height of the abdomen while the subjects are in lying position. This anthropometric measurement has not been widely used to measure fat tissue in the abdominal area. SAD measurements using computed tomography or magnetic resonance imaging, and are associated with components of metabolic syndrome. The measurements of SAD are taken when the subject is lying down on the examination table with naked upper body. SAD is related to central obesity in individuals with obese and normal nutritional status. Furthermore, SAD is associated with diabetes mellitus and a predictor of cardiovascular disease incidence, even when SAD is measured in standing position (Pajunen <i>et al.</i> , 2013). Based on the above mentioned problems, our study aims to analyse the anthropometric indicators
		related to metabolic syndrome in female college students. Already written In lines 86-95
25.	Research design/Methodology Clearly described and reproducible Good What criteria that researcher has been applied in order to be concluded as purposive sampling	Already written in lines 86-95 Purposive sampling was used in this study and the total number of subjects required was 163. Samples are selected based on inclusion criteria, such as willing to be research subjects, female college students in Semarang City, aged 19-24 years in Semarang, not consuming alcohol, not smoking, willing to be a study participant and willing to follow a series of study instructions. Exclusion criteria are subjects who withdraw and those who are ill during the research study. Based on the exclusion criteria mentioned, no subjects are included in the exclusion

		Already written In lines 107-113
	Mention health protocols that has been applied when collecting data	The health protocol applied during the anthropometric and biochemical data collection process, consist of the subject filled out a Covid sign/symptom screening questionnaire, the subject was checked for temperature, washed his hands before entering the room, the distance between subjects was at least 1 meter, the subject and researcher used a mask and face shield. Researchers used gloves and protective clothing. During the study, hand sanitizers were provided, anthropometric tools that were on the subject's skin were wiped with alcohol.
	Please mention the person conducted the antropometric data collection to make sure that data taken were valid Mention how to perform this measurement. Where enumerators put the abdominal caliper	Already written In lines 115-120 Weight and height data were obtained through direct measurements using a digital stamp scale GEA brand with an accuracy of 0.1 kg and microtoise with an accuracy of 0.1 cm. Waist circumference and hip circumference was measured using a measuring tape (Medline) to the nearest 1 mm and abdominal height was measured using the Abawerk Schaffenburg abdominal calliper to the nearest 1 mm. SAD measurements were performed with the subject in a supine position on a flat surface with both knees forming an angle of 900 (Firouzi et al., 2018). Already written 124-127 Revised, obese BMI (≥25.0 kg/m <sup>2</sup> ) in line 135
26.	<b>Data Analysis</b> <i>Results well presented and discussed</i> Please add more information about what statistical analysis that researchers use	All data were analyzed using computer programs and statistical analyses were performed using SPSS Statistical software version 22. Univariate analysis was used to describe subjects characteristic. The distribution of data for normality was assessed using the Kolmogorov Smirnov test before statistical. The relationship of anthropometric indicators with metabolic profile (Blood Pressure, Triglycerides, Blood Sugar, HDL and metabolic syndrome

		scores) were determined using the Person correlation test. Furthermore, Anthropometric indicators that are most related to the metabolic component and metabolic syndrome score were analyzed using the Multiple Linear Regression test. Already written 161-167
27.	Is it in one chapter or in separate chapter ? Please adjust with the guideline <b>Results and</b> discussion/Results	Results and Discussion, line 169
	Consize this sentence. The mean of WHtR value in this study was 0.51. Meanwhile, the mean of WHR was 0.80; the mean of BMI was 24.04 kg/m2; the mean of SAD was 16.79 cm; and the mean of waist circumference was 79.44 cm.	The mean of WHtR value in this study was 0.51. Meanwhile, the mean of WHR was 0.80; the mean of BMI was 24.04 kg/m <sup>2</sup> ; the mean of SAD was 16.79 cm; and the mean of waist circumference was 79.44 cm. <b>Already revised in lines 172-174</b>
	Use sentence which can show the finding more clearly. Author can use comparation sentence	We found that 43.6% of the subjects had normal BMI, 17.2% were overweight and 35.6% were obese. Based on the WHtR anthropometric indicator, 72.4% of subjects were at risk of having obesity; based on WHR, 22.1% had central obesity; based on BMI, 35.6% were obese; based on SAD 12.3% of the subjects were at risk; and based on waist circumference 55.2% had central obesity. According to the metabolic profile that was assessed, 16.6% had high Fasting Blood Glucose levels, 8.6% had hypertriglycerides, 17.2% had low HDL, 16.6% had high systolic blood pressure, and 21.5% had high diastolic blood pressure <b>Already revised in lines 175-181</b>
	Please add more sentence. A paragraph should consist more than 1 sentence, where there is 1 main sentence and the other act as supporting sentences (line 188-190)	Already revised in lines 175-181 Table 4 shows the results of the analysis using multiple linear regression to determine anthropometric indicators that are most associated with each metabolic profile and metabolic syndrome score. The results showed that BMI was the anthropometric indicator that is most associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood sugar (p<0.05), and HDL (p <0.001). In addition, waist circumference was the anthropometric indicator that is most associated with triglycerides and metabolic syndrome score (p<0.001). Already revised in lines 248-253

	Incorporate with the age base subject, and describe the reasons( Line 230)	The correlation test results indicated that all anthropometric indicators had a positive relationship with the metabolic syndrome scores with p <0.001. Meanwhile, the regression analyses show that BMI and WHR were inversely related to cMetS. This is in line with research who stated that an increase in the WHR value could be associated with the risk of metabolic syndrome in children and adolescents in Florida (Moore <i>et al.</i> , 2015). Another study stated that there was a strong relationship between overweight and obese adolescents with metabolic syndrome (Al-Bachir and Bakir, 2017). Furthermore, a study on the adolescents in South Africa found that central obesity as measured by the hip circumference could lead to an increased risk of cardiovascular. <b>Already</b> <b>written in lines 257-264</b> The finding is in line with the research on the subject of students at Universitas Diponegoro aged 18-21 years. They found that 40% of their study population had obesity level I and 36.3% had obesity level II (Rose et al., 2020). <b>Already written in lines 274-275</b>
	Please add r value (line 62) How many time? Line 65	Not available data
28.	<b>Conclusion</b> A clear summary of the study Compared to ? incorporate with the age and gender base subjects	Metabolic syndrome in female students can be identified using anthropometric measurements, one of which is BMI and WHR which are very easy to measure and efficient. BMI and WHR have the strongest relationship and can be used to detect early risk of metabolic syndrome in female college students. <b>Already written in lines 287-290</b>
29.	<b>References</b> <i>References should follow the journal's format</i> Add doi please if present, line 392	Not available doi Sri Rahayu, M. and Maulina, M. (2017). Hubungan Rasio Lingkar Pinggang dan Lingkar Pinggul dengan Penyakit Jantung Koroner. Jurnal Aceh Medika, 1(1), 1–10. Available at: www.jurnal.abulyatama.ac.id/acehmedika (Accessed: 8 April 2021)
30.	<b>English Proficiency</b> Please check your grammar and spelling	Revised all

31.	Additional comments/suggestions reviewer about the article	by	the	

# **Overall Evaluation**

Please choose one.

Accept	$\checkmark$	Major Revision	
Minor Revision	$\checkmark$	Reject	

# Please return Manuscript and/or Review Comments to:

Food Research

Email: foodresearch.my@outlook.com

#### 1 Anthropometry indicators that are most related to female student's metabolic profiles

#### 2

### 3 Abstract

4 Metabolic syndrome is not a disease, but is a set of several disorders and causes an increased risk of 5 cardiovascular disease and diabetes mellitus complications. Several studies have shown that non-invasive approaches such as anthropometric measurements can be used for early detection of metabolic 6 7 syndrome. This study aims to analyse the anthropometric indicators related to metabolic syndrome in 8 female students. This cross-sectional study with a total of 163 female students, aged between 19 and 24 9 years old. Purposive sampling was used in this study. The independent variables in this study were the 10 Waist-to-Height Ratio (WHtR), Waist-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference. The dependent variable in this study is the metabolic syndrome 11 component that has been converted into a metabolic syndrome score (cMetS). The analysis results 12 13 showed that all anthropometric indicators, namely WHtR, BMI, SAD, waist circumference, hip 14 circumference and WHR have a strong positive relationship with the metabolic syndrome score (p<0.001). 15 BMI was the anthropometric indicator that is most associated with the metabolic profiles, such as systolic 16 blood pressure (p<0.001), blood sugar (p<0.05), and HDL (p<0.001). Waist circumference was the 17 anthropometric indicator that is most associated with triglycerides and metabolic syndrome score 18 (p<0.001). Metabolic syndrome in female students in Semarang can be identified using anthropometric 19 measurements, one of which is BMI and WHR which are very easy to measure and efficient. In addition, 20 the use of cMetS in the metabolic assessment of a person was found to be more effective.

**Commented [ASUS1]:** can these results be generalized?

- 21 **Keywords:** Adolescent; Anthropometric Indicator; Female; Metabolic Profile; Metabolic Syndrome.
- 22
- 23

#### 24 1. Introduction

Metabolic syndrome is a set of body metabolic disorders such as dyslipidaemia, hyperglycaemia, hypertension, and central obesity (Srikanthan *et al.*, 2016; Devi *et al.*, 2017; Christijani, 2019). Metabolic syndrome is not a disease, but is a set of several disorders and causes an increased risk of cardiovascular disease and diabetes mellitus complications. Some epidemiological studies have shown that metabolic syndrome doubles the risk of cardiovascular diseases (Sri Rahayu and Maulina, 2017).

31 Several studies found that the prevalence of metabolic syndrome keeps increasing every year. A 32 study in China shows the prevalence of metabolic syndrome in adults was 24.2% (Li et al., 2018). 33 Another study indicated that the prevalence of metabolic syndrome in Indonesia was 21.66% (Herningtyas and Ng, 2019). In recent studies metabolic syndrome can be assessed using the 34 35 continuous value of metabolic syndrome (cMets) or the metabolic syndrome score recommended by 36 the American Diabetic Association of Diabetes. The metabolic syndrome score is a z-score resulting 37 from the assessment of all components of the metabolic syndrome (Pratiwi, et al., 2017). The 38 advantages of using cMetS are (1) reducing dichotomization factors because cardiovascular disease 39 is a progression of several components of the metabolic syndrome, (2) cMetS is more sensitive and less error-prone than categoric metabolic syndrome assessments, (3) increasing the statistical power
 (Okosun, Lyn, *et al.*, 2010).

42 Central obesity is one of the components of metabolic syndrome parameters. Central obesity is 43 associated with increased blood pressure, serum triglycerides, decreased HDL, and glucose 44 intolerance. Based on the National Basic Health Research (Riskesdas) in 2018, the prevalence of 45 obesity in adults was 21.8%, and the prevalence of central obesity at age of more than 15 years 46 increased from 26.6% in 2013 to 31% in 2018 (Badan Penelitian dan Pengembangan Kesehatan, 47 2018). Obesity is closely related to degenerative diseases. The Riskesdas 2018 showed that the 48 prevalence of stroke, diabetes mellitus, heart disease, and hypertension is higher in women than 49 men.

50 Several studies have shown that non-invasive approaches such as anthropometric measurements can be used for early detection of metabolic syndrome (Pratiwi, et al., 2017). Anthropometric 51 52 measurements are described as the measurements of body dimensions and body composition to 53 assess nutritional status. The advantages of anthropometric measurements are relatively fast and 54 easy, as it can be performed using portable and calibrated instruments with standardized methods 55 (Rokhmah, et al., 2015). Some anthropometric measurements that can be used for early detection 56 of metabolic syndrome are Waist-to-Height Ratio (WHtR), waist-to-hip ratio (WHR), hip 57 circumference, Body Mass Index (BMI), Sagital Abdominal Diameter (SAD).

58 One of the anthropometric measurements which can be a parameter for central obesity is the 59 ratio of waist circumference to height (WHtR). The instruments used in the measurement are 60 microtoise and measuring tape so that it takes longer time. Studies on waist circumference have been 61 shown to have a strong correlation with abdominal fat deposits (Zhou et al., 2014). The distribution 62 of abdominal adipose tissue (central obesity) in adults is associated with a component of the 63 metabolic syndrome (Rodea-Montero, et al., 2014). A study on adult subjects has shown that people 64 who have the same waist circumference but are shorter in height have a greater risk of developing 65 metabolic syndrome than taller people (Zhou et al., 2014). Therefore, WHtR can be used as a simple and effective anthropometric index to identify the metabolic risk associated with obesity (Rodea-66 Montero, et al., 2014). 67

68 The waist-to-hip ratio (WHR) is a measurement that may indicate central obesity (Karimah, 2018). 69 The higher the WHR value, the higher the risk level for several metabolic diseases. The waist-to-hip 70 ratio is calculated by dividing the measurement of the waist circumference by the circumference of 71 the hip. The cut-off points for WHR are  $\geq$ 1.0 for men and  $\geq$ 0.85 for women (Rokhmah, et al., 2015). 72 Individuals with a high waist and hip circumference will also have a higher distribution of fat in their 73 abdominal area. Irregular fats distribution in the abdominal area indirectly causes higher triglyceride levels circulating in the blood, which will affect blood pressure (Sumardiyono et al., 2018). WHR 74 75 measurement is more sensitive in assessing the distribution of fat in the body, especially in the 76 abdominal. This measurement is three times better than BMI in reflecting the presence of harmful 77 fats in the abdominal. Measurement of waist circumference is performed by determining the lower 78 part of arcus costae and crista iliaca (Sri Rahayu and Maulina, 2017).

Body Mass Index (BMI) is a practical and easy measurement to perform, but it cannot distinguish
 between fat mass, bone mass and muscle mass. BMI is calculated as body weight (kg) / height

squared (m<sup>2</sup>) (Okura *et al.*, 2018). BMI can be used as the first measurement before any other
 anthropometric measurements.

83 Sagittal Abdominal Diameter (SAD) or the height of the abdomen while the subjects are in lying 84 position. This anthropometric measurement has not been widely used to measure fat tissue in the 85 abdominal area. SAD measurements using computed tomography or magnetic resonance imaging, 86 and are associated with components of metabolic syndrome. The measurements of SAD are taken 87 when the subject is lying down on the examination table with naked upper body. SAD is related to 88 central obesity in individuals with obese and normal nutritional status. Furthermore, SAD is 89 associated with diabetes mellitus and a predictor of cardiovascular disease incidence, even when SAD 90 is measured in standing position (Pajunen et al., 2013). Based on the abovementioned problems, our 91 study aims to analyse the anthropometric indicators related to metabolic syndrome in female 92 students.

Commented [ASUS2]: space

Commented [ASUS3]: why?

### 94 2. Materials and methods

93

96

97

98

99

107 108

- 95 2.1 Design, location, and time
  - The scope of this study is community nutrition with a cross-sectional study design.
  - Anthropometric and biochemical data were collected at the Cito Laboratory, Banyumanik Semarang with health protocols applied. The study started from March to July 2020.

#### 100 2.2 Samplings

101 This study was conducted during the SARS-CoV-2 outbreak, which later was named COVID-19 by 102 the WHO, so the registration for study participants was done online. The inclusion criteria were 103 female students aged 19-24, resided in Semarang, willing to be a study participant and willing to 104 follow a series of study instructions. Subjects were asked to fill in personal data using a Google form; 105 and eligible subjects will be contacted by the researchers to plan a direct meeting. Purposive 106 sampling was used in this study and the total number of subjects required was 163.

#### 2.3 Data collected

109 The independent variables in this study were the Waist-to-Height Ratio (WHtR), Waist-Hip Ratio 110 (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference. 111 Bodyweight was measured using a digital scale to the nearest 0.01 kg, height was measured using a 112 microtoise to the nearest 0.1 cm, waist circumference and hip circumference was measured using a 113 measuring tape (Medline) to the nearest 1 mm and abdominal height was measured using the 114 Abawerk Schaffenburg abdominal calliper to the nearest 1 mm. SAD measurements were performed 115 with the subject in a supine position on a flat surface with both knees forming an angle of 90° (Firouzi 116 et al., 2018).

117The cut-off point used in this study refers to previous studies because it had been adjusted for the118Asian race (Rose *et al.*, 2020). Each anthropometric measurement is stated as "at risk" if the119individuals have  $\geq 0.50$  for WHtR (Zhang *et al.*, 2016),  $\geq 0.85$  for WHR (Rokhmah, *et al.*, 2015),  $\geq 19.3$ 120cm for (Dieny *et al.*, 2020), and have the normal to overweight BMI (18.5 - 25 kg/m<sup>2</sup>) or obese BMOI121( $\geq 25.0$  kg/m<sup>2</sup>) (Susetyowati, 2016).

122 The dependent variable in this study is the metabolic syndrome component that has been 123 converted into a metabolic syndrome score (cMetS) with the cut-off point on cMetS> 2.21 (Rose *et*  Commented [ASUS4]: State the type and the brand Commented [ASUS5]: State the type and the brand

Commented [ASUS6]: No space
Commented [ASUS7]: For what?

124 al., 2020). The guidelines for metabolic syndrome in this study are taken from the National 125 Cholesterol Education Program-Adult Treatment Panel (NCEP-ATP III) 2005 which has been 126 frequently used in Indonesia. There are 5 parameters to assess metabolic syndrome: (1) fasting blood glucose levels ≥110 mg/dL, (2) triglyceride levels ≥150 mg/dL (3) HDL cholesterol levels <50 mg/dL, 127 128 (4) central obesity in women with waist circumference ≥80 cm, and (5) systolic and diastolic blood 129 pressures ≥130 mmHg and ≥85 mmHg, respectively (Soewondo et al., 2010). The calculation of the 130 metabolic syndrome score (cMetS) was done in the following steps: (1) after measuring all 131 parameters of the metabolic syndrome, standardisation was carried out to obtain a Z-score; (2) the 132 blood pressure must be converted into Mean Arterial Blood (MAP) by dividing the difference 133 between systolic and diastolic blood pressure by three and summed with the diastolic blood pressure; (3) the HDL cholesterol standardisation results were multiplied by (-1) because the 134 135 parameter was inversely related to the risk of metabolic syndrome; (4) All Z-scores were added to 136 obtain the cMetS values; (5) The final step was to compare the cMetS values with the cut-off point 137 of ≥2,21 (Eisenmann et al., 2010; Okosun, Boltri, et al., 2010; Rose et al., 2020). The subjects were 138 instructed to do fasting for at least 8 hours; only drinking water was permitted.

Other than the cMetS score, metabolic syndrome risk can also be assessed from the classification
 of metabolic types. This classification combines the internal and external signs of the body such as
 biochemical parameters, the ratio of subcutaneous fat to abdominal fat, and blood pressure (Prybyla
 O, 2020). The main phenotypes that reflect the possible combination of metabolic profile and the
 degree of obesity are metabolic healthy obese weight, metabolic healthy normal weight, metabolic
 unhealthy normal weight, and metabolic unhealthy normal weight.

#### 146 2.4 Data analysis

145

147

148

149

150

Statistical analyses were performed using SPSS Statistical software. This study has received an ethical clearance issued by the Medical/Health Research Bioethics Commission, Faculty of Medicine, Sultan Agung Islamic University Semarang with Number No.296 /IX /2020 /Bioethical Commission.

# 151152 3. Results and discussion/Results

The subject characteristics measured in female student aged 19-24 years include age, anthropometric indicators, and metabolic syndromes. Table 1 shows the characteristics of the study subjects. The mean of WHtR value in this study was 0.51. Meanwhile, the mean of WHR was 0.80; the mean of BMI was 24.04 kg/m<sup>2</sup>; the mean of SAD was 16.79 cm; and the mean of waist circumference was 79.44 cm.

158 Table 2 shows various nutritional status of the subjects based on BMI. We found that 43.6% of the 159 subjects had normal BMI, 17.2% were overweight and 35.6% were obese. Based on the WHtR 160 anthropometric indicator, 72.4% of subjects were at risk of having obesity; based on WHR, 22.1% had central obesity; based on BMI, 35.6% were obese; based on SAD 12.3% of the subjects were at risk; 161 and based on waist circumference 55.2% had central obesity. According to the metabolic profile that 162 was assessed, 16.6% had high FBG levels, 8.6% had hypertriglycerides, 17.2% had low HDL, 16.6% had 163 high systolic blood pressure, and 21.5% had high diastolic blood pressure. In addition, we found 33.1% 164 165 of the subjects had high metabolic syndrome (cMetS) scores. This proportion was similar to the 166 assessment based on the metabolic type of unhealthy subjects (subjects who had  $\geq$  3 risk factors of

Commented [ASUS8]: ???

the metabolic profile), which was 33.7%. Moreover, two subjects had five risk factors: abdominalobesity, hypertension, hyperglycaemia, hypertriglycerides, and low HDL.

169 If we are considering metabolic type based on nutritional status (subjects with non-obese BMI 170 (<25kg/m<sup>2</sup>) with metabolic healthy and metabolic unhealthy and subjects with obese BMI (>25kg/m<sup>2</sup>) 171 with metabolic healthy and metabolic unhealthy), subjects are categorised as metabolic unhealthy 172 (experiencing metabolic syndrome) if they fulfil ≥ 3 risk factors including high waist circumference, 173 blood pressure, GDP and triglyceride levels, and low HDL levels. Based on these criteria, we found that 174 10.4% of the subjects had metabolic unhealthy normal weight (MUNW) and 23.3% of the subjects had 175 metabolic unhealthy obesity weight (MUOW). In non-obese subjects, 54% of them were metabolic 176 healthy.

177 Table 3 and Table 4 show the results of statistical analyses on anthropometric indicators related 178 to the metabolic syndromes. Table 3 shows the bivariate statistical analysis using the Pearson 179 correlation test. The analysis results showed that all anthropometric indicators, namely WHtR, BMI, 180 SAD, waist circumference, hip circumference and WHR have a strong positive relationship with the 181 metabolic syndrome score (p<0.001), which means that the higher the anthropometric value, the 182 higher the metabolic syndrome score. In addition, the analysis on the relationship between 183 anthropometric indicators and each metabolic profile revealed that almost all of the independent 184 variables (WHtR, waist and hip circumference, WHR, BMI, and SAD) were associated with each 185 metabolic profile, such as baseline systolic pressure, diastolic blood pressure, triglyceride levels, blood 186 sugar levels, and HDL. Only WHR that was not associated with diastolic blood pressure (p>0.005).

Table 4 shows the results of the analysis using multiple linear regression to determine anthropometric indicators that are most associated with each metabolic profile and metabolic syndrome score.

The results showed that BMI was the anthropometric indicator that is most associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood sugar (p<0.05), and HDL (p <0.001). In addition, waist circumference was the anthropometric indicator that is most associated with triglycerides and metabolic syndrome score (p<0.001). Based on the Adjusted R2 value on the metabolic syndrome score, we found that 37.5% of the metabolic syndrome score was related to anthropometric indicators, such as WHtR, waist and hip circumference, WHR, BMI, and SAD. The rest may be influenced by other variables that are not included in this study.

#### 198 4. Discussion

197

199 The objective of this study was to determine the anthropometric indicators associated with 200 metabolic syndromes in female students. The study included 163 female students aged 19-24 years. 201 The students are in their late adolescents who begin to have an independent life. Inappropriate and unhealthy eating behaviours will have an impact on the student's nutritional status. Excessive 202 203 nutritional status and obesity will affect student's body metabolism. Based on the study results, 204 33.1% of the subjects had a high metabolic syndrome (cMetS) score. In line with the previous study 205 conducted in 2019 on 18-to-21-year-old students at Diponegoro University, 20% of the subjects had 206 high cMetS (Rose et al., 2020). Meanwhile, a study conducted by Pratiwi et al in 2017 using secondary 207 data from the National Basic Health Research 2013 found that 19.98% of adolescents aged 15-24 208 years had high cMetS (Pratiwi, et al., 2017). Therefore, we conclude that there is a trend of Metabolic 209 Syndrome Score (cMetS) among young women in Semarang.

210 The assessment of metabolic syndrome using a continuous type (scoring) rather than using a 211 dichotomy or binary ("yes" and "no") is recommended (Christijani, 2019). An adolescent can be 212 diagnosed with metabolic syndrome if their Metabolic Syndrome Score (cMetS) >2.21 (Pratiwi, et al., 213 2017). Anthropometric indicators used in this study are Waist and Height Ratio (WHtR), Waist-to-Hip 214 Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and Waist Circumference. 215 Based on the correlation analyses, all anthropometric indicators have a significant positive 216 relationship with the Metabolic Syndrome Score (cMetS). Furthermore, the multivariate analyses 217 show that the anthropometric indicators of BMI and RLPP are strongly associated with cMetS.

218 According to the metabolic type, most of the subjects (54%) in this study had metabolic healthy 219 normal weight (MHNW) metabolic type. In this type, the individuals have a normal BMI and does not 220 show any metabolic risk. Our study also shows that 10.4% of the subjects were classified as metabolic 221 unhealthy normal weight (MUNW). The subjects' BMI in this category is in the normal range but has 222 a high percentage of body fat that makes them at high risk of developing metabolic disorders (Eckel 223 et al., 2015; Suliga et al., 2015). Several recent cohort studies have shown a greater risk of type II 224 diabetes mellitus in individuals with MUNW compared to individuals with MHNW (Ärnlöv et al., 2011; 225 Hadaegh et al., 2011; Aung et al., 2014; Jung et al., 2014; Hinnouho et al., 2015). Other studies have 226 shown that women with the MUNW type have a long-term impact of an increased risk of 227 cardiovascular diseases such as higher blood pressure, triglyceride and glucose levels as well as lower 228 levels of adiponectin, HDL, and LDL compared to women with the MHNW type (Kim et al., 2013).

In our study, 23.3% of the subjects belonged to the Metabolic Unhealthy Obese Weight (MUOW)
 type. Subjects with this metabolic type have an obese BMI and have a high risk of developing
 metabolic disorders. A study conducted in Japan on 29,564 subjects showed that individuals with
 MUOW had a greater risk of developing type II diabetes mellitus compared to individuals with MHOW
 (Heianza *et al.*, 2015).

234 We also found that 12.3% of the subjects were categorized as metabolic healthy obese weight 235 (MHOW). Individuals in this metabolic type have an obese BMI but do not show any metabolic risks. 236 Given the impact of obesity in relation to the risk of metabolic diseases, various studies have been 237 conducted to examine the long-term effects of MHOW. Individuals with MHOW had a different fat 238 distribution pattern (less ectopic and visceral fat), and lower inflammatory markers (Samocha-Bonet 239 et al., 2014). Other studies also have shown that women with MHOW had lower blood pressure, 240 triglyceride levels, and glucose levels, but higher levels of HDL, adiponectin, and LDL compared to 241 women with MUNW (Kim et al., 2013). This condition was associated with good diet quality in 242 individuals with MHOW. Based on National Health and Nutrition Examination Surveys (NHANES) 243 data, Camhi et al examined the quality of diet in obese subjects, and found that adolescents and adult 244 women with the MHOW metabolic type had higher diet quality scores due to high intake of fruit, 245 whole grains, meat, and nuts (Camhi et al., 2015).

246 The correlation test results indicated that all anthropometric indicators had a positive relationship with the metabolic syndrome scores with p <0.001. Meanwhile, the regression analyses 247 248 show that BMI and WHR were inversely related to cMetS. This is in line with research conducted by 249 Lindy et al, who stated that an increase in the WHR value could be associated with the risk of metabolic syndrome in children and adolescents in Florida (Moore et al., 2015). A study conducted 250 251 by Al-Bachir and Bakir stated that there was a strong relationship between overweight and obese 252 adolescents with metabolic syndrome (Al-Bachir and Bakir, 2017). Furthermore, a study conducted 253 by Adrian et al on 15-year-old adolescents in South Africa found that central obesity as measured by Commented [ASUS9]: ???

Commented [ASUS10]: this

Commented [ASUS11]: Camhi et al. (2015)

Commented [ASUS12]: delete

Commented [ASUS13]: year???

Commented [ASUS14]: (2017)

Commented [ASUS15]: delete

**Commented [ASUS16]:** year??? Not mention in the references

254 the hip circumference could lead to an increased risk of cardiovascular diseases and death. Therefore, 255 hip circumference and waist circumference can be used to predict the risk of cardiovascular diseases 256 and death in the future (Cameron et al., 2012).

Body Mass Index (BMI) is the most widely used indicator of measurement in epidemiological 257 258 studies and is used as a substitute for evaluating body composition. However, BMI cannot distinguish 259 fat from fat mass and lean mass, and it fails to show the presence of adipose and body fat distribution 260 (Ofer et al., 2019; Leone et al., 2020). However, the BMI cut-offs for metabolic syndrome has not yet 261 been determined (Ofer et al., 2019). Obesity in adolescents is generally assessed using a BMI of ≥25.0 262 kg/m<sup>2</sup>. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m<sup>2</sup>) and 263 obesity (≥25.0 kg/m<sup>2</sup>), and we found that 35.6% of the subjects were obese. The finding is in line with 264 the research conducted by Sophia et al on the subject of students at Universitas Diponegoro aged 265 18-21 years. They found that 40% of their study population had obesity level I and 36.3% had obesity 266 level II (Rose et al., 2020).

267 Abdominal obesity is often assessed to determine a metabolic syndrome in people. One of the 268 indicators used to measure abdominal obesity is the Waist-to-Hip Ratio (WHR) which is calculated by 269 dividing the waist circumference and the hip circumference. Measurement of waist circumference is 270 more sensitive in assessing the distribution of body fat in the abdominal wall, which is also a 271 component in the metabolic syndrome. The limit of the WHR value for female is  $\geq$  0.85 (Rokhmah, et 272 al., 2015). This study shows that every 1% increase in the WHR value will increase the cMetS value 273 by 10.411. Hip circumference is also an indicator that has a strong correlation with cMetS, but many 274 studies have used it as a ratio along with waist circumference for assessing a person's central obesity 275 status.

#### 277 5. Conclusion

278 Metabolic syndrome in female students in Semarang can be identified using anthropometric 279 measurements, one of which is BMI and WHR which are very easy to measure and efficient. In the discussion section 280 addition, the use of cMetS in the metabolic assessment of a person was found to be more effective.

281

276

#### 282 Conflict of interest - Disclose any potential conflict of interest appropriately.

283 The authors declare no conflict of interest.

#### 284 Acknowledgments

285 The authors would like to thank all the subjects who participated in this study. We would also like to

- express our gratitude to The Ministry of Research, Technology and Higher Education, Indonesia" was 286
- 287 funded by the "Hibah Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) 2019.
- 288
- 289

Commented [ASUS17]: Sophia and rose are same???

Commented [ASUS18]: can these results be generalized? You can add the reason in

#### 290 References

- 291 Al-Bachir, M. and Bakir, M. A. (2017). Predictive value of body mass index to metabolic syndrome risk 292 factors in Syrian adolescents. Journal of Medical Case Reports, 11(1). doi: 10.1186/s13256-017-1315-2.
- 293

294 Ärnlöv, J., Sundström, J., Ingelsson, E., Lind, L. (2011). Impact of BMI and the metabolic syndrome on the 295 risk of diabetes in middle-aged men. Diabetes Care, 34(1), 61-65. doi: 10.2337/dc10-0955.

- 296 Aung, K. K., Lorenzo, C., Hinojosa, M. A., Haffner, S. M. (2014). Risk of developing diabetes and 297 cardiovascular disease in metabolically unhealthy normal-weight and metabolically healthy obese 298 individuals. Journal of Clinical Endocrinology and Metabolism, 99(2), 462-468. doi: 10.1210/jc.2013-299 2832
- 300 Badan Penelitian dan Pengembangan Kesehatan. (2018). Riset Kesehatan Dasar (RISKESDAS) 2018. 301 Jakarta, Indonesia.
- 302 Cameron, A. J., Magliano, D. J., Shaw, J. E., Zimmet, P. Z., Carstensen, B., Alberti, K. G. M. M., Tuomilehto, 303 J., Barr, E. L. M., Pauvaday, V. K., Kowlessur, S., Söderberg, S. (2012). The influence of hip circumference 304 on the relationship between abdominal obesity and mortality. International Journal of Epidemiology, 305 41(2), 484-494. doi: 10.1093/ije/dyr198.
- 306 Camhi, S. M., Whitney Evans, E., Hayman, L. L., Lichtenstein, A. H., Must, A. (2015). Healthy eating index 307 and metabolically healthy obesity in U.S. adolescents and adults. Preventive Medicine, 77, 23–27. doi: 308 10.1016/j.ypmed.2015.04.023.
- 309 Christijani, R. (2019). Determination of Diagnosis of Metabolic Syndrome based on Assessment of 310 Metabolic Syndrome and NCEP ATP-III Score in Adolescent. The Journal of Nutrition and Food Research, 311 42(1), 21-28. doi: 10.22435/pgm.v42i1.2418.
- 312 Devi, R., Manhas, S., Prasad, S., Sharma, S., Bhaskar, N., Mahajan, S. (2017). Short Review of Metabolic 313 Syndrome. International Journal of Research & Review, 4(2), p. 29.
- 314 Dieny, F. F., Setyaningsih, R. F., Fitranti, D. Y., Jauharany, F. F., Putra, Y. D., Tsani, A. F. A. (2020). Abdominal diameter profiles have relationship with insulin resistance in obese female adolescents. Electronic 315 316 Journal of General Medicine, 17(5), p. em219. doi: 10.29333/ejgm/7882.
- 317 Eckel, N., Mühlenbruch, K., Meidtner, K., Boeing, H., Stefan, N., Schulze, M. B. (2015). Characterization of 318 metabolically unhealthy normal-weight individuals: Risk factors and their associations with type 2 319 diabetes. Metabolism: Clinical and Experimental, 64(8), 862–871. doi: 10.1016/j.metabol.2015.03.009.
- 320 Eisenmann, J. C., Laurson, K. R., Dubose, K. D., Smith, B. K., Donnelly, J. E. (2010). Construct validity of a 321 continuous metabolic syndrome score in children. Diabetology and Metabolic Syndrome, 2(1). doi: 322 10.1186/1758-5996-2-8.
- 323 Firouzi, S. A., Tucker, L. A., LeCheminant, J. D., Bailey, B. W. (2018). Sagittal abdominal diameter, waist 324 circumference, and BMI as predictors of multiple measures of glucose metabolism: An NHANES investigation of US adults. Journal of Diabetes Research, 2018, 1–14. doi: 10.1155/2018/3604108. 325
- 326 Hadaegh, F., Bozorgmanesh, M., Safarkhani, M., Khalili, D., Azizi, F. (2011). Predictability of body mass 327 index for diabetes: Affected by the presence of metabolic syndrome?. BMC Public Health, 11(1), p. 383. 328 doi: 10.1186/1471-2458-11-383.
- 329 Heianza, Y., Kato, K., Kodama, S., Ohara, N., Suzuki, A., Tanaka, S., Hanyu, O., Sato, K., Sone, H. (2015). Risk 330 of the development of Type 2 diabetes in relation to overall obesity, abdominal obesity and the 331 clustering of metabolic abnormalities in Japanese individuals: Does metabolically healthy overweight 332 really exist? The Niigata Wellness Study. Diabetic Medicine, 32(5), 665-672. doi: 10.1111/dme.12646.
- Herningtyas, E. H. and Ng, T. S. (2019). Prevalence and distribution of metabolic syndrome and its 333 334 components among provinces and ethnic groups in Indonesia. BMC Public Health, 19(1), p. 377. doi: 335 10.1186/s12889-019-6711-7.
- 336 Hinnouho, G. M., Czernichow, S., Dugravot, A., Nabi, H., Brunner, E. J., Kivimaki, M., Singh-Manoux, A.

- (2015). Metabolically healthy obesity and the risk of cardiovascular disease and type 2 diabetes: The
   Whitehall II cohort study. *European Heart Journal*, 36(9), 551–559. doi: 10.1093/eurheartj/ehu123.
- Jung, H. S., Chang, Y., Eun, Y. K., Kim, C. W., Choi, E. S., Kwon, M. J., Cho, J., Zhang, Y., Rampal, S., Zhao, D.,
  Soo, K. H., Shin, H., Guallar, E., Ryu, S. (2014). Impact of body mass index, metabolic health and weight
  change on incident diabetes in a Korean population. *Obesity*, 22(8), 1880–1887. doi:
  10.1002/oby.20751.
- Karimah, M. (2018). Rasio Lingkar Pinggal-panggul Memiliki Hubungan Paling Kuat dengan Kadar Glukosa
   Darah'. Jurnal Berkala Epidemiologi, 6(3), 219–226.
- Kim, M., Paik, J. K., Kang, R., Kim, S. Y., Lee, S. H., Lee, J. H. (2013). Increased oxidative stress in normalweight postmenopausal women with metabolic syndrome compared with metabolically healthy
  overweight/obese individuals. *Metabolism: Clinical and Experimental*, 62(4), 554–560. doi:
  10.1016/j.metabol.2012.10.006.
- Leone, A. *et al.* (2020). Evaluation of different adiposity indices and association with metabolic syndrome
   risk in obese children: Is there a winner?. *International Journal of Molecular Sciences*, 21(11), p. 4083.
   doi: 10.3390/ijms21114083.
- Li, Y. *et al.* (2018). Metabolic syndrome prevalence and its risk factors among adults in China: A nationally
   representative cross-sectional study. *PLoS ONE*, 13(6), p. e0199293. doi:
   10.1371/journal.pone.0199293.
- Moore, L. M. *et al.* (2015). Analysis of Pediatric Waist to Hip Ratio Relationship to Metabolic Syndrome
   Markers. *Journal of Pediatric Health Care*, 29(4), 319–324. doi: 10.1016/j.pedhc.2014.12.003.
- Ofer, K. *et al.* (2019). Normal body mass index (BMI) can rule out metabolic syndrome: An Israeli cohort
   study. *Medicine*, 98(9), p. e14712. doi: 10.1097/MD.00000000014712.
- Okosun, I. S., Boltri, J. M., *et al.* (2010). Continuous metabolic syndrome risk score, body mass index
   percentile, and leisure time physical activity in American children. *Journal of Clinical Hypertension*,
   12(8), 636–644. doi: 10.1111/j.1751-7176.2010.00338.x.
- Okosun, I. S., Lyn, R., *et al.* (2010). Validity of a Continuous Metabolic Risk Score as an Index for Modeling
   Metabolic Syndrome in Adolescents. *Annals of Epidemiology*, 20(11), 843–851. doi:
   10.1016/j.annepidem.2010.08.001.
- Okura, T. *et al.* (2018). Body mass index ≥23 is a risk factor for insulin resistance and diabetes in Japanese
   people: A brief report. *PLOS ONE*. Edited by P. Bjornstad, 13(7), p. e0201052. doi:
   10.1371/journal.pone.0201052.
- Pajunen, P. *et al.* (2013). Sagittal abdominal diameter as a new predictor for incident diabetes. *Diabetes Care*, 36(2), 283–288. doi: 10.2337/dc11-2451.
- Pratiwi, Z. A., Hasanbasri, M. and Huriyati, E. (2017). Penentuan titik potong skor sindroma metabolik
   remaja dan penilaian validitas diagnostik parameter antropometri: analisis Riskesdas 2013. Jurnal Gizi
   *Klinik Indonesia*, 14(2), p. 80. doi: 10.22146/ijcn.25590.
- Prybyla, O. (2020). *Metabolic phenotyping: is it so important?*. *Journal of Cognitive Neuropsychology*.
  iMedPub., 4(1), 1-3.
- Rodea-Montero, E. R., Evia-Viscarra, M. L. and Apolinar-Jiménez, E. (2014). Waist-to-height ratio is a better
   anthropometric index than waist circumference and BMI in predicting metabolic syndrome among
   obese mexican adolescents. *International Journal of Endocrinology*, 2014, 195407. doi:
   10.1155/2014/195407.
- Rokhmah, F. D., Handayani, D. and Al-Rasyid, H. (2015). Korelasi lingkar pinggang dan rasio lingkar
   pinggang-panggul terhadap kadar glukosa plasma menggunakan tes toleransi glukosa oral. Jurnal Gizi
   Klinik Indonesia, 12(1), 28–35. doi: 10.22146/ijcn.22425.
- Rose, S., Dieny, F. F., Nuryanto, N., Tsani, A. F. A. (2020). The correlation between waist-to-height ratio (wHtR) and second to fourth digit ratio (2D:4D) with an increase in metabolic syndrome scores in obese
- adolescent girls. *Electronic Journal of General Medicine*, 17(3), p. em211. doi: 10.29333/ejgm/7872.

- Samocha-Bonet, D., Dixit, V. D., Kahn, C. R., Leibel, R. L., Lin, X., Nieuwdorp, M., Pietiläinen, K. H., Rabasa Lhoret, R., Roden, M., Scherer, P. E., Klein, S., Ravussin, E. (2014). Metabolically healthy and unhealthy
   obese The 2013 stock conference report. *Obesity Reviews*, 15(9), 697–708. doi: 10.1111/obr.12199.
- Soewondo, P., Purnamasari, D., Oemardi, M., Waspadji, S., Soegondo, S. (2010). Prevalence of Metabolic
   Syndrome Using NCEP/ATP III Criteria in Jakarta, Indonesia: The Jakarta Primary Non-communicable
   Disease Risk Factors Surveillance 2006. *Acta Med Indones.*, 42(4), 199–203.
- Sri Rahayu, M. and Maulina, M. (2017). Hubungan Rasio Lingkar Pinggang dan Lingkar Pinggul dengan
   Penyakit Jantung Koroner. Jurnal Aceh Medika, 1(1), 1–10. Available at:
   www.jurnal.abulyatama.ac.id/acehmedika (Accessed: 8 April 2021).
- Srikanthan, K., Feyh, A., Visweshwar, H., Shapiro, J. I., Sodhi, K.(2016). Systematic review of metabolic
   syndrome biomarkers: A panel for early detection, management, and risk stratification in the West
   Virginian population. *International Journal of Medical Sciences*, 13(1), 25–38. doi: 10.7150/ijms.13800.
- Suliga, E., Kozieł, D., Cieśla, E., Głuszek, S. (2015). Association between dietary patterns and metabolic
   syndrome in individuals with normal weight: A cross-sectional study. *Nutrition Journal*, 14(1), p. 55.
   doi: 10.1186/s12937-015-0045-9.
- Sumardiyono, S., Pamungkasari, E. P., Mahendra, A. G., Utomo, O. S., Mahajana, D., Cahyadi, W. R., Ulfia,
  M. (2018). Hubungan Lingkar Pinggang dan Lingkar Panggul dengan Tekanan Darah pada Pasien
  Program Pengelolaan Penyakit Kronis (Prolanis). *Smart Medical Journal*, 1(1), p. 26. doi:
  10.13057/smj.v1i1.24504.
- 404 Susetyowati, S. (2016). Gizi Remaja, in Ilmu Gizi: Teori dan Aplikasi. Jakarta, Indonesia: EGC, 160–164.
- Zhang, Y. X., Wang, Z. X., Chu, Z. H., Zhao, J. S. (2016). Profiles of body mass index and the nutritional
  status among children and adolescents categorized by waist-to-height ratio cut-offs. *International Journal of Cardiology*, 223, 529–533. doi: 10.1016/j.ijcard.2016.07.303.
- Zhou, D., Yang, M., Yuan, Z. P., Zhang, D. D., Liang, L., Wang, C. L., Zhang, S., Zhu, H. H., Lai, M. D., Zhu, Y.
   M. (2014). Waist-to-Height Ratio: A simple, effective and practical screening tool for childhood obesity
   and metabolic syndrome. *Preventive Medicine*, 67, 35–40. doi: 10.1016/j.ypmed.2014.06.025.
- 411 412

# Tables and Figures – 1 PAGE 1 TABLE/FIGURE. PLACE ALL TABLES AND FIGURES AT THE END OF THE MANUSCRIPT BODY AFTER THE REFERENCES

Variabel	Minimum	Maximum	Mean	SD
Anthropometric Indicators				
WHtR (rasio)	0.37	0.71	0.51	0.07
RLPP (rasio)	0.67	0.96	0.80	0.06
BMI (kg/m²)	15.81	39.30	24.04	4.72
Sagital Abdominal Diameter (cm)	11.35	25.50	16.79	2.42
Hip Circumference (cm)	80.60	138.45	98.96	9.30
Waist Circumference (cm)	58.00	112.10	79.44	10.78
Metabolic Profiles				
Blood Glucose Levels (mg/dL)	66.00	110.00	92.00	7.59
Trygliceride Levels (mg/dL)	29.00	309.00	88.35	44.68
Cholesterol Levels HDL (mg/dL)	36.00	109.00	61.73	26.43
Sistolic Blood Pressure (mmHg)	84.00	144.00	114.63	11.13
Diastolic Blood Pressure (mmHg)	55.00	178.00	82.40	55.52
cMetS (Score of Metabolic Syndrome)	-7.10	11.93	0.01	2.90

Characteristics	n	%
Anthropometric		
Body Mass Index (BMI)		
Underweight (< 18.5 kg/m <sup>2</sup> )	6	3.7
Normal $(18.5 - 22.9 \text{ kg/m}^2)$	71	43.6
Overweight (23-24.9 kg/m <sup>2</sup> )	28	17.2
Obese ( $\geq 25.0 \text{ kg/m}^2$ )	58	35.6
Waist Height Ratio (WHtR)		
Normal (<0.50)	45	27.6
Risk (≥0.50)		72.4
Waist Hip Ratio		
Normal (<0.85)	127	77.9
Central Obesity (≥0.85)	36	22.1
Sagital Abdominal Diameter (SAD)	50	22.1
Normal (≤19.3 cm)	143	87.7
	20	
Risk (>19.3 cm)	20	12.3
Wait Circumference	70	44.0
Normal (<80 cm)	73	44.8
Obese (≤80 cm)	90	55.2
Metabolic Profiles		
Blood Glucose Levels		
Normal (<110 mg/dL)	136	83.4
High (≥110 mg/dL)	27	16.6
Triglycerides		
Normal (<150 mg/dL)	149	914
High (≥150 mg/dL)	14	8.6
Cholesterol HDL		
Normal (≥150 mg/dL)	135	82.8
Rendah (<150 mg/dL)	28	17.2
Sistolic Blood Pressure		
Normal (<130 mg/dL)	136	83.4
High $(\geq 130 \text{ mg/dL})$	27	16.6
Diastolic Blood Pressure	27	10.0
Normal (<85 mg/dL)	128	78.5
High ( $\geq$ 85 mg/dL)	35	21.5
	55	21.5
cMetS (Score of Metabolic Syndrome)	100	<b>CC 0</b>
Normal (<2.21)	109	66.9
Risk (≥2.21)	54	33.1
Tipe Metabolik		
Metabolic Unhealthy Normal Weight (MUNW)	17	10.4
Metabolic Healthy Normal Weight (MHNW)	88	54
Metabolic Unhealthy Obese Weight (MUOW)	38	23.3
Metabolic Healthy Obese Weight (MHOW)	20	12.3

437	The subsciences, block sugar, tibe and metabolic synctrome scores)											
Variable	Sistolic	BP	P Distolic BP TG Blood Gl		Blood Glucose HDL			cMetS				
	r	р	r	р	r	р	r	р	r	р	r	р
WHtR	0.358	<0.001	0.306	<0.001	0.289	<0.001	0.210	0.007	-0.266	0.001	0.599	<0.001
BMI	0.370	<0.001	0.313	<0.001	0.315	<0.001	0.221	0.005	-0.292	<0.001	0.600	<0.001
SAD	0.352	<0.001	0.284	<0.001	0.278	<0.001	0.191	0.015	-0.264	0.001	0.575	<0.001
WC	0.377	<0.001	0.284	<0.001	0.295	<0.001	0.212	0.005	-0.243	0.002	0.616	<0.001
HC	0.369	<0.001	0.332	<0.001	0.302	<0.001	0.179	0.002	-0.273	<0.001	0.581	<0.001
WHR	0.244	0.002	0.128	0.104	0.194	0.013	0.172	0.028	-0.149	0.048	0.415	<0.001
438												

Table 3.The Relationship between Anthropometric Indicators and Metabolic Profiles (Blood Pressure,
 Triglycerides, Blood Sugar, HDL and metabolic syndrome scores)

		syndrome so	ores			
Variable	Sistolic BP					
	Konstanta	USC <sup>a</sup>	<b>р1</b> <sup>ь</sup>	p2 <sup>c</sup>	<sup>d</sup> Adjusted R <sup>2</sup>	Commented [ASUS21]: Translate in english
BMI	91.759	0.951	<0.001	<0.001	0.158	
	Blood Glucose	Levels				
	Konstanta	USC <sup>a</sup>	<b>р1</b> <sup>ь</sup>	р2 <sup>с</sup>	Adjusted R <sup>2</sup>	Commented [ASUS22]: Translate in english
BMI	83.454	0.355	0.005	<0.001	0.043	
	HDL					
	Konstanta	USC <sup>a</sup>	<i>р1<sup>ь</sup></i>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>	Commented [ASUS23]: Translate in english
3 <i>MI</i>	81.429	-0.819	<0.001	<0.001	0.080	
	Triglycerides					
	Konstanta	USC <sup>a</sup>	<b>р1</b> <sup>ь</sup>	р2 <sup>с</sup>	Adjusted R <sup>2</sup>	Commented [ASUS24]: Translate in english
VC	-6.614	1.195	<0.001	<0.001	0.078	
	Score of Meta	bolic Syndrom	е			
	Konstanta	USC <sup>a</sup>	<i>р1<sup>ь</sup></i>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>	Commented [ASUS25]: Translate in english
NC	-13.163	0.166	<0.001	<0.001	0.375	
dardized Coe	efficient, <sup>b</sup> p-value, <sup>c</sup> p l	Jji F (ANOVA),	<sup>d</sup> Koefisien D	eterminasi		Commented [ASUS26]: Translate in english

Table 4. Anthropometric indicators most associated with metabolic components and metabolic

442 <sup>a</sup>Un

440

441

**Commented [ASUS27]:** Translate in english

## 1 Anthropometry indicators that are most related to female student's

- 2 metabolic profiles
- 3

### 4 Abstract

Metabolic syndrome is not a disease, but is a set of several disorders and causes an increased risk of 5 cardiovascular disease and diabetes mellitus complications. Several studies have shown that non-invasive 6 7 approaches such as anthropometric measurements can be used for early detection of metabolic 8 syndrome. This study aims to analyse the anthropometric indicators related to metabolic syndrome in 9 female students. This cross-sectional study with a total of 163 female students, aged between 19 and 24 10 years old. Purposive sampling was used in this study. The independent variables in this study were the Waist-to-Height Ratio (WHR), Waist-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal 11 12 Diameter (SAD), and hip circumference. The dependent variable in this study is the metabolic syndrome 13 component that has been converted into a metabolic syndrome score (cMetS). The analysis results showed that all anthropometric indicators, namely WHtR, BMI, SAD, waist circumference, hip 14 circumference and WHR have a strong positive relationship with the metabolic syndrome score (p<0.001). 15 BMI was the anthropometric indicator that is most associated with the metabolic profiles, such as systolic 16 17 blood pressure (p<0.001), blood sugar (p<0.05), and HDL (p<0.001). Waist circumference was the 18 anthropometric indicator that is most associated with triglycerides and metabolic syndrome score 19 (p<0.001). Metabolic syndrome in female students in Semarang can be identified using anthropometric 20 measurements, one of which is BMI and WHR which are very easy to measure and efficient. In addition, the use of cMetS in the metabolic assessment of a person was found to be more effective. 21

22 Keywords: Adolescent; Anthropometric Indicator; Female; Metabolic Profile; Metabolic Syndrome.

- 23
- 24

### 25 1. Introduction

26 Metabolic syndrome is a set of body metabolic disorders such as dyslipidaemia, hyperglycaemia, 27 hypertension, and central obesity (Srikanthan *et al.*, 2016; Devi *et al.*, 2017; Christijani, 2019). 28 Metabolic syndrome is not a disease, but is a set of several disorders and causes an increased risk of 29 cardiovascular disease and diabetes mellitus complications. Some epidemiological studies have 30 shown that metabolic syndrome doubles the risk of cardiovascular diseases (Sri Rahayu and Maulina, 31 2017).

Several studies found that the prevalence of metabolic syndrome keeps increasing every year. A study in China shows the prevalence of metabolic syndrome in adults was 24.2% (Li *et al.*, 2018). Another study indicated that the prevalence of metabolic syndrome in Indonesia was 21.66% (Herningtyas and Ng, 2019). In recent studies metabolic syndrome can be assessed using the continuous value of metabolic syndrome (cMets) or the metabolic syndrome score recommended by the American Diabetic Association of Diabetes. The metabolic syndrome (Pratiwi, *et al.*, 2017). The

**Commented [A1]:** If the main sentence in this paragraph is in this first sentence, make the other sentence to support the main.

Commented [A2]: In what subjects ?

advantages of using cMetS are (1) reducing dichotomization factors because cardiovascular disease
 is a progression of several components of the metabolic syndrome, (2) cMetS is more sensitive and
 less error-prone than categoric metabolic syndrome assessments, (3) increasing the statistical power
 (Okosun, Lyn, *et al.*, 2010).

43 Central obesity is one of the components of metabolic syndrome parameters. Central obesity is 44 associated with increased blood pressure, serum triglycerides, decreased HDL, and glucose 45 intolerance. Based on the National Basic Health Research (Riskesdas) in 2018, the prevalence of 46 obesity in adults was 21.8%, and the prevalence of central obesity at age of more than 15 years 47 increased from 26.6% in 2013 to 31% in 2018 (Badan Penelitian dan Pengembangan Kesehatan, 48 2018). Obesity is closely related to degenerative diseases. The Riskesdas 2018 showed that the prevalence of stroke, diabetes mellitus, heart disease, and hypertension is higher in women than 49 50 men.

51 Several studies have shown that non-invasive approaches such as anthropometric measurements 52 can be used for early detection of metabolic syndrome (Pratiwi, et al., 2017). Anthropometric 53 measurements are described as the measurements of body dimensions and body composition to 54 assess nutritional status. The advantages of anthropometric measurements are relatively fast and 55 easy, as it can be performed using portable and calibrated instruments with standardized methods 56 (Rokhmah, et al., 2015). Some anthropometric measurements that can be used for early detection 57 of metabolic syndrome are Waist-to-Height Ratio (WHtR), waist-to-hip ratio (WHR), hip 58 circumference, Body Mass Index (BMI), Sagital Abdominal Diameter (SAD).

59 One of the anthropometric measurements which can be a parameter for central obesity is the ratio of waist circumference to height (WHtR). The instruments used in the measurement are 60 microtoise and measuring tape so that it takes longer time. Studies on waist circumference have been 61 62 shown to have a strong correlation with abdominal fat deposits (Zhou et al., 2014). The distribution 63 of abdominal adipose tissue (central obesity) in adults is associated with a component of the 64 metabolic syndrome (Rodea-Montero, et al., 2014). A study on adult subjects has shown that people who have the same waist circumference but are shorter in height have a greater risk of developing 65 metabolic syndrome than taller people (Zhou et al., 2014). Therefore, WHtR can be used as a simple 66 and effective anthropometric index to identify the metabolic risk associated with obesity (Rodea-67 68 Montero, et al., 2014).

69 The waist-to-hip ratio (WHR) is a measurement that may indicate central obesity (Karimah, 2018). The higher the WHR value, the higher the risk level for several metabolic diseases. The waist-to-hip 70 71 ratio is calculated by dividing the measurement of the waist circumference by the circumference of 72 the hip. The cut-off points for WHR are  $\geq$ 1.0 for men and  $\geq$ 0.85 for women (Rokhmah, et al., 2015). Individuals with a high waist and hip circumference will also have a higher distribution of fat in their 73 74 abdominal area. Irregular fats distribution in the abdominal area indirectly causes higher triglyceride 75 levels circulating in the blood, which will affect blood pressure (Sumardiyono et al., 2018). WHR 76 measurement is more sensitive in assessing the distribution of fat in the body, especially in the 77 abdominal. This measurement is three times better than BMI in reflecting the presence of harmful 78 fats in the abdominal. Measurement of waist circumference is performed by determining the lower 79 part of arcus costae and crista iliaca (Sri Rahayu and Maulina, 2017).

**Commented [A3]:** Connect with the subjects taken in this research which is college female students

Commented [A4]: Please add r value

Commented [A5]: How many time ?

**Commented [A6]:** Please add conjunction word or sentence to connect WHR and previous antropometric indicator in previous paragraph. Or adding the similarity or the differences between 2 indicators.

84 85 86 87 88 89 90 91 92 93		Sagittal Abdominal Diameter (SAD) or the height of the abdomen while the subjects are in lying position. This anthropometric measurement has not been widely used to measure fat tissue in the abdominal area. SAD measurements using computed tomography or magnetic resonance imaging, and are associated with components of metabolic syndrome. The measurements of SAD are taken when the subject is lying down on the examination table with naked upper body. SAD is related to central obesity in individuals with obese and normal nutritional status. Furthermore, SAD is associated with diabetes mellitus and a predictor of cardiovascular disease incidence, even when SAD is measured in standing position (Pajunen <i>et al.</i> , 2013). Based on the abovementioned problems, our study aims to analyse the anthropometric indicators related to metabolic syndrome in female students.		<b>Commented [A8]:</b> What is the differences or similarity between SAD and previous indicator ? or what is the advantages of using SAD compare to other indicators etc
94				
95	2.	Materials and methods		
96		2.1 Design, location, and time		
97		The scope of this study is community nutrition with a cross-sectional study design.		
98		Anthropometric and biochemical data were collected at the Cito Laboratory, Banyumanik Semarang		
99 100		with health protocols applied. The study started from March to July 2020.		<b>Commented [A9]:</b> Mention health protocols that has been applied when collecting data
100		2.2 Samplings		
101		This study was conducted during the SARS-CoV-2 outbreak, which later was named COVID-19 by		
102		the WHO, so the registration for study participants was done online. The inclusion criteria were		
104		female students aged 19-24, resided in Semarang, willing to be a study participant and willing to		
105		follow a series of study instructions. Subjects were asked to fill in personal data using a Google form;		
106		and eligible subjects will be contacted by the researchers to plan a direct meeting. Purposive		Commented [A10]: What criteria that researcher has
107		sampling was used in this study and the total number of subjects required was 163.		been applied in order to be concluded as purposive
108				sampling
109		2.3 Data collected		
110		The independent variables in this study were the Waist-to-Height Ratio (WHtR), Waist-Hip Ratio		
111		(WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference.		
112		Bodyweight was measured using a digital scale to the nearest 0.01 kg, height was measured using a		
113		microtoise to the nearest 0.1 cm, waist circumference and hip circumference was measured using a		
114		measuring tape (Medline) to the nearest 1 mm and abdominal height was measured using the		
115		Abawerk Schaffenburg abdominal calliper to the nearest 1 mm. SAD measurements were performed		
116		with the subject in a supine position on a flat surface with both knees forming an angle of 90° (Firouzi		Commented [A11]: Please mention the person
117		et al., 2018).		conducted the antropometric data collection to make sure
118 119		The cut-off point used in this study refers to previous studies because it had been adjusted for the Asian race (Rose <i>et al.</i> , 2020). Each anthropometric measurement is stated as "at risk" if the	$\mathbf{i}$	that data taken were valid
119		individuals have $\geq 0.50$ for WHtR (Zhang <i>et al.</i> , 2016), $\geq 0.85$ for WHR (Rokhmah, <i>et al.</i> , 2015), > 19.3		Commented [A12]: Mention how to perform this
120		cm for (Dieny <i>et al.</i> , 2020), and have the normal to overweight BMI (18.5 - 25 kg/m <sup>2</sup> ) or obese BMO		measurement. Where enumerators put the abdominal calliper
122		$(\geq 25.0 \text{ kg/m}^2)$ (Susetyowati, 2016).		Commented [A13]: Please add the meaning
				Commented [Proj. nease and the meaning

Body Mass Index (BMI) is a practical and easy measurement to perform, but it cannot distinguish

between fat mass, bone mass and muscle mass. BMI is calculated as body weight (kg) / height

squared (m<sup>2</sup>) (Okura et al., 2018). BMI can be used as the first measurement before any other

80

81

82

83

anthropometric measurements.

Commented [A7]: What is the differences or similarity between BMI and previous indicator ?

123 The dependent variable in this study is the metabolic syndrome component that has been 124 converted into a metabolic syndrome score (cMetS) with the cut-off point on cMetS> 2.21 (Rose et 125 al., 2020). The guidelines for metabolic syndrome in this study are taken from the National Cholesterol Education Program-Adult Treatment Panel (NCEP-ATP III) 2005 which has been 126 127 frequently used in Indonesia. There are 5 parameters to assess metabolic syndrome: (1) fasting blood 128 glucose levels ≥110 mg/dL, (2) triglyceride levels ≥150 mg/dL (3) HDL cholesterol levels <50 mg/dL, 129 (4) central obesity in women with waist circumference ≥80 cm, and (5) systolic and diastolic blood 130 pressures  $\geq$ 130 mmHg and  $\geq$ 85 mmHg, respectively (Soewondo *et al.*, 2010). The calculation of the 131 metabolic syndrome score (cMetS) was done in the following steps: (1) after measuring all 132 parameters of the metabolic syndrome, standardisation was carried out to obtain a Z-score; (2) the blood pressure must be converted into Mean Arterial Blood (MAP) by dividing the difference 133 134 between systolic and diastolic blood pressure by three and summed with the diastolic blood 135 pressure; (3) the HDL cholesterol standardisation results were multiplied by (-1) because the 136 parameter was inversely related to the risk of metabolic syndrome; (4) All Z-scores were added to 137 obtain the cMetS values; (5) The final step was to compare the cMetS values with the cut-off point 138 of ≥2,21 (Eisenmann et al., 2010; Okosun, Boltri, et al., 2010; Rose et al., 2020). The subjects were 139 instructed to do fasting for at least 8 hours; only drinking water was permitted.

140Other than the cMetS score, metabolic syndrome risk can also be assessed from the classification141of metabolic types. This classification combines the internal and external signs of the body such as142biochemical parameters, the ratio of subcutaneous fat to abdominal fat, and blood pressure (Prybyla143O, 2020). The main phenotypes that reflect the possible combination of metabolic profile and the144degree of obesity are metabolic healthy obese weight, metabolic healthy normal weight, metabolic145unhealthy normal weight, and metabolic unhealthy normal weight.

#### 2.4 Data analysis

146 147

148

149

150

151 152

154

155

156

157

158

Statistical analyses were performed using SPSS Statistical software. This study has received an ethical clearance issued by the Medical/Health Research Bioethics Commission, Faculty of Medicine, Sultan Agung Islamic University Semarang with Number No.296 /IX /2020 /Bioethical Commission.

#### 153 3. Results and discussion/Results

The subject characteristics measured in female student aged 19-24 years include age, anthropometric indicators, and metabolic syndromes. Table 1 shows the characteristics of the study subjects. The mean of WHR value in this study was 0.51. Meanwhile, the mean of WHR was 0.80; the mean of BMI was 24.04 kg/m<sup>2</sup>; the mean of SAD was 16.79 cm; and the mean of waist circumference was 79.44 cm.

159 Table 2 shows various nutritional status of the subjects based on BMI. We found that 43.6% of the subjects had normal BMI, 17.2% were overweight and 35.6% were obese. Based on the WHtR 160 anthropometric indicator, 72.4% of subjects were at risk of having obesity; based on WHR, 22.1% had 161 162 central obesity; based on BMI, 35.6% were obese; based on SAD 12.3% of the subjects were at risk; and based on waist circumference 55.2% had central obesity. According to the metabolic profile that 163 164 was assessed, 16.6% had high FBG levels, 8.6% had hypertriglycerides, 17.2% had low HDL, 16.6% had 165 high systolic blood pressure, and 21.5% had high diastolic blood pressure. In addition, we found 33.1% 166 of the subjects had high metabolic syndrome (cMetS) scores. This proportion was similar to the **Commented [A14]:** Please add more information about what statistical analysis that researchers use

**Commented [A15]:** Is it in one chapter or in separate chapter ? Please adjust with the guideline

Commented [A16]: Consize this sentence.

**Commented [A17]:** Use sentence which can show the finding more clearly. Author can use comparation sentence.

assessment based on the metabolic type of unhealthy subjects (subjects who had ≥ 3 risk factors of
 the metabolic profile), which was 33.7%. Moreover, two subjects had five risk factors: abdominal
 obesity, hypertension, hyperglycaemia, hypertriglycerides, and low HDL.

170 If we are considering metabolic type based on nutritional status (subjects with non-obese BMI 171 (<25kg/m<sup>2</sup>) with metabolic healthy and metabolic unhealthy and subjects with obese BMI (> 25kg/m<sup>2</sup>) 172 with metabolic healthy and metabolic unhealthy), subjects are categorised as metabolic unhealthy 173 (experiencing metabolic syndrome) if they fulfil ≥ 3 risk factors including high waist circumference, 174 blood pressure, GDP and triglyceride levels, and low HDL levels. Based on these criteria, we found that 175 10.4% of the subjects had metabolic unhealthy normal weight (MUNW) and 23.3% of the subjects had 176 metabolic unhealthy obesity weight (MUOW). In non-obese subjects, 54% of them were metabolic 177 healthy.

178 Table 3 and Table 4 show the results of statistical analyses on anthropometric indicators related 179 to the metabolic syndromes. Table 3 shows the bivariate statistical analysis using the Pearson 180 correlation test. The analysis results showed that all anthropometric indicators, namely WHtR, BMI, 181 SAD, waist circumference, hip circumference and WHR have a strong positive relationship with the 182 metabolic syndrome score (p<0.001), which means that the higher the anthropometric value, the 183 higher the metabolic syndrome score. In addition, the analysis on the relationship between 184 anthropometric indicators and each metabolic profile revealed that almost all of the independent 185 variables (WHtR, waist and hip circumference, WHR, BMI, and SAD) were associated with each 186 metabolic profile, such as baseline systolic pressure, diastolic blood pressure, triglyceride levels, blood 187 sugar levels, and HDL. Only WHR that was not associated with diastolic blood pressure (p>0.005).

Table 4 shows the results of the analysis using multiple linear regression to determine anthropometric indicators that are most associated with each metabolic profile and metabolic syndrome score.

The results showed that BMI was the anthropometric indicator that is most associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood sugar (p<0.05), and HDL (p <0.001). In addition, waist circumference was the anthropometric indicator that is most associated with triglycerides and metabolic syndrome score (p<0.001). Based on the Adjusted R2 value on the metabolic syndrome score, we found that 37.5% of the metabolic syndrome score was related to anthropometric indicators, such as WHtR, waist and hip circumference, WHR, BMI, and SAD. The rest may be influenced by other variables that are not included in this study.

#### 199 4. Discussion

188

189

190

198

200 The objective of this study was to determine the anthropometric indicators associated with 201 metabolic syndromes in female students. The study included 163 female students aged 19-24 years. 202 The students are in their late adolescents who begin to have an independent life. Inappropriate and 203 unhealthy eating behaviours will have an impact on the student's nutritional status. Excessive 204 nutritional status and obesity will affect student's body metabolism. Based on the study results, 205 33.1% of the subjects had a high metabolic syndrome (cMetS) score. In line with the previous study 206 conducted in 2019 on 18-to-21-year-old students at Diponegoro University, 20% of the subjects had 207 high cMetS (Rose et al., 2020). Meanwhile, a study conducted by Pratiwi et al in 2017 using secondary 208 data from the National Basic Health Research 2013 found that 19.98% of adolescents aged 15-24 209 years had high cMetS (Pratiwi, et al., 2017). Therefore, we conclude that there is a trend of Metabolic 210 Syndrome Score (cMetS) among young women in Semarang.

Commented [A18]: Consize this sentence

**Commented [A19]:** Please add more sentence. A paragraph should consist more than 1 sentence, where there is 1 main sentence and the other act as supporting sentences

211 The assessment of metabolic syndrome using a continuous type (scoring) rather than using a 212 dichotomy or binary ("yes" and "no") is recommended (Christijani, 2019). An adolescent can be 213 diagnosed with metabolic syndrome if their Metabolic Syndrome Score (cMetS) >2.21 (Pratiwi, et al., 2017). Anthropometric indicators used in this study are Waist and Height Ratio (WHtR), Waist-to-Hip 214 215 Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and Waist Circumference. 216 Based on the correlation analyses, all anthropometric indicators have a significant positive 217 relationship with the Metabolic Syndrome Score (cMetS). Furthermore, the multivariate analyses 218 show that the anthropometric indicators of BMI and RLPP are strongly associated with cMetS.

219 According to the metabolic type, most of the subjects (54%) in this study had metabolic healthy 220 normal weight (MHNW) metabolic type. In this type, the individuals have a normal BMI and does not 221 show any metabolic risk. Our study also shows that 10.4% of the subjects were classified as metabolic 222 unhealthy normal weight (MUNW). The subjects' BMI in this category is in the normal range but has 223 a high percentage of body fat that makes them at high risk of developing metabolic disorders (Eckel 224 et al., 2015; Suliga et al., 2015). Several recent cohort studies have shown a greater risk of type II 225 diabetes mellitus in individuals with MUNW compared to individuals with MHNW (Ärnlöv et al., 2011; 226 Hadaegh et al., 2011; Aung et al., 2014; Jung et al., 2014; Hinnouho et al., 2015). Other studies have 227 shown that women with the MUNW type have a long-term impact of an increased risk of 228 cardiovascular diseases such as higher blood pressure, triglyceride and glucose levels as well as lower 229 levels of adiponectin, HDL, and LDL compared to women with the MHNW type (Kim et al., 2013).

In our study, 23.3% of the subjects belonged to the Metabolic Unhealthy Obese Weight (MUOW)
 type. Subjects with this metabolic type have an obese BMI and have a high risk of developing
 metabolic disorders. A study conducted in Japan on 29,564 subjects showed that individuals with
 MUOW had a greater risk of developing type II diabetes mellitus compared to individuals with MHOW
 (Heianza *et al.*, 2015).

235 We also found that 12.3% of the subjects were categorized as metabolic healthy obese weight 236 (MHOW). Individuals in this metabolic type have an obese BMI but do not show any metabolic risks. 237 Given the impact of obesity in relation to the risk of metabolic diseases, various studies have been 238 conducted to examine the long-term effects of MHOW. Individuals with MHOW had a different fat 239 distribution pattern (less ectopic and visceral fat), and lower inflammatory markers (Samocha-Bonet 240 et al., 2014). Other studies also have shown that women with MHOW had lower blood pressure, 241 triglyceride levels, and glucose levels, but higher levels of HDL, adiponectin, and LDL compared to 242 women with MUNW (Kim et al., 2013). This condition was associated with good diet quality in 243 individuals with MHOW. Based on National Health and Nutrition Examination Surveys (NHANES) 244 data, Camhi et al examined the quality of diet in obese subjects, and found that adolescents and adult 245 women with the MHOW metabolic type had higher diet quality scores due to high intake of fruit, 246 whole grains, meat, and nuts (Camhi et al., 2015).

247 The correlation test results indicated that all anthropometric indicators had a positive 248 relationship with the metabolic syndrome scores with p <0.001. Meanwhile, the regression analyses show that BMI and WHR were inversely related to cMetS. This is in line with research conducted by 249 250 Lindy et al, who stated that an increase in the WHR value could be associated with the risk of metabolic syndrome in children and adolescents in Florida (Moore et al., 2015). A study conducted 251 252 by Al-Bachir and Bakir stated that there was a strong relationship between overweight and obese 253 adolescents with metabolic syndrome (Al-Bachir and Bakir, 2017). Furthermore, a study conducted 254 by Adrian et al on 15-year-old adolescents in South Africa found that central obesity as measured by **Commented [A20]:** Incorporate with the age base subject, and describe the reasons.

the hip circumference could lead to an increased risk of cardiovascular diseases and death. Therefore,
 hip circumference and waist circumference can be used to predict the risk of cardiovascular diseases
 and death in the future (Cameron *et al.*, 2012).

Body Mass Index (BMI) is the most widely used indicator of measurement in epidemiological 258 259 studies and is used as a substitute for evaluating body composition. However, BMI cannot distinguish 260 fat from fat mass and lean mass, and it fails to show the presence of adipose and body fat distribution 261 (Ofer et al., 2019; Leone et al., 2020). However, the BMI cut-offs for metabolic syndrome has not yet been determined (Ofer et al., 2019). Obesity in adolescents is generally assessed using a BMI of ≥25.0 262 263 kg/m<sup>2</sup>. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m<sup>2</sup>) and 264 obesity (≥25.0 kg/m<sup>2</sup>), and we found that 35.6% of the subjects were obese. The finding is in line with 265 the research conducted by Sophia et al on the subject of students at Universitas Diponegoro aged 266 18-21 years. They found that 40% of their study population had obesity level I and 36.3% had obesity 267 level II (Rose et al., 2020).

268 Abdominal obesity is often assessed to determine a metabolic syndrome in people. One of the 269 indicators used to measure abdominal obesity is the Waist-to-Hip Ratio (WHR) which is calculated by 270 dividing the waist circumference and the hip circumference. Measurement of waist circumference is 271 more sensitive in assessing the distribution of body fat in the abdominal wall, which is also a 272 component in the metabolic syndrome. The limit of the WHR value for female is  $\geq$  0.85 (Rokhmah, et 273 al., 2015). This study shows that every 1% increase in the WHR value will increase the cMetS value 274 by 10.411. Hip circumference is also an indicator that has a strong correlation with cMetS, but many 275 studies have used it as a ratio along with waist circumference for assessing a person's central obesity 276 status.

#### 278 5. Conclusion

Metabolic syndrome in female students in Semarang can be identified using anthropometric
 measurements, one of which is BMI and WHR which are very easy to measure and efficient. In
 addition, the use of cMetS in the metabolic assessment of a person was found to be more effective.

282

277

### 283 Conflict of interest - Disclose any potential conflict of interest appropriately.

284 The authors declare no conflict of interest.

#### 285 Acknowledgments

- 286 The authors would like to thank all the subjects who participated in this study. We would also like to
- 287 express our gratitude to The Ministry of Research, Technology and Higher Education, Indonesia" was
- 288 funded by the "Hibah Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) 2019.
- 289
- 290

**Commented [A21]:** Compared to ? incorporate with the age and gender base subjects

#### 291 References

- 292 Al-Bachir, M. and Bakir, M. A. (2017). Predictive value of body mass index to metabolic syndrome risk 293 factors in Syrian adolescents. Journal of Medical Case Reports, 11(1). doi: 10.1186/s13256-017-1315-294 2.

295 Ärnlöv, J., Sundström, J., Ingelsson, E., Lind, L. (2011). Impact of BMI and the metabolic syndrome on the 296 risk of diabetes in middle-aged men. Diabetes Care, 34(1), 61-65. doi: 10.2337/dc10-0955.

- 297 Aung, K. K., Lorenzo, C., Hinojosa, M. A., Haffner, S. M. (2014). Risk of developing diabetes and 298 cardiovascular disease in metabolically unhealthy normal-weight and metabolically healthy obese 299 individuals. Journal of Clinical Endocrinology and Metabolism, 99(2), 462-468. doi: 10.1210/jc.2013-300 2832
- 301 Badan Penelitian dan Pengembangan Kesehatan. (2018). Riset Kesehatan Dasar (RISKESDAS) 2018. 302 Jakarta, Indonesia.
- 303 Cameron, A. J., Magliano, D. J., Shaw, J. E., Zimmet, P. Z., Carstensen, B., Alberti, K. G. M. M., Tuomilehto, 304 J., Barr, E. L. M., Pauvaday, V. K., Kowlessur, S., Söderberg, S. (2012). The influence of hip circumference 305 on the relationship between abdominal obesity and mortality. International Journal of Epidemiology, 306 41(2), 484-494. doi: 10.1093/ije/dyr198.
- 307 Camhi, S. M., Whitney Evans, E., Hayman, L. L., Lichtenstein, A. H., Must, A. (2015). Healthy eating index 308 and metabolically healthy obesity in U.S. adolescents and adults. Preventive Medicine, 77, 23–27. doi: 309 10.1016/j.ypmed.2015.04.023.
- 310 Christijani, R. (2019). Determination of Diagnosis of Metabolic Syndrome based on Assessment of 311 Metabolic Syndrome and NCEP ATP-III Score in Adolescent. The Journal of Nutrition and Food Research, 312 42(1), 21-28. doi: 10.22435/pgm.v42i1.2418.
- 313 Devi, R., Manhas, S., Prasad, S., Sharma, S., Bhaskar, N., Mahajan, S. (2017). Short Review of Metabolic 314 Syndrome. International Journal of Research & Review, 4(2), p. 29.
- 315 Dieny, F. F., Setyaningsih, R. F., Fitranti, D. Y., Jauharany, F. F., Putra, Y. D., Tsani, A. F. A. (2020). Abdominal diameter profiles have relationship with insulin resistance in obese female adolescents. Electronic 316 317 Journal of General Medicine, 17(5), p. em219. doi: 10.29333/ejgm/7882.
- 318 Eckel, N., Mühlenbruch, K., Meidtner, K., Boeing, H., Stefan, N., Schulze, M. B. (2015). Characterization of 319 metabolically unhealthy normal-weight individuals: Risk factors and their associations with type 2 320 diabetes. Metabolism: Clinical and Experimental, 64(8), 862–871. doi: 10.1016/j.metabol.2015.03.009.
- 321 Eisenmann, J. C., Laurson, K. R., Dubose, K. D., Smith, B. K., Donnelly, J. E. (2010). Construct validity of a 322 continuous metabolic syndrome score in children. Diabetology and Metabolic Syndrome, 2(1). doi: 323 10.1186/1758-5996-2-8.
- 324 Firouzi, S. A., Tucker, L. A., LeCheminant, J. D., Bailey, B. W. (2018). Sagittal abdominal diameter, waist 325 circumference, and BMI as predictors of multiple measures of glucose metabolism: An NHANES investigation of US adults. Journal of Diabetes Research, 2018, 1–14. doi: 10.1155/2018/3604108. 326
- 327 Hadaegh, F., Bozorgmanesh, M., Safarkhani, M., Khalili, D., Azizi, F. (2011). Predictability of body mass 328 index for diabetes: Affected by the presence of metabolic syndrome?. BMC Public Health, 11(1), p. 383. 329 doi: 10.1186/1471-2458-11-383.
- 330 Heianza, Y., Kato, K., Kodama, S., Ohara, N., Suzuki, A., Tanaka, S., Hanyu, O., Sato, K., Sone, H. (2015). Risk 331 of the development of Type 2 diabetes in relation to overall obesity, abdominal obesity and the 332 clustering of metabolic abnormalities in Japanese individuals: Does metabolically healthy overweight 333 really exist? The Niigata Wellness Study. Diabetic Medicine, 32(5), 665-672. doi: 10.1111/dme.12646.
- Herningtyas, E. H. and Ng, T. S. (2019). Prevalence and distribution of metabolic syndrome and its 334 335 components among provinces and ethnic groups in Indonesia. BMC Public Health, 19(1), p. 377. doi: 336 10.1186/s12889-019-6711-7.
- 337 Hinnouho, G. M., Czernichow, S., Dugravot, A., Nabi, H., Brunner, E. J., Kivimaki, M., Singh-Manoux, A.

- 338 (2015). Metabolically healthy obesity and the risk of cardiovascular disease and type 2 diabetes: The 339 Whitehall II cohort study. European Heart Journal, 36(9), 551–559. doi: 10.1093/eurheartj/ehu123.
- 340 Jung, H. S., Chang, Y., Eun, Y. K., Kim, C. W., Choi, E. S., Kwon, M. J., Cho, J., Zhang, Y., Rampal, S., Zhao, D., 341 Soo, K. H., Shin, H., Guallar, E., Ryu, S. (2014). Impact of body mass index, metabolic health and weight 342 change on incident diabetes in a Korean population. Obesity, 22(8), 1880–1887. doi: 343 10.1002/oby.20751.
- Karimah, M. (2018). Rasio Lingkar Pinggal-panggul Memiliki Hubungan Paling Kuat dengan Kadar Glukosa 344 345 Darah'. Jurnal Berkala Epidemiologi, 6(3), 219-226.
- 346 Kim, M., Paik, J. K., Kang, R., Kim, S. Y., Lee, S. H., Lee, J. H. (2013). Increased oxidative stress in normal-347 weight postmenopausal women with metabolic syndrome compared with metabolically healthy 348 overweight/obese individuals. Metabolism: Clinical and Experimental, 62(4), 554-560. doi: 349 10.1016/j.metabol.2012.10.006.
- 350 Leone, A. et al. (2020). Evaluation of different adiposity indices and association with metabolic syndrome 351 risk in obese children: Is there a winner?. International Journal of Molecular Sciences, 21(11), p. 4083. 352 doi: 10.3390/ijms21114083.
- 353 Li, Y. et al. (2018). Metabolic syndrome prevalence and its risk factors among adults in China: A nationally 354 representative cross-sectional study. PLoS ONE, 13(6), e0199293. р. doi: 10.1371/journal.pone.0199293. 355
- 356 Moore, L. M. et al. (2015). Analysis of Pediatric Waist to Hip Ratio Relationship to Metabolic Syndrome Markers. Journal of Pediatric Health Care, 29(4), 319-324. doi: 10.1016/j.pedhc.2014.12.003. 357
- Ofer, K. et al. (2019). Normal body mass index (BMI) can rule out metabolic syndrome: An Israeli cohort 358 359 study. Medicine, 98(9), p. e14712. doi: 10.1097/MD.00000000014712.
- Okosun, I. S., Boltri, J. M., et al. (2010). Continuous metabolic syndrome risk score, body mass index 360 361 percentile, and leisure time physical activity in American children. Journal of Clinical Hypertension, 362 12(8), 636–644. doi: 10.1111/j.1751-7176.2010.00338.x.
- Okosun, I. S., Lyn, R., et al. (2010). Validity of a Continuous Metabolic Risk Score as an Index for Modeling 363 364 Metabolic Syndrome in Adolescents. Annals of Epidemiology, 20(11), 843-851. doi: 365 10.1016/j.annepidem.2010.08.001.
- 366 Okura, T. et al. (2018). Body mass index ≥23 is a risk factor for insulin resistance and diabetes in Japanese people: A brief report. PLOS ONE. Edited by P. Bjornstad, 13(7), p. e0201052. doi: 367 368 10.1371/journal.pone.0201052.
- 369 Pajunen, P. et al. (2013). Sagittal abdominal diameter as a new predictor for incident diabetes. Diabetes 370 Care, 36(2), 283-288. doi: 10.2337/dc11-2451.
- 371 Pratiwi, Z. A., Hasanbasri, M. and Huriyati, E. (2017). Penentuan titik potong skor sindroma metabolik 372 remaja dan penilaian validitas diagnostik parameter antropometri: analisis Riskesdas 2013. Jurnal Gizi 373 Klinik Indonesia, 14(2), p. 80. doi: 10.22146/ijcn.25590.
- 374 Prybyla, O. (2020). Metabolic phenotyping: is it so important?. Journal of Cognitive Neuropsychology. 375 iMedPub., 4(1), 1-3.
- 376 Rodea-Montero, E. R., Evia-Viscarra, M. L. and Apolinar-Jiménez, E. (2014). Waist-to-height ratio is a better 377 anthropometric index than waist circumference and BMI in predicting metabolic syndrome among 378 obese mexican adolescents. International Journal of Endocrinology, 2014, 195407. doi: 379 10.1155/2014/195407.
- Rokhmah, F. D., Handayani, D. and Al-Rasyid, H. (2015). Korelasi lingkar pinggang dan rasio lingkar 380 381 pinggang-panggul terhadap kadar glukosa plasma menggunakan tes toleransi glukosa oral. Jurnal Gizi 382 Klinik Indonesia, 12(1), 28-35. doi: 10.22146/ijcn.22425.
- 383 Rose, S., Dieny, F. F., Nuryanto, N., Tsani, A. F. A. (2020). The correlation between waist-to-height ratio 384 (wHtR) and second to fourth digit ratio (2D:4D) with an increase in metabolic syndrome scores in obese 385
- adolescent girls. Electronic Journal of General Medicine, 17(3), p. em211. doi: 10.29333/ejgm/7872.

- Samocha-Bonet, D., Dixit, V. D., Kahn, C. R., Leibel, R. L., Lin, X., Nieuwdorp, M., Pietiläinen, K. H., Rabasa Lhoret, R., Roden, M., Scherer, P. E., Klein, S., Ravussin, E. (2014). Metabolically healthy and unhealthy
   obese The 2013 stock conference report. *Obesity Reviews*, 15(9), 697–708. doi: 10.1111/obr.12199.
- Soewondo, P., Purnamasari, D., Oemardi, M., Waspadji, S., Soegondo, S. (2010). Prevalence of Metabolic
   Syndrome Using NCEP/ATP III Criteria in Jakarta, Indonesia: The Jakarta Primary Non-communicable
   Disease Risk Factors Surveillance 2006. *Acta Med Indones.*, 42(4), 199–203.
- Sri Rahayu, M. and Maulina, M. (2017). Hubungan Rasio Lingkar Pinggang dan Lingkar Pinggul dengan
  Penyakit Jantung Koroner. Jurnal Aceh Medika, 1(1), 1–10. Available at:
  www.jurnal.abulyatama.ac.id/acehmedika (Accessed: 8 April 2021).
- Srikanthan, K., Feyh, A., Visweshwar, H., Shapiro, J. I., Sodhi, K.(2016). Systematic review of metabolic
   syndrome biomarkers: A panel for early detection, management, and risk stratification in the West
   Virginian population. *International Journal of Medical Sciences*, 13(1), 25–38. doi: 10.7150/ijms.13800.
- Suliga, E., Kozieł, D., Cieśla, E., Głuszek, S. (2015). Association between dietary patterns and metabolic
   syndrome in individuals with normal weight: A cross-sectional study. *Nutrition Journal*, 14(1), p. 55.
   doi: 10.1186/s12937-015-0045-9.
- Sumardiyono, S., Pamungkasari, E. P., Mahendra, A. G., Utomo, O. S., Mahajana, D., Cahyadi, W. R., Ulfia,
  M. (2018). Hubungan Lingkar Pinggang dan Lingkar Panggul dengan Tekanan Darah pada Pasien
  Program Pengelolaan Penyakit Kronis (Prolanis). *Smart Medical Journal*, 1(1), p. 26. doi:
  10.13057/smj.v1i1.24504.
- 405 Susetyowati, S. (2016). Gizi Remaja, in Ilmu Gizi: Teori dan Aplikasi. Jakarta, Indonesia: EGC, 160–164.
- Zhang, Y. X., Wang, Z. X., Chu, Z. H., Zhao, J. S. (2016). Profiles of body mass index and the nutritional
  status among children and adolescents categorized by waist-to-height ratio cut-offs. *International Journal of Cardiology*, 223, 529–533. doi: 10.1016/j.ijcard.2016.07.303.
- Zhou, D., Yang, M., Yuan, Z. P., Zhang, D. D., Liang, L., Wang, C. L., Zhang, S., Zhu, H. H., Lai, M. D., Zhu, Y.
   M. (2014) . Waist-to-Height Ratio: A simple, effective and practical screening tool for childhood obesity
   and matabalic surdrome. *Proventive Medicine*, 67, 35–40, doi: 10.1016/j.vpmed.2014.06.025
- and metabolic syndrome. *Preventive Medicine*, 67, 35–40. doi: 10.1016/j.ypmed.2014.06.025.
- 412 413

Commented [A22]: Add doi please if present.

# Tables and Figures – 1 PAGE 1 TABLE/FIGURE. PLACE ALL TABLES AND FIGURES AT THE END OF THE MANUSCRIPT BODY AFTER THE REFERENCES

Variabel	Minimum	Maximum	Mean	SD
Anthropometric Indicators				
WHtR (rasio)	0.37	0.71	0.51	0.07
RLPP (rasio)	0.67	0.96	0.80	0.06
BMI (kg/m²)	15.81	39.30	24.04	4.72
Sagital Abdominal Diameter (cm)	11.35	25.50	16.79	2.42
Hip Circumference (cm)	80.60	138.45	98.96	9.30
Waist Circumference (cm)	58.00	112.10	79.44	10.78
Metabolic Profiles				
Blood Glucose Levels (mg/dL)	66.00	110.00	92.00	7.59
Trygliceride Levels (mg/dL)	29.00	309.00	88.35	44.68
Cholesterol Levels HDL (mg/dL)	36.00	109.00	61.73	26.43
Sistolic Blood Pressure (mmHg)	84.00	144.00	114.63	11.13
Diastolic Blood Pressure (mmHg)	55.00	178.00	82.40	55.52
cMetS (Score of Metabolic Syndrome)	-7.10	11.93	0.01	2.90

Characteristics	n	%
Anthropometric		
Body Mass Index (BMI)		
Underweight (< 18.5 kg/m <sup>2</sup> )	6	3.7
Normal (18.5 – 22.9 kg/m <sup>2</sup> )	71	43.6
Overweight (23-24.9 kg/m <sup>2</sup> )	28	17.2
Obese (≥25.0 kg/m <sup>2</sup> )	58	35.6
Waist Height Ratio (WHtR)		
Normal (<0.50)	45	27.6
Risk (≥0.50)	118	72.4
Waist Hip Ratio		
Normal (<0.85)	127	77.9
Central Obesity (≥0.85)	36	22.1
Sagital Abdominal Diameter (SAD)		
Normal (≤19.3 cm)	143	87.7
Risk (>19.3 cm)	20	12.3
Wait Circumference		
Normal (<80 cm)	73	44.8
Obese (≤80 cm)	90	55.2
Metabolic Profiles		
Blood Glucose Levels		
Normal (<110 mg/dL)	136	83.4
High (≥110 mg/dL)	27	16.6
Triglycerides		10.
Normal (<150 mg/dL)	149	914
High (≥150 mg/dL)	14	8.6
Cholesterol HDL		
Normal (≥150 mg/dL)	135	82.8
Rendah (<150 mg/dL)	28	17.2
Sistolic Blood Pressure		
Normal (<130 mg/dL)	136	83.4
High (≥130 mg/dL)	27	16.6
Diastolic Blood Pressure		
Normal (<85 mg/dL)	128	78.5
High (≥85 mg/dL)	35	21.5
cMetS (Score of Metabolic Syndrome)		
Normal (<2.21)	109	66.9
Risk (≥2.21)	54	33.1
Tipe Metabolik		
Metabolic Unhealthy Normal Weight (MUNW)	17	10.4
Metabolic Healthy Normal Weight (MHNW)	88	54
Metabolic Unhealthy Obese Weight (MUOW)	38	23.3
Metabolic Healthy Obese Weight (MHOW)	20	12.3

450	Ingryceniues, Blood Sugar, HDL and metabolic syndrome scores)											
Variable	Sistolic	BP	Distolic BP		TG	TG		Blood Glucose			cMetS	
	r	р	r	р	r	р	r	р	r	р	r	р
WHtR	0.358	<0.001	0.306	<0.001	0.289	<0.001	0.210	0.007	-0.266	0.001	0.599	<0.001
BMI	0.370	<0.001	0.313	<0.001	0.315	<0.001	0.221	0.005	-0.292	<0.001	0.600	<0.001
SAD	0.352	<0.001	0.284	<0.001	0.278	<0.001	0.191	0.015	-0.264	0.001	0.575	< 0.001
WC	0.377	<0.001	0.284	<0.001	0.295	<0.001	0.212	0.005	-0.243	0.002	0.616	< 0.001
HC	0.369	<0.001	0.332	<0.001	0.302	<0.001	0.179	0.002	-0.273	<0.001	0.581	<0.001
WHR	0.244	0.002	0.128	0.104	0.194	0.013	0.172	0.028	-0.149	0.048	0.415	<0.001

Table 3.The Relationship between Anthropometric Indicators and Metabolic Profiles (Blood Pressure,
 Triglycerides, Blood Sugar, HDL and metabolic syndrome scores)

		syndrome	scores							
Variable	Sistolic BP									
	Konstanta	USC <sup>a</sup>	<b>р1</b> <sup>ь</sup>	p2 <sup>c</sup>	<sup>d</sup> Adjusted R <sup>2</sup>					
BMI	91.759	0.951	<0.001	<0.001	0.158					
	Blood Gluco	Blood Glucose Levels								
	Konstanta	USC <sup>a</sup>	р1 <sup>ь</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>					
BMI	83.454	0.355	0.005	<0.001	0.043					
	HDL									
	Konstanta	USC <sup>a</sup>	<b>р1</b> <sup>ь</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>					
BMI	81.429	-0.819	<0.001	<0.001	0.080					
	Triglyceride	Triglycerides								
	Konstanta	USC <sup>a</sup>	<b>р1</b> <sup>b</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>					
WC	-6.614	1.195	<0.001	<0.001	0.078					
	Score of Me	Score of Metabolic Syndrome								
	Konstanta	USC <sup>a</sup>	<b>р1</b> <sup>ь</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>					
WC	-13.163	0.166	<0.001	<0.001	0.375					

Table 4. Anthropometric indicators most associated with metabolic components and metabolic syndrome scores

443 <sup>a</sup>Unstandardized Coefficient, <sup>b</sup> p-value, <sup>c</sup> p Uji F (ANOVA), <sup>d</sup> Koefisien Determinasi

441

### Anthropometry indicators that are most related to metabolic profiles in female college students

### 2 3

1

## 4 Abstract

Metabolic syndrome is not a disease, but is a set of several disorders and causes an increased risk of 5 6 cardiovascular disease and diabetes mellitus complications. Several studies have shown that non-7 invasive approaches such as anthropometric measurements can be used for early detection of 8 metabolic syndrome. This study aims to analyse the anthropometric indicators related to metabolic 9 syndrome in female college students. This cross-sectional study with a total of 163 female college 10 students, aged between 19 and 24 years old. Purposive sampling was used in this study. The 11 independent variables in this study were the Waist-to-Height Ratio (WHR), Waist-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference. The dependent 12 13 variable in this study is the metabolic syndrome component that has been converted into a metabolic 14 syndrome score (cMetS). The analysis results showed that all anthropometric indicators, namely 15 WHtR, BMI, SAD, waist circumference, hip circumference and WHR have a strong positive 16 relationship with the metabolic syndrome score (p<0.001). BMI was the anthropometric indicator 17 that is most associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood 18 sugar (p<0.05), and HDL (p<0.001). Waist circumference was the anthropometric indicator that is 19 most associated with triglycerides and metabolic syndrome score (p<0.001). Metabolic syndrome in 20 female college students can be identified using anthropometric measurements, one of which is BMI 21 and WHR which are very easy to measure and efficient. BMI and WHR have the strongest relationship 22 and can be used to detect early risk of metabolic syndrome in female college students.

23 Keywords: Adolescent; Anthropometric Indicator; Female; Metabolic Profile; Metabolic Syndrome.

#### 24

25

### 26 1. Introduction

Metabolic syndrome is a set of body metabolic disorders such as dyslipidaemia, hyperglycaemia,
 hypertension, and central obesity (Srikanthan *et al.*, 2016; Devi *et al.*, 2017; Christijani, 2019).
 Metabolic syndrome is not a disease, but is a set of several disorders and causes an increased risk of
 cardiovascular disease and diabetes mellitus complications. Some epidemiological studies have
 shown that metabolic syndrome doubles the risk of cardiovascular diseases (Sri Rahayu and Maulina,
 2017).

Indonesia as a developing country cannot be separated from the existing nutritional problems in the world, including the incidence of obesity and metabolic syndrome. Several studies found that the prevalence of metabolic syndrome keeps increasing every year. A study in China showed the prevalence of metabolic syndrome in adults was 24.2% (Li *et al.*, 2018). Another study indicated that the prevalence of metabolic syndrome in Indonesia was 21.66% (Herningtyas and Ng, 2019). In recent studies metabolic syndrome can be assessed using the continuous value of metabolic syndrome (cMets) or the metabolic syndrome score recommended by the American Diabetic Association of Commented [A1]: revised

Commented [A2]: revised

Diabetes. The metabolic syndrome score is a z-score resulting from the assessment of all components
 of the metabolic syndrome (Pratiwi, *et al.*, 2017). The advantages of using cMetS are (1) reducing
 dichotomization factors because cardiovascular disease is a progression of several components of
 the metabolic syndrome, (2) cMetS is more sensitive and less error-prone than categoric metabolic
 syndrome assessments, (3) increasing the statistical power (Okosun, Lyn, *et al.*, 2010).

45 Central obesity is one of the components of metabolic syndrome parameters. Central obesity is 46 associated with increased blood pressure, serum triglycerides, decreased HDL, and glucose 47 intolerance. Based on the National Basic Health Research (Riskesdas) in 2018, the prevalence of 48 obesity in adults was 21.8%, and the prevalence of central obesity at age of more than 15 years 49 increased from 26.6% in 2013 to 31% in 2018 (Badan Penelitian dan Pengembangan Kesehatan, 50 2018). Obesity is closely related to degenerative diseases. The Riskesdas 2018 showed that the 51 prevalence of stroke, diabetes mellitus, heart disease, and hypertension is higher in women than 52 men.

53 Several studies have shown that non-invasive approaches such as anthropometric measurements can be used for early detection of metabolic syndrome (Pratiwi, et al., 2017). Anthropometric 54 55 measurements are described as the measurements of body dimensions and body composition to 56 assess nutritional status. The advantages of anthropometric measurements are relatively fast and 57 easy, as it can be performed using portable and calibrated instruments with standardized methods 58 (Rokhmah, et al., 2015). Some anthropometric measurements that can be used for early detection 59 of metabolic syndrome are Waist-to-Height Ratio (WHtR), waist-to-hip ratio (WHR), hip 60 circumference, Body Mass Index (BMI), Sagital Abdominal Diameter (SAD).

61 One of the anthropometric measurements which can be a parameter for central obesity is the ratio of waist circumference to height (WHtR). The instruments used in the measurement are 62 63 microtoise and measuring tape so that it takes longer time. Studies on waist circumference have been 64 shown to have a strong correlation with abdominal fat deposits (Zhou et al., 2014). The distribution 65 of abdominal adipose tissue (central obesity) in adults is associated with a component of the metabolic syndrome (Rodea-Montero, et al., 2014). A study on adult subjects has shown that people 66 who have the same waist circumference but are shorter in height have a greater risk of developing 67 68 metabolic syndrome than taller people (Zhou et al., 2014). Therefore, WHtR can be used as a simple 69 and effective anthropometric index to identify the metabolic risk associated with obesity (Rodea-70 Montero, et al., 2014).

71 The waist-to-hip ratio (WHR) is a measurement that may indicate central obesity (Karimah, 2018). 72 The higher the WHR value, the higher the risk level for several metabolic diseases. The waist-to-hip 73 ratio is calculated by dividing the measurement of the waist circumference by the circumference of the hip. The cut-off points for WHR are  $\geq$ 1.0 for men and  $\geq$ 0.85 for women (Rokhmah, et al., 2015). 74 75 Individuals with a high waist and hip circumference will also have a higher distribution of fat in their 76 abdominal area. Irregular fats distribution in the abdominal area indirectly causes higher triglyceride 77 levels circulating in the blood, which will affect blood pressure (Sumardiyono et al., 2018). WHR 78 measurement is more sensitive in assessing the distribution of fat in the body, especially in the 79 abdominal. This measurement is three times better than BMI in reflecting the presence of harmful 80 fats in the abdominal. Measurement of waist circumference is performed by determining the lower 81 part of arcus costae and crista iliaca (Sri Rahayu and Maulina, 2017).

Commented [A3]: revised

82 Body Mass Index (BMI) is a practical and easy measurement to perform, but it cannot distinguish 83 between fat mass, bone mass and muscle mass. BMI is calculated as body weight (kg) / height squared (m<sup>2</sup>) (Okura et al., 2018). BMI can be used as the first measurement before any other 84 85 anthropometric measurements.

Sagittal Abdominal Diameter (SAD) or the height of the abdomen while the subjects are in lying 86 position. This anthropometric measurement has not been widely used to measure fat tissue in the 87 88 abdominal area. SAD measurements using computed tomography or magnetic resonance imaging, 89 and are associated with components of metabolic syndrome. The measurements of SAD are taken 90 when the subject is lying down on the examination table with naked upper body. SAD is related to 91 central obesity in individuals with obese and normal nutritional status. Furthermore, SAD is 92 associated with diabetes mellitus and a predictor of cardiovascular disease incidence, even when SAD 93 is measured in standing position (Pajunen *et al.*, 2013). Based on the above mentioned problems, our 94 study aims to analyse the anthropometric indicators related to metabolic syndrome in female college 95 students.

#### 96

98

101

104 105

#### 97 2. Materials and methods

#### 2.1 Design, location, and time

99 A cross-sectional study design and this research wasc onducted from March to July 2020. 100 Anthropometric and biochemical data were collected at the Cito Laboratory, Banyumanik Semarang with health protocols applied. This study was approved by the Medical/Health Research Bioethics 102 Commission, Faculty of Medicine, Sultan Agung Islamic University Semarang with Number No.296 /IX 103 /2020 /Bioethical Commission.

#### 2.2 Samplings

106 This study was conducted during the SARS-CoV-2 outbreak, which later was named COVID-19 by 107 the WHO, so the registration for study participants was done online. Purposive sampling was used in 108 this study and the total number of subjects required was 163. Samples are selected based on 109 inclusion criteria, such as willing to be research subjects, female college students in Semarang City, 110 aged 19-24 years in Semarang, not consuming alcohol, not smoking, willing to be a study participant 111 and willing to follow a series of study instructions. Exclusion criteria are subjects who withdraw and 112 those who are ill during the research study. Based on the exclusion criteria mentioned, no subjects 113 <mark>are included in the exclusion</mark> criteria<mark>.</mark> Subjects were asked to fill in personal data using a Google form; 114 and eligible subjects will be contacted by the researchers to plan a direct meeting.

115 The health protocol applied during the anthropometric and biochemical data collection process, 116 consist of the subject filled out a Covid sign/symptom screening questionnaire, the subject was 117 checked for temperature, washed his hands before entering the room, the distance between subjects was at least 1 meter, the subject and researcher used a mask and face shield. Researchers used gloves 118 and protective clothing. During the study, hand sanitizers were provided, anthropometric tools that 119 120 were on the subject's skin were wiped with alcohol. 121

122 2.3 Data collected

123 The independent variables in this study were the Waist-to-Height Ratio (WHtR), Waist-Hip Ratio 124 (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference. Weight Commented [ASUS4]: space

Commented [A5R4]: revised

Commented [A6]: revised

Commented [A7]: revised

125and height data were obtained through direct measurements using a digital stamp scale GEA brand126with an accuracy of 0.1 kg and microtoise with an accuracy of 0.1 cm. Waist circumference and hip127circumference was measured using a measuring tape (Medline) to the nearest 1 mm and abdominal128height was measured using the Abawerk Schaffenburg abdominal calliper to the nearest 1 mm. SAD129measurements were performed with the subject in a supine position on a flat surface with both knees130forming an angle of 90° (Firouzi *et al.*, 2018).

131The cut-off point used in this study refers to previous studies because it had been adjusted for the132Asian race (Rose *et al.*, 2020). Each anthropometric measurement is stated as "at risk" if the133individuals have  $\geq 0.50$  for WHtR (Zhang *et al.*, 2016),  $\geq 0.85$  for WHR (Rokhmah, *et al.*, 2015), > 19.3134cm for Sagital Abdominal Diameter (SAD) (Dieny *et al.*, 2020), and have the normal to overweight135BMI (18.5 - 25 kg/m²) or obese BMI ( $\geq 25.0$  kg/m²) (Susetyowati, 2016).

136 The dependent variable in this study is the metabolic syndrome component that has been 137 converted into a metabolic syndrome score (cMetS) with the cut-off point on cMetS> 2.21 (Rose et 138 al., 2020). The guidelines for metabolic syndrome in this study are taken from the National 139 Cholesterol Education Program-Adult Treatment Panel (NCEP-ATP III) 2005 which has been 140 frequently used in Indonesia. There are 5 parameters to assess metabolic syndrome: (1) fasting blood 141 glucose levels ≥110 mg/dL, (2) triglyceride levels ≥150 mg/dL (3) HDL cholesterol levels <50 mg/dL, 142 (4) central obesity in women with waist circumference ≥80 cm, and (5) systolic and diastolic blood 143 pressures  $\geq$ 130 mmHg and  $\geq$ 85 mmHg, respectively (Soewondo *et al.*, 2010). The calculation of the 144 metabolic syndrome score (cMetS) was done in the following steps: (1) after measuring all 145 parameters of the metabolic syndrome, standardisation was carried out to obtain a Z-score; (2) the 146 blood pressure must be converted into Mean Arterial Blood (MAP) by dividing the difference 147 between systolic and diastolic blood pressure by three and summed with the diastolic blood 148 pressure; (3) the HDL cholesterol standardisation results were multiplied by (-1) because the 149 parameter was inversely related to the risk of metabolic syndrome; (4) All Z-scores were added to 150 obtain the cMetS values; (5) The final step was to compare the cMetS values with the cut-off point 151 of ≥2,21 (Eisenmann et al., 2010; Okosun, Boltri, et al., 2010; Rose et al., 2020). The subjects were 152 instructed to do fasting for at least 8 hours; only drinking water was permitted.

Other than the cMetS score, metabolic syndrome risk can also be assessed from the classification of metabolic types. This classification combines the internal and external signs of the body such as biochemical parameters, the ratio of subcutaneous fat to abdominal fat, and blood pressure (Prybyla O, 2020). The main phenotypes that reflect the possible combination of metabolic profile and the degree of obesity are metabolic healthy obese weight, metabolic healthy normal weight, metabolic unhealthy normal weight, and metabolic unhealthy normal weight.

#### 2.4 Data analysis

159 160

All data were analyzed using computer programs and statistical analyses were performed using SPSS Statistical software version 22. Univariate analysis was used to describe subjects characteristic. The distribution of data for normality was assessed using the Kolmogorov Smirnov test before statistical. The relationship of anthropometric indicators with metabolic profile (Blood Pressure, Triglycerides, Blood Sugar, HDL and metabolic syndrome scores) were determined using the Person correlation test. Furthermore, Anthropometric indicators that are most related to the metabolic component and metabolic syndrome score were analyzed using the Multiple Linear Regression test for Commented [A8]: revised

Commented [ASUS9]: For what?

Commented [A10R9]: revised

Commented [A11]: revised

#### 169 3. Results and Discussion

170The subject characteristics measured in female student aged 19-24 years include age,171anthropometric indicators, and metabolic syndromes. Table 1 shows the characteristics of the study172subjects. The mean of WHtR value in this study was 0.51. Meanwhile, the mean of WHR was 0.80; the173mean of BMI was 24.04 kg/m²; the mean of SAD was 16.79 cm; and the mean of waist circumference174was 79.44 cm.

175 Table 2 shows various nutritional status of the subjects based on BMI. We found that 43.6% of the subjects had normal BMI, 17.2% were overweight and 35.6% were obese. Based on the WHtR 176 177 anthropometric indicator, 72.4% of subjects were at risk of having obesity; based on WHR, 22.1% had 178 central obesity; based on BMI, 35.6% were obese; based on SAD 12.3% of the subjects were at risk; 179 and based on waist circumference 55.2% had central obesity. According to the metabolic profile that 180 was assessed, 16.6% had high Fasting Blood Glucose levels, 8.6% had hypertriglycerides, 17.2% had 181 low HDL, 16.6% had high systolic blood pressure, and 21.5% had high diastolic blood pressure. In 182 addition, we found 33.1% of the subjects had high metabolic syndrome (cMetS) scores. This 183 proportion was similar to the assessment based on the metabolic type of unhealthy subjects (subjects 184 who had  $\geq$  3 risk factors of the metabolic profile), which was 33.7%. Moreover, two subjects had five 185 risk factors: abdominal obesity, hypertension, hyperglycaemia, hypertriglycerides, and low HDL.

The objective of this study was to determine the anthropometric indicators associated with 186 187 metabolic syndromes in female students. The study included 163 female students aged 19-24 years. 188 The students are in their late adolescents who begin to have an independent life. Inappropriate and 189 unhealthy eating behaviours will have an impact on the student's nutritional status. Excessive 190 nutritional status and obesity will affect student's body metabolism. Based on the study results, 33.1% 191 of the subjects had a high metabolic syndrome (cMetS) score. In line with the previous study 192 conducted in 2019 on 18-to-21-year-old students at Universitas Diponegoro, 20% of the subjects had 193 high cMetS (Rose et al., 2020). Meanwhile, a study conducted by Pratiwi et al in 2017 using secondary 194 data from the National Basic Health Research 2013 found that 19.98% of adolescents aged 15-24 years 195 had high cMetS (Pratiwi, et al., 2017). Therefore, we conclude that there is a trend of Metabolic 196 Syndrome Score (cMetS) among young women in Semarang.

197 The assessment of metabolic syndrome using a continuous type (scoring) rather than using a 198 dichotomy or binary ("yes" and "no") is recommended (Christijani, 2019). An adolescent can be 199 diagnosed with metabolic syndrome if their Metabolic Syndrome Score (cMetS) >2.21 (Pratiwi, et al., 200 2017). Anthropometric indicators used in this study are Waist and Height Ratio (WHtR), Waist-to-Hip 201 Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and Waist Circumference. 202 Based on the correlation analyses, all anthropometric indicators have a significant positive 203 relationship with the Metabolic Syndrome Score (cMetS). Furthermore, the multivariate analyses 204 show that the anthropometric indicators of BMI and WHR are strongly associated with cMetS.

If we are considering metabolic type based on nutritional status (subjects with non-obese BMI 205 206 (<25kg/m<sup>2</sup>) with metabolic healthy and metabolic unhealthy and subjects with obese BMI (>25kg/m<sup>2</sup>) with metabolic healthy and metabolic unhealthy), subjects are categorised as metabolic unhealthy 207 208 (experiencing metabolic syndrome) if they fulfil ≥ 3 risk factors including high waist circumference, blood pressure, GDP and triglyceride levels, and low HDL levels. Based on these criteria, we found that 209 10.4% of the subjects had metabolic unhealthy normal weight (MUNW) and 23.3% of the subjects had 210 211 metabolic unhealthy obesity weight (MUOW). In non-obese subjects, 54% of them were metabolic 212 healthy. Our study also shows that 10.4% of the subjects were classified as metabolic unhealthy Commented [A12]: revised

Commented [A13]: revised

Commented [A14]: revised

Commented [A15]: revised

213 normal weight (MUNW). The subjects' BMI in this category is in the normal range but has a high 214 percentage of body fat that makes them at high risk of developing metabolic disorders (Eckel et al., 215 2015; Suliga et al., 2015). Several recent cohort studies have shown a greater risk of type II diabetes mellitus in individuals with MUNW compared to individuals with MHNW (Ärnlöv et al., 2011; Hadaegh 216 217 et al., 2011; Aung et al., 2014; Jung et al., 2014; Hinnouho et al., 2015). Other studies have shown that 218 women with the MUNW type have a long-term impact of an increased risk of cardiovascular diseases 219 such as higher blood pressure, triglyceride and glucose levels as well as lower levels of adiponectin, 220 HDL, and LDL compared to women with the MHNW type (Kim et al., 2013).

In this study, 23.3% of the subjects belonged to the Metabolic Unhealthy Obese Weight (MUOW)
 type. Subjects with this metabolic type have an obese BMI and have a high risk of developing
 metabolic disorders. A study conducted in Japan on 29,564 subjects showed that individuals with
 MUOW had a greater risk of developing type II diabetes mellitus compared to individuals with MHOW
 (Heianza *et al.*, 2015).

226 We also found that 12.3% of the subjects were categorized as metabolic healthy obese weight 227 (MHOW). Individuals in this metabolic type have an obese BMI but do not show any metabolic risks. 228 Given the impact of obesity in relation to the risk of metabolic diseases, various studies have been 229 conducted to examine the long-term effects of MHOW. Individuals with MHOW had a different fat 230 distribution pattern (less ectopic and visceral fat), and lower inflammatory markers (Samocha-Bonet 231 et al., 2014). Other studies also have shown that women with MHOW had lower blood pressure, 232 triglyceride levels, and glucose levels, but higher levels of HDL, adiponectin, and LDL compared to 233 women with MUNW (Kim et al., 2013). This condition was associated with good diet quality in 234 individuals with MHOW. Based on National Health and Nutrition Examination Surveys (NHANES) 235 data, Camhi et al examined the quality of diet in obese subjects, and found that adolescents and 236 adult women with the MHOW metabolic type had higher diet quality scores due to high intake of 237 fruit, whole grains, meat, and nuts (Camhi et al., 2015).

238 Table 3 and Table 4 show the results of statistical analyses on anthropometric indicators related 239 to the metabolic syndromes. Table 3 shows the bivariate statistical analysis using the Pearson 240 correlation test. The analysis results showed that all anthropometric indicators, namely WHtR, BMI, SAD, waist circumference, hip circumference and WHR have a strong positive relationship with the 241 242 metabolic syndrome score (p<0.001), which means that the higher the anthropometric value, the 243 higher the metabolic syndrome score. In addition, the analysis on the relationship between 244 anthropometric indicators and each metabolic profile revealed that almost all of the independent 245 variables (WHtR, waist and hip circumference, WHR, BMI, and SAD) were associated with each 246 metabolic profile, such as baseline systolic pressure, diastolic blood pressure, triglyceride levels, blood 247 sugar levels, and HDL. Only WHR that was not associated with diastolic blood pressure (p>0.005).

248 Table 4 shows the results of the analysis using multiple linear regression to determine 249 anthropometric indicators that are most associated with each metabolic profile and metabolic 250 syndrome score. The results showed that BMI was the anthropometric indicator that is most 251 associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood sugar (p<0.05), and HDL (p <0.001). In addition, waist circumference was the anthropometric indicator that 252 is most associated with triglycerides and metabolic syndrome score (p<0.001). Based on the Adjusted 253 254 R<sup>2</sup> value on the metabolic syndrome score, we found that 37.5% of the metabolic syndrome score was 255 related to anthropometric indicators, such as WHtR, waist and hip circumference, WHR, BMI, and 256 SAD. The rest may be influenced by other variables that are not included in this study.

Commented [A16]: revised

257 The correlation test results indicated that all anthropometric indicators had a positive 258 relationship with the metabolic syndrome scores with p <0.001. Meanwhile, the regression analyses 259 show that BMI and WHR were inversely related to cMetS. This is in line with research who stated that 260 an increase in the WHR value could be associated with the risk of metabolic syndrome in children 261 and adolescents in Florida (Moore et al., 2015). Another study stated that there was a strong 262 relationship between overweight and obese adolescents with metabolic syndrome (Al-Bachir and 263 Bakir, 2017). Furthermore, a study on the adolescents in South Africa found that central obesity as 264 measured by the hip circumference could lead to an increased risk of cardiovascular diseases and 265 death. Therefore, hip circumference and waist circumference can be used to predict the risk of 266 cardiovascular diseases and death in the future (Cameron et al., 2012).

267 Body Mass Index (BMI) is the most widely used indicator of measurement in epidemiological 268 studies and is used as a substitute for evaluating body composition. However, BMI cannot distinguish 269 fat from fat mass and lean mass, and it fails to show the presence of adipose and body fat distribution 270 (Ofer et al., 2019; Leone et al., 2020). However, the BMI cut-offs for metabolic syndrome has not yet 271 been determined (Ofer et al., 2019). Obesity in adolescents is generally assessed using a BMI of ≥25.0 272 kg/m<sup>2</sup>. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m<sup>2</sup>) and 273 obesity (≥25.0 kg/m<sup>2</sup>), and we found that 35.6% of the subjects were obese. The finding is in line with 274 the research on the subject of students at Universitas Diponegoro aged 18-21 years. They found that 275 40% of their study population had obesity level I and 36.3% had obesity level II (Rose et al., 2020).

276 Abdominal obesity is often assessed to determine a metabolic syndrome in people. One of the 277 indicators used to measure abdominal obesity is the Waist-to-Hip Ratio (WHR) which is calculated by 278 dividing the waist circumference and the hip circumference. Measurement of waist circumference is 279 more sensitive in assessing the distribution of body fat in the abdominal wall, which is also a 280 component in the metabolic syndrome. The limit of the WHR value for female is ≥ 0.85 (Rokhmah, et 281 al., 2015). This study shows that every 1% increase in the WHR value will increase the cMetS value 282 by 10.411. Hip circumference is also an indicator that has a strong correlation with cMetS, but many 283 studies have used it as a ratio along with waist circumference for assessing a person's central obesity 284 status.

#### 286 **4.** Conclusion

287 Metabolic syndrome in female students can be identified using anthropometric measurements, one
 288 of which is BMI and WHR which are very easy to measure and efficient. BMI and WHR have the
 289 strongest relationship and can be used to detect early risk of metabolic syndrome in female college
 290 students.

#### 291

285

292 Conflict of interest - Disclose any potential conflict of interest appropriately.

293 The authors declare no conflict of interest.

#### 294 Acknowledgments

- 295 The authors would like to thank all the subjects who participated in this study. We would also like to
- express our gratitude to The Ministry of Research, Technology and Higher Education, Indonesia" was
   funded by the "Hibah Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) 2019.

Commented [A17]: revised

Commented [A18]: revised

Commented [A19]: revised

#### 298 References

- 299 Al-Bachir, M. and Bakir, M. A. (2017). Predictive value of body mass index to metabolic syndrome risk 300 factors in Syrian adolescents. Journal of Medical Case Reports, 11(1). doi: 10.1186/s13256-017-1315-301 2.

302 Ärnlöv, J., Sundström, J., Ingelsson, E., Lind, L. (2011). Impact of BMI and the metabolic syndrome on the 303 risk of diabetes in middle-aged men. Diabetes Care, 34(1), 61-65. doi: 10.2337/dc10-0955.

- 304 Aung, K. K., Lorenzo, C., Hinojosa, M. A., Haffner, S. M. (2014). Risk of developing diabetes and 305 cardiovascular disease in metabolically unhealthy normal-weight and metabolically healthy obese 306 individuals. Journal of Clinical Endocrinology and Metabolism, 99(2), 462-468. doi: 10.1210/jc.2013-307 2832
- 308 Badan Penelitian dan Pengembangan Kesehatan. (2018). Riset Kesehatan Dasar (RISKESDAS) 2018. 309 Jakarta, Indonesia.
- 310 Cameron, A. J., Magliano, D. J., Shaw, J. E., Zimmet, P. Z., Carstensen, B., Alberti, K. G. M. M., Tuomilehto, 311 J., Barr, E. L. M., Pauvaday, V. K., Kowlessur, S., Söderberg, S. (2012). The influence of hip circumference 312 on the relationship between abdominal obesity and mortality. International Journal of Epidemiology, 41(2), 484-494. doi: 10.1093/ije/dyr198. 313
- 314 Camhi, S. M., Whitney Evans, E., Hayman, L. L., Lichtenstein, A. H., Must, A. (2015). Healthy eating index 315 and metabolically healthy obesity in U.S. adolescents and adults. Preventive Medicine, 77, 23–27. doi: 316 10.1016/j.ypmed.2015.04.023.
- 317 Christijani, R. (2019). Determination of Diagnosis of Metabolic Syndrome based on Assessment of 318 Metabolic Syndrome and NCEP ATP-III Score in Adolescent. The Journal of Nutrition and Food Research, 319 42(1), 21-28. doi: 10.22435/pgm.v42i1.2418.
- 320 Devi, R., Manhas, S., Prasad, S., Sharma, S., Bhaskar, N., Mahajan, S. (2017). Short Review of Metabolic 321 Syndrome. International Journal of Research & Review, 4(2), p. 29.
- 322 Dieny, F. F., Setyaningsih, R. F., Fitranti, D. Y., Jauharany, F. F., Putra, Y. D., Tsani, A. F. A. (2020). Abdominal 323 diameter profiles have relationship with insulin resistance in obese female adolescents. Electronic 324 Journal of General Medicine, 17(5), p. em219. doi: 10.29333/ejgm/7882.
- 325 Eckel, N., Mühlenbruch, K., Meidtner, K., Boeing, H., Stefan, N., Schulze, M. B. (2015). Characterization of 326 metabolically unhealthy normal-weight individuals: Risk factors and their associations with type 2 327 diabetes. Metabolism: Clinical and Experimental, 64(8), 862–871. doi: 10.1016/j.metabol.2015.03.009.
- 328 Eisenmann, J. C., Laurson, K. R., Dubose, K. D., Smith, B. K., Donnelly, J. E. (2010). Construct validity of a 329 continuous metabolic syndrome score in children. Diabetology and Metabolic Syndrome, 2(1). doi: 330 10.1186/1758-5996-2-8.
- 331 Firouzi, S. A., Tucker, L. A., LeCheminant, J. D., Bailey, B. W. (2018). Sagittal abdominal diameter, waist 332 circumference, and BMI as predictors of multiple measures of glucose metabolism: An NHANES 333 investigation of US adults. Journal of Diabetes Research, 2018, 1–14. doi: 10.1155/2018/3604108.
- 334 Hadaegh, F., Bozorgmanesh, M., Safarkhani, M., Khalili, D., Azizi, F. (2011). Predictability of body mass 335 index for diabetes: Affected by the presence of metabolic syndrome?. BMC Public Health, 11(1), p. 383. 336 doi: 10.1186/1471-2458-11-383.
- 337 Heianza, Y., Kato, K., Kodama, S., Ohara, N., Suzuki, A., Tanaka, S., Hanyu, O., Sato, K., Sone, H. (2015). Risk 338 of the development of Type 2 diabetes in relation to overall obesity, abdominal obesity and the 339 clustering of metabolic abnormalities in Japanese individuals: Does metabolically healthy overweight 340 really exist? The Niigata Wellness Study. Diabetic Medicine, 32(5), 665-672. doi: 10.1111/dme.12646.
- Herningtyas, E. H. and Ng, T. S. (2019). Prevalence and distribution of metabolic syndrome and its 341 342 components among provinces and ethnic groups in Indonesia. BMC Public Health, 19(1), p. 377. doi: 343 10.1186/s12889-019-6711-7.
- Hinnouho, G. M., Czernichow, S., Dugravot, A., Nabi, H., Brunner, E. J., Kivimaki, M., Singh-Manoux, A. 344

- (2015). Metabolically healthy obesity and the risk of cardiovascular disease and type 2 diabetes: The
   Whitehall II cohort study. *European Heart Journal*, 36(9), 551–559. doi: 10.1093/eurheartj/ehu123.
- Jung, H. S., Chang, Y., Eun, Y. K., Kim, C. W., Choi, E. S., Kwon, M. J., Cho, J., Zhang, Y., Rampal, S., Zhao, D.,
  Soo, K. H., Shin, H., Guallar, E., Ryu, S. (2014). Impact of body mass index, metabolic health and weight
  change on incident diabetes in a Korean population. *Obesity*, 22(8), 1880–1887. doi:
  10.1002/oby.20751.
- Karimah, M. (2018). Rasio Lingkar Pinggal-panggul Memiliki Hubungan Paling Kuat dengan Kadar Glukosa
   Darah'. Jurnal Berkala Epidemiologi, 6(3), 219–226.
- Kim, M., Paik, J. K., Kang, R., Kim, S. Y., Lee, S. H., Lee, J. H. (2013). Increased oxidative stress in normal weight postmenopausal women with metabolic syndrome compared with metabolically healthy
   overweight/obese individuals. *Metabolism: Clinical and Experimental*, 62(4), 554–560. doi:
   10.1016/j.metabol.2012.10.006.
- Leone, A. *et al.* (2020). Evaluation of different adiposity indices and association with metabolic syndrome
   risk in obese children: Is there a winner?. *International Journal of Molecular Sciences*, 21(11), p. 4083.
   doi: 10.3390/ijms21114083.
- Li, Y. *et al.* (2018). Metabolic syndrome prevalence and its risk factors among adults in China: A nationally
   representative cross-sectional study. *PLoS ONE*, 13(6), p. e0199293. doi:
   10.1371/journal.pone.0199293.
- Moore, L. M. *et al.* (2015). Analysis of Pediatric Waist to Hip Ratio Relationship to Metabolic Syndrome
   Markers. *Journal of Pediatric Health Care*, 29(4), 319–324. doi: 10.1016/j.pedhc.2014.12.003.
- Ofer, K. *et al.* (2019). Normal body mass index (BMI) can rule out metabolic syndrome: An Israeli cohort
   study. *Medicine*, 98(9), p. e14712. doi: 10.1097/MD.00000000014712.
- Okosun, I. S., Boltri, J. M., *et al.* (2010). Continuous metabolic syndrome risk score, body mass index
   percentile, and leisure time physical activity in American children. *Journal of Clinical Hypertension*,
   12(8), 636–644. doi: 10.1111/j.1751-7176.2010.00338.x.
- Okosun, I. S., Lyn, R., *et al.* (2010). Validity of a Continuous Metabolic Risk Score as an Index for Modeling
   Metabolic Syndrome in Adolescents. *Annals of Epidemiology*, 20(11), 843–851. doi:
   10.1016/j.annepidem.2010.08.001.
- Okura, T. *et al.* (2018). Body mass index ≥23 is a risk factor for insulin resistance and diabetes in Japanese
   people: A brief report. *PLOS ONE*. Edited by P. Bjornstad, 13(7), p. e0201052. doi:
   10.1371/journal.pone.0201052.
- Pajunen, P. *et al.* (2013). Sagittal abdominal diameter as a new predictor for incident diabetes. *Diabetes Care*, 36(2), 283–288. doi: 10.2337/dc11-2451.
- Pratiwi, Z. A., Hasanbasri, M. and Huriyati, E. (2017). Penentuan titik potong skor sindroma metabolik
   remaja dan penilaian validitas diagnostik parameter antropometri: analisis Riskesdas 2013. Jurnal Gizi
   *Klinik Indonesia*, 14(2), p. 80. doi: 10.22146/ijcn.25590.
- Prybyla, O. (2020). Metabolic phenotyping: is it so important?. Journal of Cognitive Neuropsychology.
   iMedPub., 4(1), 1-3.
- Rodea-Montero, E. R., Evia-Viscarra, M. L. and Apolinar-Jiménez, E. (2014). Waist-to-height ratio is a better
   anthropometric index than waist circumference and BMI in predicting metabolic syndrome among
   obese mexican adolescents. *International Journal of Endocrinology*, 2014, 195407. doi:
   10.1155/2014/195407.
- Rokhmah, F. D., Handayani, D. and Al-Rasyid, H. (2015). Korelasi lingkar pinggang dan rasio lingkar
   pinggang-panggul terhadap kadar glukosa plasma menggunakan tes toleransi glukosa oral. Jurnal Gizi
   *Klinik Indonesia*, 12(1), 28–35. doi: 10.22146/ijcn.22425.
- Rose, S., Dieny, F. F., Nuryanto, N., Tsani, A. F. A. (2020). The correlation between waist-to-height ratio
   (wHtR) and second to fourth digit ratio (2D:4D) with an increase in metabolic syndrome scores in obese
- adolescent girls. *Electronic Journal of General Medicine*, 17(3), p. em211. doi: 10.29333/ejgm/7872.

- Samocha-Bonet, D., Dixit, V. D., Kahn, C. R., Leibel, R. L., Lin, X., Nieuwdorp, M., Pietiläinen, K. H., Rabasa Lhoret, R., Roden, M., Scherer, P. E., Klein, S., Ravussin, E. (2014). Metabolically healthy and unhealthy
   obese The 2013 stock conference report. *Obesity Reviews*, 15(9), 697–708. doi: 10.1111/obr.12199.
- Soewondo, P., Purnamasari, D., Oemardi, M., Waspadji, S., Soegondo, S. (2010). Prevalence of Metabolic
   Syndrome Using NCEP/ATP III Criteria in Jakarta, Indonesia: The Jakarta Primary Non-communicable
   Disease Risk Factors Surveillance 2006. Acta Med Indones., 42(4), 199–203.
- Sri Rahayu, M. and Maulina, M. (2017). Hubungan Rasio Lingkar Pinggang dan Lingkar Pinggul dengan
   Penyakit Jantung Koroner. Jurnal Aceh Medika, 1(1), 1–10. Available at:
   www.jurnal.abulyatama.ac.id/acehmedika (Accessed: 8 April 2021).
- Srikanthan, K., Feyh, A., Visweshwar, H., Shapiro, J. I., Sodhi, K.(2016). Systematic review of metabolic
   syndrome biomarkers: A panel for early detection, management, and risk stratification in the West
   Virginian population. *International Journal of Medical Sciences*, 13(1), 25–38. doi: 10.7150/ijms.13800.
- Suliga, E., Kozieł, D., Cieśla, E., Głuszek, S. (2015). Association between dietary patterns and metabolic
   syndrome in individuals with normal weight: A cross-sectional study. *Nutrition Journal*, 14(1), p. 55.
   doi: 10.1186/s12937-015-0045-9.
- Sumardiyono, S., Pamungkasari, E. P., Mahendra, A. G., Utomo, O. S., Mahajana, D., Cahyadi, W. R., Ulfia,
  M. (2018). Hubungan Lingkar Pinggang dan Lingkar Panggul dengan Tekanan Darah pada Pasien
  Program Pengelolaan Penyakit Kronis (Prolanis). *Smart Medical Journal*, 1(1), p. 26. doi:
  10.13057/smj.v1i1.24504.
- 412 Susetyowati, S. (2016). Gizi Remaja, in Ilmu Gizi: Teori dan Aplikasi. Jakarta, Indonesia: EGC, 160–164.
- Zhang, Y. X., Wang, Z. X., Chu, Z. H., Zhao, J. S. (2016). Profiles of body mass index and the nutritional
  status among children and adolescents categorized by waist-to-height ratio cut-offs. *International Journal of Cardiology*, 223, 529–533. doi: 10.1016/j.ijcard.2016.07.303.
- Zhou, D., Yang, M., Yuan, Z. P., Zhang, D. D., Liang, L., Wang, C. L., Zhang, S., Zhu, H. H., Lai, M. D., Zhu, Y.
  M. (2014). Waist-to-Height Ratio: A simple, effective and practical screening tool for childhood obesity and metabolic syndrome. *Preventive Medicine*, 67, 35–40. doi: 10.1016/j.ypmed.2014.06.025.
- 419 420

## Tables and Figures – 1 PAGE 1 TABLE/FIGURE. PLACE ALL TABLES AND FIGURES AT THE END OF THE

### 422 MANUSCRIPT BODY AFTER THE REFERENCES

Table 1. Minimum, Maximu	m, Average a	and Standard	Deviation	
Variabel	Minimum	Maximum	Mean	SD
Anthropometric Indicators				
WHtR <mark>(ratio)</mark>	0.37	0.71	0.51	0.07
WHR (ratio <mark>)</mark>	0.67	0.96	0.80	0.06
BMI (kg/m²)	15.81	39.30	24.04	4.72
Sagital Abdominal Diameter (cm)	11.35	25.50	16.79	2.42
Hip Circumference (cm)	80.60	138.45	98.96	9.30
Waist Circumference (cm)	58.00	112.10	79.44	10.78
Metabolic Profiles				
Blood Glucose Levels (mg/dL)	66.00	110.00	92.00	7.59
Trygliceride Levels (mg/dL)	29.00	309.00	88.35	44.68
Cholesterol HDL Levels (mg/dL)	36.00	109.00	61.73	26.43
Sistolic Blood Pressure (mmHg)	84.00	144.00	114.63	11.13
Diastolic Blood Pressure (mmHg)	55.00	178.00	82.40	55.52
cMetS (Score of Metabolic Syndrome)	-7.10	11.93	0.01	2.90

426	Table 2. Anthropometric Overview and Components of		
427			•
428	Characteristics	n	%
429	Anthropometric		
430	Body Mass Index (BMI)		
130 131	Underweight (< 18.5 kg/m <sup>2</sup> )	6	3.7
432	Normal (18.5 – 22.9 kg/m <sup>2</sup> )	71	43.6
	Overweight (23-24.9 kg/m <sup>2</sup> )	28	17.2
33	Obese (≥25.0 kg/m <sup>2</sup> )	58	35.6
34	Waist Height Ratio (WHtR)		
135	Normal (<0.50)	45	27.6
36	Risk (≥0.50)	118	
137	Waist Hip Ratio	110	72.4
138	Normal (<0.85)	127	77.9
139			
440	Central Obesity (≥0.85)	36	22.1
441	Sagital Abdominal Diameter (SAD)		
442	Normal (≤19.3 cm)	143	87.7
443	Risk (>19.3 cm)	20	12.3
	Wait Circumference		
	Normal (<80 cm)	73	44.8
	Obese (≤80 cm)	90	55.2
	Metabolic Profiles		
	Blood Glucose Levels		
	Normal (<110 mg/dL)	136	83.4
	High (≥110 mg/dL)	27	16.6
	Triglycerides		
	Normal (<150 mg/dL)	149	914
	High ( $\geq 150 \text{ mg/dL}$ )	14	8.6
	Cholesterol HDL	14	0.0
	Normal (≥150 mg/dL)	135	82.8
	Low (<150 mg/dL)	28	17.2
	Sistolic Blood Pressure		
	Normal (<130 mg/dL)	136	
	High (≥130 mg/dL)	27	16.6
	Diastolic Blood Pressure		
	Normal (<85 mg/dL)	128	78.5
	High (≥85 mg/dL)	35	21.5
	cMetS (Score of Metabolic Syndrome)		
	Normal (<2.21)	109	66.9
	Risk (≥2.21)	54	33.1
	Metabolic Type		
	Metabolic Unhealthy Normal Weight (MUNW)	17	10.4
	Metabolic Healthy Normal Weight (MHNW)	88	54
	Metabolic Unhealthy Obese Weight (MUOW)	38	23.3
	Metabolic Healthy Obese Weight (MOOW)	20	12.3
		20	12.3

445	mgiycendes, blood sugar, HDL and metabolic syndrome scores)											
Variable	Sistolic	BP	Distolic	BP	TG	Blood Glucose		HDL		cMetS		
	r	р	r	р	r	р	r	р	r	р	r	р
WHtR	0.358	<0.001	0.306	<0.001	0.289	<0.001	0.210	0.007	-0.266	0.001	0.599	<0.001
BMI	0.370	<0.001	0.313	<0.001	0.315	<0.001	0.221	0.005	-0.292	<0.001	0.600	<0.001
SAD	0.352	<0.001	0.284	<0.001	0.278	<0.001	0.191	0.015	-0.264	0.001	0.575	<0.001
WC	0.377	<0.001	0.284	<0.001	0.295	<0.001	0.212	0.005	-0.243	0.002	0.616	<0.001
HC	0.369	<0.001	0.332	<0.001	0.302	<0.001	0.179	0.002	-0.273	<0.001	0.581	<0.001
WHR	0.244	0.002	0.128	0.104	0.194	0.013	0.172	0.028	-0.149	0.048	0.415	<0.001
446												

Table 3.The Relationship between Anthropometric Indicators and Metabolic Profiles (Blood Pressure,
 Triglycerides, Blood Sugar, HDL and metabolic syndrome scores)

		syndrome	scores						
Variable	Sistolic BP								
	<mark>Constant</mark>	USC <sup>a</sup>	<b>р1</b> <sup>ь</sup>	p2 <sup>c</sup>	<sup>d</sup> Adjusted R <sup>2</sup>				
BMI	91.759	0.951	<0.001	<0.001	0.158				
	Blood Gluce	ose Levels							
	Constant	USC <sup>a</sup>	р1 <sup>ь</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>				
BMI	83.454	0.355	0.005	<0.001	0.043				
	HDL								
	Constant	USC <sup>a</sup>	р1 <sup>ь</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>				
BMI	81.429	-0.819	<0.001	<0.001	0.080				
	Triglyceride	Triglycerides							
	Constant	USC <sup>a</sup>	р1 <sup>ь</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>				
WC	-6.614	1.195	<0.001	<0.001	0.078				
	Score of Me	etabolic Synd	Irome						
	Constant	USC <sup>a</sup>	р1 <sup>ь</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>				
WC	-13.163	0.166	<0.001	<0.001	0.375				
<sup>a</sup> Unstandardized				coefficient of					

Table 4. Anthropometric indicators most associated with metabolic components and metabolic

Commented [ASUS23]: Translate in english

Commented [A24R23]: revised

# Anthropometry indicators that are most related to metabolic profiles in female college students

#### 4 Abstract

1 2

3

Metabolic syndrome is not a disease, but is a set of several disorders and causes an increased risk of 5 6 cardiovascular disease and diabetes mellitus complications. Several studies have shown that non-7 invasive approaches such as anthropometric measurements can be used for early detection of 8 metabolic syndrome. This study aims to analyse the anthropometric indicators related to metabolic 9 syndrome in female college students. This cross-sectional study with a total of 163 female college 10 students, aged between 19 and 24 years old. Purposive sampling was used in this study. The 11 independent variables in this study were the Waist-to-Height Ratio (WHR), Waist-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference. The dependent 12 13 variable in this study is the metabolic syndrome component that has been converted into a metabolic 14 syndrome score (cMetS). The analysis results showed that all anthropometric indicators, namely 15 WHtR, BMI, SAD, waist circumference, hip circumference and WHR have a strong positive 16 relationship with the metabolic syndrome score (p<0.001). BMI was the anthropometric indicator 17 that is most associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood 18 sugar (p<0.05), and HDL (p<0.001). Waist circumference was the anthropometric indicator that is 19 most associated with triglycerides and metabolic syndrome score (p<0.001). Metabolic syndrome in 20 female college students can be identified using anthropometric measurements, one of which is BMI 21 and WHR which are very easy to measure and efficient. BMI and WHR have the strongest relationship 22 and can be used to detect early risk of metabolic syndrome in female college students.

23 Keywords: Adolescent; Anthropometric Indicator; Female; Metabolic Profile; Metabolic Syndrome.

- 24
- 25

#### 26 1. Introduction

27 Metabolic syndrome is a set of body metabolic disorders such as dyslipidaemia, hyperglycaemia, 28 hypertension, and central obesity (Srikanthan *et al.*, 2016; Devi *et al.*, 2017; Christijani, 2019). 29 Metabolic syndrome is not a disease, but is a set of several disorders and causes an increased risk of 30 cardiovascular disease and diabetes mellitus complications. Some epidemiological studies have 31 shown that metabolic syndrome doubles the risk of cardiovascular diseases (Sri Rahayu and Maulina, 32 2017).

Indonesia as a developing country cannot be separated from the existing nutritional problems in the world, including the incidence of obesity and metabolic syndrome. Several studies found that the prevalence of metabolic syndrome keeps increasing every year. A study in China showed the prevalence of metabolic syndrome in adults was 24.2% (Li *et al.*, 2018). Another study indicated that the prevalence of metabolic syndrome in Indonesia was 21.66% (Herningtyas and Ng, 2019). In recent studies metabolic syndrome can be assessed using the continuous value of metabolic syndrome (cMets) or the metabolic syndrome score recommended by the American Diabetic Association of Commented [acer1]: Include author information

Commented [A2]: revised

Diabetes. The metabolic syndrome score is a z-score resulting from the assessment of all components
 of the metabolic syndrome (Pratiwi, *et al.*, 2017). The advantages of using cMetS are (1) reducing
 dichotomization factors because cardiovascular disease is a progression of several components of
 the metabolic syndrome, (2) cMetS is more sensitive and less error-prone than categoric metabolic
 syndrome assessments, (3) increasing the statistical power (Okosun, Lyn, *et al.*, 2010).

45 Central obesity is one of the components of metabolic syndrome parameters. Central obesity is 46 associated with increased blood pressure, serum triglycerides, decreased HDL, and glucose 47 intolerance. Based on the National Basic Health Research (Riskesdas) in 2018, the prevalence of 48 obesity in adults was 21.8%, and the prevalence of central obesity at age of more than 15 years 49 increased from 26.6% in 2013 to 31% in 2018 (Badan Penelitian dan Pengembangan Kesehatan, 50 2018). Obesity is closely related to degenerative diseases. The Riskesdas 2018 showed that the 51 prevalence of stroke, diabetes mellitus, heart disease, and hypertension is higher in women than 52 men.

53 Several studies have shown that non-invasive approaches such as anthropometric measurements 54 can be used for early detection of metabolic syndrome (Pratiwi, et al., 2017). Anthropometric 55 measurements are described as the measurements of body dimensions and body composition to 56 assess nutritional status. The advantages of anthropometric measurements are relatively fast and 57 easy, as it can be performed using portable and calibrated instruments with standardized methods 58 (Rokhmah, et al., 2015). Some anthropometric measurements that can be used for early detection 59 of metabolic syndrome are Waist-to-Height Ratio (WHtR), waist-to-hip ratio (WHR), hip 60 circumference, Body Mass Index (BMI), Sagital Abdominal Diameter (SAD).

61 One of the anthropometric measurements which can be a parameter for central obesity is the ratio of waist circumference to height (WHtR). The instruments used in the measurement are 62 63 microtoise and measuring tape so that it takes longer time. Studies on waist circumference have been 64 shown to have a strong correlation with abdominal fat deposits (Zhou et al., 2014). The distribution 65 of abdominal adipose tissue (central obesity) in adults is associated with a component of the metabolic syndrome (Rodea-Montero, et al., 2014). A study on adult subjects has shown that people 66 who have the same waist circumference but are shorter in height have a greater risk of developing 67 68 metabolic syndrome than taller people (Zhou et al., 2014). Therefore, WHtR can be used as a simple 69 and effective anthropometric index to identify the metabolic risk associated with obesity (Rodea-70 Montero, et al., 2014).

71 The waist-to-hip ratio (WHR) is a measurement that may indicate central obesity (Karimah, 2018). 72 The higher the WHR value, the higher the risk level for several metabolic diseases. The waist-to-hip 73 ratio is calculated by dividing the measurement of the waist circumference by the circumference of the hip. The cut-off points for WHR are  $\geq$ 1.0 for men and  $\geq$ 0.85 for women (Rokhmah, et al., 2015). 74 75 Individuals with a high waist and hip circumference will also have a higher distribution of fat in their 76 abdominal area. Irregular fats distribution in the abdominal area indirectly causes higher triglyceride 77 levels circulating in the blood, which will affect blood pressure (Sumardiyono et al., 2018). WHR 78 measurement is more sensitive in assessing the distribution of fat in the body, especially in the 79 abdominal. This measurement is three times better than BMI in reflecting the presence of harmful 80 fats in the abdominal. Measurement of waist circumference is performed by determining the lower 81 part of arcus costae and crista iliaca (Sri Rahayu and Maulina, 2017).

82 Body Mass Index (BMI) is a practical and easy measurement to perform, but it cannot distinguish 83 between fat mass, bone mass and muscle mass. BMI is calculated as body weight (kg) / height 84 squared (m<sup>2</sup>) (Okura *et al.*, 2018). BMI can be used as the first measurement before any other 85 anthropometric measurements.

Sagittal Abdominal Diameter (SAD) or the height of the abdomen while the subjects are in lying 86 87 position. This anthropometric measurement has not been widely used to measure fat tissue in the 88 abdominal area. SAD measurements using computed tomography or magnetic resonance imaging, 89 and are associated with components of metabolic syndrome. The measurements of SAD are taken 90 when the subject is lying down on the examination table with naked upper body. SAD is related to 91 central obesity in individuals with obese and normal nutritional status. Furthermore, SAD is 92 associated with diabetes mellitus and a predictor of cardiovascular disease incidence, even when SAD 93 is measured in standing position (Pajunen et al., 2013). Based on the above mentioned problems, our 94 study aims to analyse the anthropometric indicators related to metabolic syndrome in female college 95 students.

#### 96

104 105

#### 97 2. Materials and methods

#### 98 2.1 Design, location, and time

A cross-sectional study design and this research wasc onducted from March to July 2020.
 Anthropometric and biochemical data were collected at the Cito Laboratory, Banyumanik Semarang
 with health protocols applied. This study was approved by the Medical/Health Research Bioethics
 Commission, Faculty of Medicine, Sultan Agung Islamic University Semarang with Number No.296 /IX
 /2020 /Bioethical Commission.

#### 2.2 Samplings

106 This study was conducted during the SARS-CoV-2 outbreak, which later was named COVID-19 by 107 the WHO, so the registration for study participants was done online. Purposive sampling was used in 108 this study and the total number of subjects required was 163. Samples are selected based on 109 inclusion criteria, such as willing to be research subjects, female college students in Semarang City, aged 19-24 years in Semarang, not consuming alcohol, not smoking, willing to be a study participant 110 111 and willing to follow a series of study instructions. Exclusion criteria are subjects who withdraw and 112 those who are ill during the research study. Based on the exclusion criteria mentioned, no subjects 113 <mark>are included in the exclusion</mark> criteria<mark>.</mark> Subjects were asked to fill in personal data using a Google form; 114 and eligible subjects will be contacted by the researchers to plan a direct meeting.

115The health protocol applied during the anthropometric and biochemical data collection process,116consist of the subject filled out a Covid sign/symptom screening questionnaire, the subject was117checked for temperature, washed his hands before entering the room, the distance between subjects118was at least 1 meter, the subject and researcher used a mask and face shield. Researchers used gloves119and protective clothing. During the study, hand sanitizers were provided, anthropometric tools that120were on the subject's skin were wiped with alcohol.121

122 2.3 Data collected

123The independent variables in this study were the Waist-to-Height Ratio (WHtR), Waist-Hip Ratio124(WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference. Weight

Commented [ASUS3]: space

Commented [A4R3]: revised

Commented [A5]: revised

125and height data were obtained through direct measurements using a digital stamp scale GEA brand126with an accuracy of 0.1 kg and microtoise with an accuracy of 0.1 cm.127circumference was measured using a measuring tape (Medline) to the nearest 1 mm and abdominal128height was measured using the Abawerk Schaffenburg abdominal calliper to the nearest 1 mm. SAD129measurements were performed with the subject in a supine position on a flat surface with both knees130forming an angle of 90° (Firouzi et al., 2018).

131The cut-off point used in this study refers to previous studies because it had been adjusted for the132Asian race (Rose *et al.*, 2020). Each anthropometric measurement is stated as "at risk" if the133individuals have  $\geq 0.50$  for WHtR (Zhang *et al.*, 2016),  $\geq 0.85$  for WHR (Rokhmah, *et al.*, 2015), > 19.3134for Sagital Abdominal Diameter (SAD) (Dieny *et al.*, 2020), and have the normal to overweight135BMI (18.5 - 25 kg/m²) or obese BMI ( $\geq 25.0$  kg/m²) (Susetyowati, 2016).

136 The dependent variable in this study is the metabolic syndrome component that has been 137 converted into a metabolic syndrome score (cMetS) with the cut-off point on cMetS> 2.21 (Rose et 138 al., 2020). The guidelines for metabolic syndrome in this study are taken from the National 139 Cholesterol Education Program-Adult Treatment Panel (NCEP-ATP III) 2005 which has been 140 frequently used in Indonesia. There are 5 parameters to assess metabolic syndrome: (1) fasting blood 141 glucose levels ≥110 mg/dL, (2) triglyceride levels ≥150 mg/dL (3) HDL cholesterol levels <50 mg/dL, 142 (4) central obesity in women with waist circumference ≥80 cm, and (5) systolic and diastolic blood 143 pressures  $\geq$ 130 mmHg and  $\geq$ 85 mmHg, respectively (Soewondo *et al.*, 2010). The calculation of the 144 metabolic syndrome score (cMetS) was done in the following steps: (1) after measuring all 145 parameters of the metabolic syndrome, standardisation was carried out to obtain a Z-score; (2) the 146 blood pressure must be converted into Mean Arterial Blood (MAP) by dividing the difference 147 between systolic and diastolic blood pressure by three and summed with the diastolic blood 148 pressure; (3) the HDL cholesterol standardisation results were multiplied by (-1) because the 149 parameter was inversely related to the risk of metabolic syndrome; (4) All Z-scores were added to 150 obtain the cMetS values; (5) The final step was to compare the cMetS values with the cut-off point 151 of ≥2,21 (Eisenmann et al., 2010; Okosun, Boltri, et al., 2010; Rose et al., 2020). The subjects were 152 instructed to do fasting for at least 8 hours; only drinking water was permitted.

Other than the cMetS score, metabolic syndrome risk can also be assessed from the classification of metabolic types. This classification combines the internal and external signs of the body such as biochemical parameters, the ratio of subcutaneous fat to abdominal fat, and blood pressure (Prybyla O, 2020). The main phenotypes that reflect the possible combination of metabolic profile and the degree of obesity are metabolic healthy obese weight, metabolic healthy normal weight, metabolic unhealthy normal weight, and metabolic unhealthy normal weight.

#### 2.4 Data analysis

160

All data were analyzed using computer programs and statistical analyses were performed using SPSS Statistical software version 22. Univariate analysis was used to describe subjects characteristic. The distribution of data for normality was assessed using the Kolmogorov Smirnov test before statistical. The relationship of anthropometric indicators with metabolic profile (Blood Pressure, Triglycerides, Blood Sugar, HDL and metabolic syndrome scores) were determined using the Person correlation test. Furthermore, Anthropometric indicators that are most related to the metabolic component and metabolic syndrome score were analyzed using the Multiple Linear Regression test for Commented [ASUS6]: For what?

Commented [A7R6]: revised

Commented [A8]: revised

#### 169 3. Results and Discussion

170The subject characteristics measured in female student aged 19-24 years include age,171anthropometric indicators, and metabolic syndromes. Table 1 shows the characteristics of the study172subjects. The mean of WHtR value in this study was 0.51. Meanwhile, the mean of WHR was 0.80; the173mean of BMI was 24.04 kg/m²; the mean of SAD was 16.79 cm; and the mean of waist circumference174was 79.44 cm.

175 Table 2 shows various nutritional status of the subjects based on BMI. We found that 43.6% of the 176 subjects had normal BMI, 17.2% were overweight and 35.6% were obese. Based on the WHtR 177 anthropometric indicator, 72.4% of subjects were at risk of having obesity; based on WHR, 22.1% had 178 central obesity; based on BMI, 35.6% were obese; based on SAD 12.3% of the subjects were at risk; and based on waist circumference 55.2% had central obesity. According to the metabolic profile that 179 180 was assessed, 16.6% had high Fasting Blood Glucose levels, 8.6% had hypertriglycerides, 17.2% had 181 low HDL, 16.6% had high systolic blood pressure, and 21.5% had high diastolic blood pressure. In 182 addition, we found 33.1% of the subjects had high metabolic syndrome (cMetS) scores. This 183 proportion was similar to the assessment based on the metabolic type of unhealthy subjects (subjects 184 who had  $\geq$  3 risk factors of the metabolic profile), which was 33.7%. Moreover, two subjects had five 185 risk factors: abdominal obesity, hypertension, hyperglycaemia, hypertriglycerides, and low HDL.

186 The objective of this study was to determine the anthropometric indicators associated with 187 metabolic syndromes in female students. The study included 163 female students aged 19-24 years. 188 The students are in their late adolescents who begin to have an independent life. Inappropriate and 189 unhealthy eating behaviours will have an impact on the student's nutritional status. Excessive 190 nutritional status and obesity will affect student's body metabolism. Based on the study results, 33.1% 191 of the subjects had a high metabolic syndrome (cMetS) score. In line with the previous study 192 conducted in 2019 on 18-to-21-year-old students at Universitas Diponegoro, 20% of the subjects had 193 high cMetS (Rose et al., 2020). Meanwhile, a study conducted by Pratiwi et al in 2017 using secondary 194 data from the National Basic Health Research 2013 found that 19.98% of adolescents aged 15-24 years 195 had high cMetS (Pratiwi, et al., 2017). Therefore, we conclude that there is a trend of Metabolic 196 Syndrome Score (cMetS) among young women in Semarang.

197 The assessment of metabolic syndrome using a continuous type (scoring) rather than using a 198 dichotomy or binary ("yes" and "no") is recommended (Christijani, 2019). An adolescent can be 199 diagnosed with metabolic syndrome if their Metabolic Syndrome Score (cMetS) >2.21 (Pratiwi, et al., 200 2017). Anthropometric indicators used in this study are Waist and Height Ratio (WHtR), Waist-to-Hip 201 Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and Waist Circumference. 202 Based on the correlation analyses, all anthropometric indicators have a significant positive 203 relationship with the Metabolic Syndrome Score (cMetS). Furthermore, the multivariate analyses show that the anthropometric indicators of BMI and WHR are strongly associated with cMetS. 204

205 If we are considering metabolic type based on nutritional status (subjects with non-obese BMI 206 (<25kg/m<sup>2</sup>) with metabolic healthy and metabolic unhealthy and subjects with obese BMI (>25kg/m<sup>2</sup>) 207 with metabolic healthy and metabolic unhealthy), subjects are categorised as metabolic unhealthy 208 (experiencing metabolic syndrome) if they fulfil ≥ 3 risk factors including high waist circumference, blood pressure, GDP and triglyceride levels, and low HDL levels. Based on these criteria, we found that 209 210 10.4% of the subjects had metabolic unhealthy normal weight (MUNW) and 23.3% of the subjects had 211 metabolic unhealthy obesity weight (MUOW). In non-obese subjects, 54% of them were metabolic 212 healthy. Our study also shows that 10.4% of the subjects were classified as metabolic unhealthy Commented [A9]: revised

213 normal weight (MUNW). The subjects' BMI in this category is in the normal range but has a high 214 percentage of body fat that makes them at high risk of developing metabolic disorders (Eckel et al., 215 2015; Suliga et al., 2015). Several recent cohort studies have shown a greater risk of type II diabetes mellitus in individuals with MUNW compared to individuals with MHNW (Ärnlöv et al., 2011; Hadaegh 216 217 et al., 2011; Aung et al., 2014; Jung et al., 2014; Hinnouho et al., 2015). Other studies have shown that 218 women with the MUNW type have a long-term impact of an increased risk of cardiovascular diseases 219 such as higher blood pressure, triglyceride and glucose levels as well as lower levels of adiponectin, 220 HDL, and LDL compared to women with the MHNW type (Kim et al., 2013).

In this study, 23.3% of the subjects belonged to the Metabolic Unhealthy Obese Weight (MUOW)
 type. Subjects with this metabolic type have an obese BMI and have a high risk of developing
 metabolic disorders. A study conducted in Japan on 29,564 subjects showed that individuals with
 MUOW had a greater risk of developing type II diabetes mellitus compared to individuals with MHOW
 (Heianza *et al.*, 2015).

226 We also found that 12.3% of the subjects were categorized as metabolic healthy obese weight 227 (MHOW). Individuals in this metabolic type have an obese BMI but do not show any metabolic risks. 228 Given the impact of obesity in relation to the risk of metabolic diseases, various studies have been 229 conducted to examine the long-term effects of MHOW. Individuals with MHOW had a different fat 230 distribution pattern (less ectopic and visceral fat), and lower inflammatory markers (Samocha-Bonet 231 et al., 2014). Other studies also have shown that women with MHOW had lower blood pressure, 232 triglyceride levels, and glucose levels, but higher levels of HDL, adiponectin, and LDL compared to 233 women with MUNW (Kim et al., 2013). This condition was associated with good diet quality in 234 individuals with MHOW. Based on National Health and Nutrition Examination Surveys (NHANES) 235 data, Camhi et al. (2015) examined the quality of diet in obese subjects, and found that adolescents 236 and adult women with the MHOW metabolic type had higher diet quality scores due to high intake 237 of fruit, whole grains, meat, and nuts.

238 Table 3 and Table 4 show the results of statistical analyses on anthropometric indicators related 239 to the metabolic syndromes. Table 3 shows the bivariate statistical analysis using the Pearson 240 correlation test. The analysis results showed that all anthropometric indicators, namely WHtR, BMI, SAD, waist circumference, hip circumference and WHR have a strong positive relationship with the 241 242 metabolic syndrome score (p<0.001), which means that the higher the anthropometric value, the 243 higher the metabolic syndrome score. In addition, the analysis on the relationship between 244 anthropometric indicators and each metabolic profile revealed that almost all of the independent 245 variables (WHtR, waist and hip circumference, WHR, BMI, and SAD) were associated with each 246 metabolic profile, such as baseline systolic pressure, diastolic blood pressure, triglyceride levels, blood 247 sugar levels, and HDL. Only WHR that was not associated with diastolic blood pressure (p>0.005).

248 Table 4 shows the results of the analysis using multiple linear regression to determine 249 anthropometric indicators that are most associated with each metabolic profile and metabolic 250 syndrome score. The results showed that BMI was the anthropometric indicator that is most 251 associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood sugar (p<0.05), and HDL (p <0.001). In addition, waist circumference was the anthropometric indicator that 252 is most associated with triglycerides and metabolic syndrome score (p<0.001). Based on the Adjusted 253 254 R<sup>2</sup> value on the metabolic syndrome score, we found that 37.5% of the metabolic syndrome score was 255 related to anthropometric indicators, such as WHtR, waist and hip circumference, WHR, BMI, and 256 SAD. The rest may be influenced by other variables that are not included in this study.

Commented [A10]: revised

257 The correlation test results indicated that all anthropometric indicators had a positive 258 relationship with the metabolic syndrome scores with p <0.001. Meanwhile, the regression analyses 259 show that BMI and WHR were inversely related to cMetS. This is in line with research who stated that 260 an increase in the WHR value could be associated with the risk of metabolic syndrome in children 261 and adolescents in Florida (Moore et al., 2015). Another study stated that there was a strong 262 relationship between overweight and obese adolescents with metabolic syndrome (Al-Bachir and 263 Bakir, 2017). Furthermore, a study on the adolescents in South Africa found that central obesity as 264 measured by the hip circumference could lead to an increased risk of cardiovascular diseases and 265 death. Therefore, hip circumference and waist circumference can be used to predict the risk of 266 cardiovascular diseases and death in the future (Cameron et al., 2012).

267 Body Mass Index (BMI) is the most widely used indicator of measurement in epidemiological 268 studies and is used as a substitute for evaluating body composition. However, BMI cannot distinguish 269 fat from fat mass and lean mass, and it fails to show the presence of adipose and body fat distribution 270 (Ofer et al., 2019; Leone et al., 2020). However, the BMI cut-offs for metabolic syndrome has not yet 271 been determined (Ofer et al., 2019). Obesity in adolescents is generally assessed using a BMI of ≥25.0 272 kg/m<sup>2</sup>. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m<sup>2</sup>) and 273 obesity (≥25.0 kg/m<sup>2</sup>), and we found that 35.6% of the subjects were obese. The finding is in line with 274 the research on the subject of students at Universitas Diponegoro aged 18-21 years. They found that 275 40% of their study population had obesity level I and 36.3% had obesity level II (Rose et al., 2020).

276 Abdominal obesity is often assessed to determine a metabolic syndrome in people. One of the 277 indicators used to measure abdominal obesity is the Waist-to-Hip Ratio (WHR) which is calculated by 278 dividing the waist circumference and the hip circumference. Measurement of waist circumference is 279 more sensitive in assessing the distribution of body fat in the abdominal wall, which is also a 280 component in the metabolic syndrome. The limit of the WHR value for female is  $\geq$  0.85 (Rokhmah, et 281 al., 2015). This study shows that every 1% increase in the WHR value will increase the cMetS value 282 by 10.411. Hip circumference is also an indicator that has a strong correlation with cMetS, but many 283 studies have used it as a ratio along with waist circumference for assessing a person's central obesity 284 status.

#### 286 4. Conclusion

287 Metabolic syndrome in female students can be identified using anthropometric measurements, one 288 of which is BMI and WHR which are very easy to measure and efficient. BMI and WHR have the 289 strongest relationship and can be used to detect early risk of metabolic syndrome in female college 290 students.

#### 291

285

#### 292 Conflict of interest - Disclose any potential conflict of interest appropriately.

293 The authors declare no conflict of interest.

#### 294 Acknowledgments

- 295 The authors would like to thank all the subjects who participated in this study. We would also like to
- express our gratitude to The Ministry of Research, Technology and Higher Education, Indonesia" wasfunded by the "Hibah Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) 2019.

Commented [A11]: revised

Commented [A12]: revised

#### 298 References

- Al-Bachir, M. and Bakir, M. A. (2017). Predictive value of body mass index to metabolic syndrome risk
   factors in Syrian adolescents. *Journal of Medical Case Reports*, 11(1). doi: 10.1186/s13256-017-1315 2.
- Ärnlöv, J., Sundström, J., Ingelsson, E. and Lind, L. (2011). Impact of BMI and the metabolic syndrome on
   the risk of diabetes in middle-aged men. *Diabetes Care*, 34(1), 61–65. doi: 10.2337/dc10-0955.
- Aung, K. K., Lorenzo, C., Hinojosa, M. A. and Haffner, S. M. (2014). Risk of developing diabetes and
   cardiovascular disease in metabolically unhealthy normal-weight and metabolically healthy obese
   individuals. *Journal of Clinical Endocrinology and Metabolism*, 99(2), 462–468. doi: 10.1210/jc.2013 2832.
- Badan Penelitian dan Pengembangan Kesehatan. (2018). *Riset Kesehatan Dasar (RISKESDAS) 2018.* Jakarta, Indonesia.
- Cameron, A. J., Magliano, D. J., Shaw, J. E., Zimmet, P. Z., Carstensen, B., Alberti, K. G. M. M., Tuomilehto,
   J., Barr, E. L. M., Pauvaday, V. K., Kowlessur, S. and Söderberg, S. (2012). The influence of hip
   circumference on the relationship between abdominal obesity and mortality. *International Journal of Epidemiology*, 41(2), 484–494. doi: 10.1093/ije/dyr198.
- Camhi, S. M., Whitney Evans, E., Hayman, L. L., Lichtenstein, A. H. and Must, A. (2015). Healthy eating
   index and metabolically healthy obesity in U.S. adolescents and adults. *Preventive Medicine*, 77, 23–
   27. doi: 10.1016/j.ypmed.2015.04.023.
- Christijani, R. (2019). Determination of Diagnosis of Metabolic Syndrome based on Assessment of
   Metabolic Syndrome and NCEP ATP-III Score in Adolescent. *The Journal of Nutrition and Food Research*,
   42(1), 21–28. doi: 10.22435/pgm.v42i1.2418.
- Devi, R., Manhas, S., Prasad, S., Sharma, S., Bhaskar, N. and Mahajan, S. (2017). Short Review of Metabolic
   Syndrome. *International Journal of Research and Review*, 4(2), p. 29.
- Dieny, F. F., Setyaningsih, R. F., Fitranti, D. Y., Jauharany, F. F., Putra, Y. D. and Tsani, A. F. A. (2020).
   Abdominal diameter profiles have relationship with insulin resistance in obese female adolescents.
   *Electronic Journal of General Medicine*, 17(5), p. em219. doi: 10.29333/ejgm/7882.
- Eckel, N., Mühlenbruch, K., Meidtner, K., Boeing, H., Stefan, N. and Schulze, M. B. (2015). Characterization
   of metabolically unhealthy normal-weight individuals: Risk factors and their associations with type 2
   diabetes. *Metabolism: Clinical and Experimental*, 64(8), 862–871. doi: 10.1016/j.metabol.2015.03.009.
- Eisenmann, J. C., Laurson, K. R., Dubose, K. D., Smith, B. K. and Donnelly, J. E. (2010). Construct validity of
   a continuous metabolic syndrome score in children. *Diabetology and Metabolic Syndrome*, 2(1). doi:
   10.1186/1758-5996-2-8.
- Firouzi, S. A., Tucker, L. A., LeCheminant, J. D. and Bailey, B. W. (2018). Sagittal abdominal diameter, waist
   circumference, and BMI as predictors of multiple measures of glucose metabolism: An NHANES
   investigation of US adults. *Journal of Diabetes Research*, 2018, 1–14. doi: 10.1155/2018/3604108.
- Hadaegh, F., Bozorgmanesh, M., Safarkhani, M., Khalili, D. and Azizi, F. (2011). Predictability of body mass
   index for diabetes: Affected by the presence of metabolic syndrome?. *BMC Public Health*, 11(1), p. 383.
   doi: 10.1186/1471-2458-11-383.
- Heianza, Y., Kato, K., Kodama, S., Ohara, N., Suzuki, A., Tanaka, S., Hanyu, O., Sato, K. and Sone, H. (2015).
   Risk of the development of Type 2 diabetes in relation to overall obesity, abdominal obesity and the
   clustering of metabolic abnormalities in Japanese individuals: Does metabolically healthy overweight
   really exist? The Niigata Wellness Study. *Diabetic Medicine*, 32(5), 665–672. doi: 10.1111/dme.12646.
- Herningtyas, E. H. and Ng, T. S. (2019). Prevalence and distribution of metabolic syndrome and its
   components among provinces and ethnic groups in Indonesia. *BMC Public Health*, 19(1), p. 377. doi:
   10.1186/s12889-019-6711-7.
- 344 Hinnouho, G. M., Czernichow, S., Dugravot, A., Nabi, H., Brunner, E. J., Kivimaki, M. and Singh-Manoux, A.

345	(2015). Metabolically healthy obesity and the risk of cardiovascular disease and type 2 diabetes: The
346	Whitehall II cohort study. European Heart Journal, 36(9), 551–559. doi: 10.1093/eurheartj/ehu123.
347	Jung, H. S., Chang, Y., Eun, Y. K., Kim, C. W., Choi, E. S., Kwon, M. J., Cho, J., Zhang, Y., Rampal, S., Zhao, D.,
348	Soo, K. H., Shin, H., Guallar, E. and Ryu, S. (2014). Impact of body mass index, metabolic health and
349	weight change on incident diabetes in a Korean population. Obesity, 22(8), 1880–1887. doi:
350	10.1002/oby.20751.
351	Karimah, M. (2018). Rasio Lingkar Pinggal-panggul Memiliki Hubungan Paling Kuat dengan Kadar Glukosa
352	Darah'. Jurnal Berkala Epidemiologi, 6(3), 219–226.
353	Kim, M., Paik, J. K., Kang, R., Kim, S. Y., Lee, S. H. and Lee, J. H. (2013). Increased oxidative stress in normal-
354	weight postmenopausal women with metabolic syndrome compared with metabolically healthy
355	overweight/obese individuals. <i>Metabolism: Clinical and Experimental</i> , 62(4), 554–560. doi:
356	10.1016/j.metabol.2012.10.006.
357	Leone, A. et al. (2020). Evaluation of different adiposity indices and association with metabolic syndrome Commented [acer13]: please list all the authors
358	risk in obese children: Is there a winner?. International Journal of Molecular Sciences, 21(11), p. 4083.
359	doi: 10.3390/ijms21114083.
360	Li, Y. et al. (2018). Metabolic syndrome prevalence and its risk factors among adults in China: A nationally
361	representative cross-sectional study. PLoS ONE, 13(6), p. e0199293. doi:
362	10.1371/journal.pone.0199293.
363	Moore, L. M. et al. (2015). Analysis of Pediatric Waist to Hip Ratio Relationship to Metabolic Syndrome Commented [acer15]: list all authors
364	Markers. Journal of Pediatric Health Care, 29(4), 319–324. doi: 10.1016/j.pedhc.2014.12.003.
365	Ofer, K. <i>et al.</i> (2019). Normal body mass index (BMI) can rule out metabolic syndrome: An Israeli cohort
366	study. <i>Medicine</i> , 98(9), p. e14712. doi: 10.1097/MD.00000000014712.
367	Okosun, I. S., Boltri, J. M., et al. (2010). Continuous metabolic syndrome risk score, body mass index
368	percentile, and leisure time physical activity in American children. Journal of Clinical Hypertension,
369	12(8), 636–644. doi: 10.1111/j.1751-7176.2010.00338.x.
370	Okosun, I. S., Lyn, R., <i>et al.</i> (2010). Validity of a Continuous Metabolic Risk Score as an Index for Modeling
371	Metabolic Syndrome in Adolescents. Annals of Epidemiology, 20(11), 843–851. doi:
372	10.1016/i.annepidem.2010.08.001.
373	Okura, T. et al. (2018). Body mass index $\geq$ 23 is a risk factor for insulin resistance and diabetes in Japanese
374	people: A brief report. <i>PLOS ONE</i> . Edited by P. Bjornstad, 13(7), p. e0201052. doi:
375	10.1371/journal.pone.0201052.
376	Pajunen, P. et al. (2013). Sagittal abdominal diameter as a new predictor for incident diabetes. Diabetes
377	Care, 36(2), 283–288. doi: 10.2337/dc11-2451.
378	Pratiwi, Z. A., Hasanbasri, M. and Huriyati, E. (2017). Penentuan titik potong skor sindroma metabolik
379	remaja dan penilaian validitas diagnostik parameter antropometri: analisis Riskesdas 2013. Jurnal Gizi
380	Klinik Indonesia, 14(2), p. 80. doi: 10.22146/ijcn.25590.
381	Prybyla, O. (2020). Metabolic phenotyping: is it so important?. Journal of Cognitive Neuropsychology.
382	iMedPub., 4(1), 1-3.
383	Rodea-Montero, E. R., Evia-Viscarra, M. L. and Apolinar-Jiménez, E. (2014). Waist-to-height ratio is a better
384	anthropometric index than waist circumference and BMI in predicting metabolic syndrome among
385	obese mexican adolescents. International Journal of Endocrinology, 2014, 195407. doi:
386	10.1155/2014/195407.
387	Rokhmah, F. D., Handayani, D. and Al-Rasyid, H. (2015). Korelasi lingkar pinggang dan rasio lingkar
388	pinggang-panggul terhadap kadar glukosa plasma menggunakan tes toleransi glukosa oral. Jurnal Gizi
389	Klinik Indonesia, 12(1), 28–35. doi: 10.22146/ijcn.22425.
390	
391	Rose, S., Dieny, F. F., Nuryanto, N., Isani, A. F. A. (2020). The correlation between waist-to-height ratio (wHtR) and second to fourth digit ratio (2D:4D) with an increase in metabolic syndrome scores in obese
391	adolescent girls. <i>Electronic Journal of General Medicine</i> , 17(3), p. em211. doi: 10.29333/ejgm/7872.
372	

- Samocha-Bonet, D., Dixit, V. D., Kahn, C. R., Leibel, R. L., Lin, X., Nieuwdorp, M., Pietiläinen, K. H., Rabasa Lhoret, R., Roden, M., Scherer, P. E., Klein, S., Ravussin, E. (2014). Metabolically healthy and unhealthy
   obese The 2013 stock conference report. *Obesity Reviews*, 15(9), 697–708. doi: 10.1111/obr.12199.
- Soewondo, P., Purnamasari, D., Oemardi, M., Waspadji, S., Soegondo, S. (2010). Prevalence of Metabolic
   Syndrome Using NCEP/ATP III Criteria in Jakarta, Indonesia: The Jakarta Primary Non-communicable
- 398 Disease Risk Factors Surveillance 2006. Acta Med Indones, 42(4), 199–203.
- Sri Rahayu, M. and Maulina, M. (2017). Hubungan Rasio Lingkar Pinggang dan Lingkar Pinggul dengan
   Penyakit Jantung Koroner. Jurnal Aceh Medika, 1(1), 1–10. Available at:
   www.jurnal.abulyatama.ac.id/acehmedika (Accessed: 8 April 2021).
- Srikanthan, K., Feyh, A., Visweshwar, H., Shapiro, J. I., Sodhi, K.(2016). Systematic review of metabolic
   syndrome biomarkers: A panel for early detection, management, and risk stratification in the West
   Virginian population. *International Journal of Medical Sciences*, 13(1), 25–38. doi: 10.7150/ijms.13800.
- Suliga, E., Kozieł, D., Cieśla, E., Głuszek, S. (2015). Association between dietary patterns and metabolic
  syndrome in individuals with normal weight: A cross-sectional study. *Nutrition Journal*, 14(1), p. 55.
  doi: 10.1186/s12937-015-0045-9.
- Sumardiyono, S., Pamungkasari, E. P., Mahendra, A. G., Utomo, O. S., Mahajana, D., Cahyadi, W. R., Ulfia,
  M. (2018). Hubungan Lingkar Pinggang dan Lingkar Panggul dengan Tekanan Darah pada Pasien
  Program Pengelolaan Penyakit Kronis (Prolanis). *Smart Medical Journal*, 1(1), p. 26. doi:
  10.13057/smj.v1i1.24504.
- 412 Susetyowati, S. (2016). Gizi Remaja, in Ilmu Gizi: Teori dan Aplikasi. Jakarta, Indonesia: EGC, 160–164.
- Zhang, Y. X., Wang, Z. X., Chu, Z. H., Zhao, J. S. (2016). Profiles of body mass index and the nutritional
  status among children and adolescents categorized by waist-to-height ratio cut-offs. *International Journal of Cardiology*, 223, 529–533. doi: 10.1016/j.ijcard.2016.07.303.
- Zhou, D., Yang, M., Yuan, Z. P., Zhang, D. D., Liang, L., Wang, C. L., Zhang, S., Zhu, H. H., Lai, M. D., Zhu, Y.
   M. (2014). Waist-to-Height Ratio: A simple, effective and practical screening tool for childhood obesity
   and metabolic syndrome. *Preventive Medicine*, 67, 35–40. doi: 10.1016/j.ypmed.2014.06.025.
- 419 420

Commented [acer18]: Journal names should be written in full Apply to all references

## Tables and Figures – 1 PAGE 1 TABLE/FIGURE. PLACE ALL TABLES AND FIGURES AT THE END OF THE

### 422 MANUSCRIPT BODY AFTER THE REFERENCES

Table 1. Minimum, Maximu	m, Average a	and Standard	Deviation		
Variabel	Minimum	Maximum	Mean	SD	-
Anthropometric Indicators					-
WHtR <mark>(ratio)</mark>	0.37	0.71	0.51	0.07	
<mark>WHR (</mark> ratio <mark>)</mark>	0.67	0.96	0.80	0.06	
BMI (kg/m²)	15.81	39.30	24.04	4.72	
Sagital Abdominal Diameter (cm)	11.35	25.50	16.79	2.42	
Hip Circumference (cm)	80.60	138.45	98.96	9.30	
Waist Circumference (cm)	58.00	112.10	79.44	10.78	
Metabolic Profiles					
Blood Glucose Levels (mg/dL)	66.00	110.00	92.00	7.59	
Trygliceride Levels (mg/dL)	29.00	309.00	88.35	44.68	
Cholesterol HDL Levels (mg/dL)	36.00	109.00	61.73	26.43	
Sistolic Blood Pressure (mmHg)	84.00	144.00	114.63	11.13	
Diastolic Blood Pressure (mmHg)	55.00	178.00	82.40	55.52	
cMetS (Score of Metabolic Syndrome)	-7.10	11.93	0.01	2.90	

426	Table 2. Anthropometric Overview and Components of	Metabo	olic Syndro
427	Characteristics	n	%
428	Anthropometric		
429	Body Mass Index (BMI)		
430	Underweight (< 18.5 kg/m <sup>2</sup> )	6	3.7
431	Normal (18.5 – 22.9 kg/m <sup>2</sup> )	0 71	43.6
432	Overweight (23-24.9 kg/m <sup>2</sup> )	28	43.0 17.2
433			
434	Obese (≥25.0 kg/m <sup>2</sup> )	58	35.6
435	Waist Height Ratio (WHtR)		
436	Normal (<0.50)	45	27.6
437	Risk (≥0.50)	118	72.4
438	Waist Hip Ratio		
439	Normal (<0.85)	127	77.9
440	Central Obesity (≥0.85)	36	22.1
441	Sagital Abdominal Diameter (SAD)		
442	Normal (≤19.3 cm)	143	87.7
442	Risk (>19.3 cm)	20	12.3
445	Wait Circumference		
	Normal (<80 cm)	73	44.8
	Obese (≤80 cm)	90	55.2
	Metabolic Profiles		
	Blood Glucose Levels		
	Normal (<110 mg/dL)	136	83.4
	High (≥110 mg/dL)	27	16.6
	Triglycerides	27	10.0
	Normal (<150 mg/dL)	149	914
	High $(\geq 150 \text{ mg/dL})$	149	8.6
		14	0.0
	Cholesterol HDL	4.25	02.0
	Normal (≥150 mg/dL)	135	82.8
	Low (<150 mg/dL)	28	17.2
	Sistolic Blood Pressure		
	Normal (<130 mg/dL)	136	83.4
	High (≥130 mg/dL)	27	16.6
	Diastolic Blood Pressure		
	Normal (<85 mg/dL)	128	78.5
	High (≥85 mg/dL)	35	21.5
	cMetS (Score of Metabolic Syndrome)		
	Normal (<2.21)	109	66.9
	Risk (≥2.21)	54	33.1
	Metabolic Type		
	Metabolic Unhealthy Normal Weight (MUNW)	17	10.4
	Metabolic Healthy Normal Weight (MHNW)	88	54
	Metabolic Unhealthy Obese Weight (MUOW)	38	23.3
	Metabolic Healthy Obese Weight (MHOW)	20	12.3

445	mgiycendes, blood sugar, HDL and metabolic syndrome scores)											
Variable	Sistolic	BP	Distolic	BP	TG	Blood Glucose		HDL		cMetS		
	r	р	r	р	r	р	r	р	r	р	r	р
WHtR	0.358	<0.001	0.306	<0.001	0.289	<0.001	0.210	0.007	-0.266	0.001	0.599	<0.001
BMI	0.370	<0.001	0.313	<0.001	0.315	<0.001	0.221	0.005	-0.292	<0.001	0.600	<0.001
SAD	0.352	<0.001	0.284	<0.001	0.278	<0.001	0.191	0.015	-0.264	0.001	0.575	<0.001
WC	0.377	<0.001	0.284	<0.001	0.295	<0.001	0.212	0.005	-0.243	0.002	0.616	<0.001
HC	0.369	<0.001	0.332	<0.001	0.302	<0.001	0.179	0.002	-0.273	<0.001	0.581	<0.001
WHR	0.244	0.002	0.128	0.104	0.194	0.013	0.172	0.028	-0.149	0.048	0.415	<0.001
446												

Table 3.The Relationship between Anthropometric Indicators and Metabolic Profiles (Blood Pressure,
 Triglycerides, Blood Sugar, HDL and metabolic syndrome scores)

		syndrome	scores				
Variable	Sistolic BP						
	<mark>Constant</mark>	USC <sup>a</sup>	<b>р1</b> <sup>b</sup>	p2 <sup>c</sup>	<sup>d</sup> Adjusted R <sup>2</sup>		
BMI	91.759	0.951	<0.001	<0.001	0.158		
	Blood Glucose Levels						
	Constant	USC <sup>a</sup>	<b>р1</b> <sup>b</sup>	р2 <sup>с</sup>	Adjusted R <sup>2</sup>		
BMI	83.454	0.355	0.005	<0.001	0.043		
	HDL						
	Constant	USC <sup>a</sup>	<b>р1</b> <sup>ь</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>		
BMI	81.429	-0.819	<0.001	<0.001	0.080		
	Triglycerides						
	Constant	USC <sup>a</sup>	<b>р1</b> <sup>ь</sup>	р2 <sup>с</sup>	Adjusted R <sup>2</sup>		
WC	-6.614	1.195	<0.001	<0.001	0.078		
	Score of Metabolic Syndrome						
	Constant	USC <sup>a</sup>	<b>р1</b> <sup>ь</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>		
WC	-13.163	0.166	<0.001	<0.001	0.375		

Table 4. Anthropometric indicators most associated with metabolic components and metabolic

Commented [ASUS22]: Translate in english

Commented [A23R22]: revised

1

Anthropometry indicators that are most related to female student's metabolic profiles

#### 2

#### 3 Abstract

4 Metabolic syndrome is not a disease, but is a set of several disorders and causes an increased risk of 5 cardiovascular disease and diabetes mellitus complications. Several studies have shown that non-invasive 6 approaches such as anthropometric measurements can be used for early detection of metabolic 7 syndrome. This study aims to analyse the anthropometric indicators related to metabolic syndrome in 8 female students. This cross-sectional study with a total of 163 female students, aged between 19 and 24 9 years old. Purposive sampling was used in this study. The independent variables in this study were the Waist-to-Height Ratio (WHR), Waist-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal 10 11 Diameter (SAD), and hip circumference. The dependent variable in this study is the metabolic syndrome component that has been converted into a metabolic syndrome score (cMetS). The analysis results 12 13 showed that all anthropometric indicators, namely WHtR, BMI, SAD, waist circumference, hip circumference and WHR have a strong positive relationship with the metabolic syndrome score (p<0.001). 14 15 BMI was the anthropometric indicator that is most associated with the metabolic profiles, such as systolic 16 blood pressure (p<0.001), blood sugar (p<0.05), and HDL (p<0.001). Waist circumference was the 17 anthropometric indicator that is most associated with triglycerides and metabolic syndrome score 18 (p<0.001). Metabolic syndrome in female students in Semarang can be identified using anthropometric 19 measurements, one of which is BMI and WHR which are very easy to measure and efficient. In addition, 20 the use of cMetS in the metabolic assessment of a person was found to be more effective.

21 Keywords: Adolescent; Anthropometric Indicator; Female; Metabolic Profile; Metabolic Syndrome.

#### 22

23

#### 24 1. Introduction

Metabolic syndrome is a set of body metabolic disorders such as dyslipidaemia, hyperglycaemia, hypertension, and central obesity (Srikanthan *et al.*, 2016; Devi *et al.*, 2017; Christijani, 2019). Metabolic syndrome is not a disease, but is a set of several disorders and causes an increased risk of cardiovascular disease and diabetes mellitus complications. Some epidemiological studies have shown that metabolic syndrome doubles the risk of cardiovascular diseases (Sri Rahayu and Maulina, 2017).

31 Several studies found that the prevalence of metabolic syndrome keeps increasing every year. A study in China shows the prevalence of metabolic syndrome in adults was 24.2% (Li et al., 2018). 32 33 Another study indicated that the prevalence of metabolic syndrome in Indonesia was 21.66% 34 (Herningtyas and Ng, 2019). In recent studies metabolic syndrome can be assessed using the 35 continuous value of metabolic syndrome (cMets) or the metabolic syndrome score recommended by the American Diabetic Association of Diabetes. The metabolic syndrome score is a z-score resulting 36 37 from the assessment of all components of the metabolic syndrome (Pratiwi, et al., 2017). The 38 advantages of using cMetS are (1) reducing dichotomization factors because cardiovascular disease 39 is a progression of several components of the metabolic syndrome, (2) cMetS is more sensitive and Commented [A1]: Analyze

Commented [A2]: dyslipidemia

Commented [A3]: hyperglycemia

Commented [A4]: In recent studies,

less error-prone than categoric metabolic syndrome assessments, (3) increasing the statistical power
(Okosun, Lyn, *et al.*, 2010).

42 Central obesity is one of the components of metabolic syndrome parameters. Central obesity is 43 associated with increased blood pressure, serum triglycerides, decreased HDL, and glucose 44 intolerance. Based on the National Basic Health Research (Riskesdas) in 2018, the prevalence of 45 obesity in adults was 21.8%, and the prevalence of central obesity at age of more than 15 years 46 increased from 26.6% in 2013 to 31% in 2018 (Badan Penelitian dan Pengembangan Kesehatan, 47 2018). Obesity is closely related to degenerative diseases. The Riskesdas 2018 showed that the 48 prevalence of stroke, diabetes mellitus, heart disease, and hypertension is higher in women than 49 men.

50 Several studies have shown that non-invasive approaches such as anthropometric measurements can be used for early detection of metabolic syndrome (Pratiwi, et al., 2017). Anthropometric 51 52 measurements are described as the measurements of body dimensions and body composition to 53 assess nutritional status. The advantages of anthropometric measurements are relatively fast and 54 easy, as it can be performed using portable and calibrated instruments with standardized methods 55 (Rokhmah, et al., 2015). Some anthropometric measurements that can be used for early detection 56 of metabolic syndrome are Waist-to-Height Ratio (WHtR), waist-to-hip ratio (WHR), hip 57 circumference, Body Mass Index (BMI), Sagital Abdominal Diameter (SAD).

58 One of the anthropometric measurements which can be a parameter for central obesity is the ratio of waist circumference to height (WHtR). The instruments used in the measurement are 59 60 microtoise and measuring tape so that it takes longer time. Studies on waist circumference have been 61 shown to have a strong correlation with abdominal fat deposits (Zhou et al., 2014). The distribution of abdominal adipose tissue (central obesity) in adults is associated with a component of the 62 63 metabolic syndrome (Rodea-Montero, et al., 2014). A study on adult subjects has shown that people 64 who have the same waist circumference but are shorter in height have a greater risk of developing 65 metabolic syndrome than taller people (Zhou et al., 2014). Therefore, WHtR can be used as a simple and effective anthropometric index to identify the metabolic risk associated with obesity (Rodea-66 Montero, et al., 2014). 67

68 The waist-to-hip ratio (WHR) is a measurement that may indicate central obesity (Karimah, 2018). 69 The higher the WHR value, the higher the risk level for several metabolic diseases. The waist-to-hip 70 ratio is calculated by dividing the measurement of the waist circumference by the circumference of 71 the hip. The cut-off points for WHR are  $\geq$ 1.0 for men and  $\geq$ 0.85 for women (Rokhmah, et al., 2015). 72 Individuals with a high waist and hip circumference will also have a higher distribution of fat in their 73 abdominal area. Irregular fats distribution in the abdominal area indirectly causes higher triglyceride 74 levels circulating in the blood, which will affect blood pressure (Sumardiyono et al., 2018). WHR 75 measurement is more sensitive in assessing the distribution of fat in the body, especially in the 76 abdominal. This measurement is three times better than BMI in reflecting the presence of harmful 77 fats in the abdominal. Measurement of waist circumference is performed by determining the lower 78 part of arcus costae and crista iliaca (Sri Rahayu and Maulina, 2017).

Body Mass Index (BMI) is a practical and easy measurement to perform, but it cannot distinguish
 between fat mass, bone mass and muscle mass. BMI is calculated as body weight (kg) / height

Commented [A5]: The

Commented [A6]: The early

Commented [A7]: a longer time

Commented [A8]: abdomen

01		caused $(m^2)$ (Okura at al. 2019) BML can be used as the first measurement before any other	
81 82		squared (m <sup>2</sup> ) (Okura <i>et al.</i> , 2018). BMI can be used as the first measurement before any other anthropometric measurements.	
83		Sagittal Abdominal Diameter (SAD) or the height of the abdomen while the subjects are in lying	Commented [A9]: in a lying
84		position. This anthropometric measurement has not been widely used to measure fat tissue in the	
85		abdominal area. SAD measurements using computed tomography or magnetic resonance imaging,	
86		and are associated with components of metabolic syndrome. The measurements of SAD are taken	
87		when the subject is lying down on the examination table with naked upper body. SAD is related to	Commented [A10]: a naked
88		central obesity in individuals with obese and normal nutritional status. Furthermore, SAD is	
89		associated with diabetes mellitus and a predictor of cardiovascular disease incidence, even when SAD	
90		is measured in standing position (Pajunen et al., 2013). Based on the abovementioned problems, our	Commented [A11]: in a standing
91		study aims to analyse the anthropometric indicators related to metabolic syndrome in female	Commented [A12]: analyze
92		students.	Commented [A13]:
93			commented [A15].
94	2.	Materials and methods	
95		2.1 Design, location, and time	
96		The scope of this study is community nutrition with a cross-sectional study design.	
97		Anthropometric and biochemical data were collected at the Cito Laboratory, Banyumanik Semarang	
98		with health protocols applied. The study started from March to July 2020.	
99			
100		2.2 Samplings	
101		This study was conducted during the SARS-CoV-2 outbreak, which later was named COVID-19 by	
102		the WHO, so the registration for study participants was done online. The inclusion criteria were	
103		female students aged 19-24, resided in Semarang, willing to be a study participant and willing to	Commented [A14]: years
104		follow a series of study instructions. Subjects were asked to fill in personal data using a Google form;	
105		and eligible subjects will be contacted by the researchers to plan a direct meeting. Purposive	
106		sampling was used in this study and the total number of subjects required was 163.	Commented [A15]:
.07			Commented prior.
08		2.3 Data collected	
.09		The independent variables in this study were the Waist-to-Height Ratio (WHtR), Waist-Hip Ratio	
.10		(WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference.	
11		Bodyweight was measured using a digital scale to the nearest 0.01 kg, height was measured using a	
.12		microtoise to the nearest 0.1 cm, waist circumference and hip circumference was measured using a	
113		measuring tape (Medline) to the nearest 1 mm and abdominal height was measured using the	
14		Abawerk Schaffenburg abdominal calliper to the nearest 1 mm. SAD measurements were performed	Commented [A16]: caliper
15		with the subject in a supine position on a flat surface with both knees forming an angle of 90° (Firouzi	Commented [Frid], comper
16		et al., 2018).	Commented [A17]: How is anthropometric data
.17		The cut-off point used in this study refers to previous studies because it had been adjusted for the	collected? Was anthropometric data collected by the
.18		Asian race (Rose <i>et al.</i> , 2020). Each anthropometric measurement is stated as "at risk" if the	enumerator?
.19		individuals have $\geq 0.50$ for WHtR (Zhang <i>et al.</i> , 2016), $\geq 0.85$ for WHR (Rokhmah, <i>et al.</i> , 2015), $> 19.3$	
.20		cm for (Dieny <i>et al.</i> , 2020), and have the normal to overweight BMI (18.5 - 25 kg/m <sup>2</sup> ) or obese BMOI	Commented [A18]: ?
121		$(\geq 25.0 \text{ kg/m}^2)$ (Susetyowati, 2016).	commented [AT0]. :
122		The dependent variable in this study is the metabolic syndrome component that has been	
122			
		converted into a metabolic syndrome score (cMetS) with the cut-off point on cMetS> 2.21 (Rose <i>et</i>	

124 al., 2020). The guidelines for metabolic syndrome in this study are taken from the National 125 Cholesterol Education Program-Adult Treatment Panel (NCEP-ATP III) 2005 which has been 126 frequently used in Indonesia. There are 5 parameters to assess metabolic syndrome: (1) fasting blood glucose levels ≥110 mg/dL, (2) triglyceride levels ≥150 mg/dL (3) HDL cholesterol levels <50 mg/dL, 127 128 (4) central obesity in women with waist circumference ≥80 cm, and (5) systolic and diastolic blood 129 pressures ≥130 mmHg and ≥85 mmHg, respectively (Soewondo et al., 2010). The calculation of the 130 metabolic syndrome score (cMetS) was done in the following steps: (1) after measuring all parameters of the metabolic syndrome, standardisation was carried out to obtain a Z-score; (2) the 131 132 blood pressure must be converted into Mean Arterial Blood (MAP) by dividing the difference 133 between systolic and diastolic blood pressure by three and summed with the diastolic blood pressure; (3) the HDL cholesterol standardisation results were multiplied by (-1) because the 134 135 parameter was inversely related to the risk of metabolic syndrome; (4) All Z-scores were added to 136 obtain the cMetS values; (5) The final step was to compare the cMetS values with the cut-off point 137 of ≥2,21 (Eisenmann et al., 2010; Okosun, Boltri, et al., 2010; Rose et al., 2020). The subjects were 138 instructed to do fasting for at least 8 hours; only drinking water was permitted.

Other than the cMetS score, metabolic syndrome risk can also be assessed from the classification of metabolic types. This classification combines the internal and external signs of the body such as biochemical parameters, the ratio of subcutaneous fat to abdominal fat, and blood pressure (Prybyla 0, 2020). The main phenotypes that reflect the possible combination of metabolic profile and the degree of obesity are metabolic healthy obese weight, metabolic healthy normal weight, metabolic unhealthy normal weight, and metabolic unhealthy normal weight.

#### 146 2.4 Data analysis

Statistical analyses were performed using SPSS Statistical software. This study has received an ethical clearance issued by the Medical/Health Research Bioethics Commission, Faculty of Medicine, Sultan Agung Islamic University Semarang with Number No.296 /IX /2020 /Bioethical Commission.

#### 150 151

145

147

148

149

152 3. Results and discussion/Results

The subject characteristics measured in female student aged 19-24 years include age, anthropometric indicators, and metabolic syndromes. Table 1 shows the characteristics of the study subjects. The mean of WHtR value in this study was 0.51. Meanwhile, the mean of WHR was 0.80; the mean of BMI was 24.04 kg/m<sup>2</sup>; the mean of SAD was 16.79 cm; and the mean of waist circumference was 79.44 cm.

158 Table 2 shows various nutritional status of the subjects based on BMI. We found that 43.6% of the 159 subjects had normal BMI, 17.2% were overweight and 35.6% were obese. Based on the WHtR 160 anthropometric indicator, 72.4% of subjects were at risk of having obesity; based on WHR, 22.1% had central obesity; based on BMI, 35.6% were obese; based on SAD 12.3% of the subjects were at risk; 161 and based on waist circumference 55.2% had central obesity. According to the metabolic profile that 162 was assessed, 16.6% had high FBG levels, 8.6% had hypertriglycerides, 17.2% had low HDL, 16.6% had 163 high systolic blood pressure, and 21.5% had high diastolic blood pressure. In addition, we found 33.1% 164 165 of the subjects had high metabolic syndrome (cMetS) scores. This proportion was similar to the 166 assessment based on the metabolic type theof unhealthy subjects (subjects who had  $\geq$  3 risk factors Commented [A19]: standardization

Commented [A20]: ?

Commented [A21]: The of

167 of the metabolic profile), which was 33.7%. Moreover, two subjects had five risk factors: abdominal 168 obesity, hypertension, hyperglycaemia, hypertriglycerides, and low HDL.

If we are considering metabolic type based on nutritional status (subjects with non-obese BMI 169 170 (<25kg/m<sup>2</sup>) with metabolic healthy and metabolic unhealthy and subjects with obese BMI (>25kg/m<sup>2</sup>) 171 with metabolic healthy and metabolic unhealthy), subjects are categorised as metabolic unhealthy 172 (experiencing metabolic syndrome) if they fulfil  $\geq$  3 risk factors including high waist circumference, 173 blood pressure, GDP and triglyceride levels, and low HDL levels. Based on these criteria, we found that 174 10.4% of the subjects had metabolic unhealthy normal weight (MUNW) and 23.3% of the subjects had 175 metabolic unhealthy obesity weight (MUOW). In non-obese subjects, 54% of them were metabolic 176 healthy.

177 Table 3 and Table 4 show the results of statistical analyses on anthropometric indicators related 178 to the metabolic syndromes. Table 3 shows the bivariate statistical analysis using the Pearson 179 correlation test. The analysis results showed that all anthropometric indicators, namely WHtR, BMI, 180 SAD, waist circumference, hip circumference and WHR have a strong positive relationship with the 181 metabolic syndrome score (p<0.001), which means that the higher the anthropometric value, the 182 higher the metabolic syndrome score. In addition, the analysis on the relationship between 183 anthropometric indicators and each metabolic profile revealed that almost all of the independent 184 variables (WHtR, waist and hip circumference, WHR, BMI, and SAD) were associated with each 185 metabolic profile, such as baseline systolic pressure, diastolic blood pressure, triglyceride levels, blood 186 sugar levels, and HDL. Only WHR that was not associated with diastolic blood pressure (p>0.005).

Table 4 shows the results of the analysis using multiple linear regression to determine anthropometric indicators that are most associated with each metabolic profile and metabolic syndrome score.

The results showed that BMI was the anthropometric indicator that is most associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood sugar (p<0.05), and HDL (p <0.001). In addition, waist circumference was the anthropometric indicator that is most associated with triglycerides and metabolic syndrome score (p<0.001). Based on the Adjusted R2 value on the metabolic syndrome score, we found that 37.5% of the metabolic syndrome score was related to anthropometric indicators, such as WHtR, waist and hip circumference, WHR, BMI, and SAD. The rest may be influenced by other variables that are not included in this study.

#### 198 4. Discussion

197

199 The objective of this study was to determine the anthropometric indicators associated with 200 metabolic syndromes in female students. The study included 163 female students aged 19-24 years. 201 The students are in their late adolescents who begin to have an independent life. Inappropriate and 202 unhealthy eating behaviours will have an impact on the student's nutritional status. Excessive 203 nutritional status and obesity will affect student's body metabolism. Based on the study results, 204 33.1% of the subjects had a high metabolic syndrome (cMetS) score. In line with the previous study 205 conducted in 2019 on 18-to-21-year-old students at Diponegoro University, 20% of the subjects had 206 high cMetS (Rose et al., 2020). Meanwhile, a study conducted by Pratiwi et al in 2017 using secondary 207 data from the National Basic Health Research 2013 found that 19.98% of adolescents aged 15-24 208 years had high cMetS (Pratiwi, et al., 2017). Therefore, we conclude that there is a trend of Metabolic 209 Syndrome Score (cMetS) among young women in Semarang.

Commented [A22]: hyperglycemia Commented [A23]: categorized Commented [A24]: ? Commented [A25]: the metabolic Commented [A26]: that was

Commented [A27]: behavior

**Commented [A28]:** Diponegoro University or Universitas Diponegoro?

210 The assessment of metabolic syndrome using a continuous type (scoring) rather than using a 211 dichotomy or binary ("yes" and "no") is recommended (Christijani, 2019). An adolescent can be 212 diagnosed with metabolic syndrome if their Metabolic Syndrome Score (cMetS) >2.21 (Pratiwi, et al., 2017). Anthropometric indicators used in this study are Waist and Height Ratio (WHtR), Waist-to-Hip 213 214 Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and Waist Circumference. 215 Based on the correlation analyses, all anthropometric indicators have a significant positive 216 relationship with the Metabolic Syndrome Score (cMetS). Furthermore, the multivariate analyses 217 show that the anthropometric indicators of BMI and RLPP are strongly associated with cMetS.

218 According to the metabolic type, most of the subjects (54%) in this study had metabolic healthy 219 normal weight (MHNW) metabolic type. In this type, the individuals have a normal BMI and does not 220 show any metabolic risk. Our study also shows that 10.4% of the subjects were classified as metabolic 221 unhealthy normal weight (MUNW). The subjects' BMI in this category is in the normal range but has 222 a high percentage of body fat that makes them at high risk of developing metabolic disorders (Eckel 223 et al., 2015; Suliga et al., 2015). Several recent cohort studies have shown a greater risk of type II 224 diabetes mellitus in individuals with MUNW compared to individuals with MHNW (Ärnlöv et al., 2011; 225 Hadaegh et al., 2011; Aung et al., 2014; Jung et al., 2014; Hinnouho et al., 2015). Other studies have 226 shown that women with the MUNW type have a long-term impact of an increased risk of 227 cardiovascular diseases such as higher blood pressure, triglyceride and glucose levels as well as lower 228 levels of adiponectin, HDL, and LDL compared to women with the MHNW type (Kim et al., 2013).

In our study, 23.3% of the subjects belonged to the Metabolic Unhealthy Obese Weight (MUOW)
 type. Subjects with this metabolic type have an obese BMI and have a high risk of developing
 metabolic disorders. A study conducted in Japan on 29,564 subjects showed that individuals with
 MUOW had a greater risk of developing type II diabetes mellitus compared to individuals with MHOW
 (Heianza *et al.*, 2015).

234 We also found that 12.3% of the subjects were categorized as metabolic healthy obese weight 235 (MHOW). Individuals in this metabolic type have an obese BMI but do not show any metabolic risks. 236 Given the impact of obesity in relation to the risk of metabolic diseases, various studies have been 237 conducted to examine the long-term effects of MHOW. Individuals with MHOW had a different fat 238 distribution pattern (less ectopic and visceral fat), and lower inflammatory markers (Samocha-Bonet 239 et al., 2014). Other studies also have shown that women with MHOW had lower blood pressure, 240 triglyceride levels, and glucose levels, but higher levels of HDL, adiponectin, and LDL compared to 241 women with MUNW (Kim et al., 2013). This condition was associated with good diet quality in 242 individuals with MHOW. Based on National Health and Nutrition Examination Surveys (NHANES) 243 data, Camhi et al examined the quality of diet in obese subjects, and found that adolescents and adult 244 women with the MHOW metabolic type had higher diet quality scores due to high intake of fruit, 245 whole grains, meat, and nuts (Camhi et al., 2015).

246 The correlation test results indicated that all anthropometric indicators had a positive relationship with the metabolic syndrome scores with p <0.001. Meanwhile, the regression analyses 247 248 show that BMI and WHR were inversely related to cMetS. This is in line with research conducted by Lindy et al, who stated that an increase in the WHR value could be associated with the risk of 249 metabolic syndrome in children and adolescents in Florida (Moore et al., 2015). A study conducted 250 251 by Al-Bachir and Bakir stated that there was a strong relationship between overweight and obese 252 adolescents with metabolic syndrome (Al-Bachir and Bakir, 2017). Furthermore, a study conducted 253 by Adrian et al on 15-year-old adolescents in South Africa found that central obesity as measured by Commented [A29]: do

the hip circumference could lead to an increased risk of cardiovascular diseases and death. Therefore,
 hip circumference and waist circumference can be used to predict the risk of cardiovascular diseases
 and death in the future (Cameron *et al.*, 2012).

Body Mass Index (BMI) is the most widely used indicator of measurement in epidemiological 257 258 studies and is used as a substitute for evaluating body composition. However, BMI cannot distinguish 259 fat from fat mass and lean mass, and it fails to show the presence of adipose and body fat distribution 260 (Ofer et al., 2019; Leone et al., 2020). However, the BMI cut-offs for metabolic syndrome has not yet been determined (Ofer et al., 2019). Obesity in adolescents is generally assessed using a BMI of ≥25.0 261 262 kg/m<sup>2</sup>. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m<sup>2</sup>) and 263 obesity (≥25.0 kg/m<sup>2</sup>), and we found that 35.6% of the subjects were obese. The finding is in line with 264 the research conducted by Sophia et al on the subject of students at Universitas Diponegoro aged 265 18-21 years. They found that 40% of their study population had obesity level I and 36.3% had obesity 266 level II (Rose et al., 2020).

267 Abdominal obesity is often assessed to determine a metabolic syndrome in people. One of the 268 indicators used to measure abdominal obesity is the Waist-to-Hip Ratio (WHR) which is calculated by 269 dividing the waist circumference and the hip circumference. Measurement of waist circumference is 270 more sensitive in assessing the distribution of body fat in the abdominal wall, which is also a 271 component in the metabolic syndrome. The limit of the WHR value for female is  $\geq$  0.85 (Rokhmah, et 272 al., 2015). This study shows that every 1% increase in the WHR value will increase the cMetS value 273 by 10.411. Hip circumference is also an indicator that has a strong correlation with cMetS, but many 274 studies have used it as a ratio along with waist circumference for assessing a person's central obesity 275 status.

#### 277 5. Conclusion

Metabolic syndrome in female students in Semarang can be identified using anthropometric
 measurements, one of which is BMI and WHR which are very easy to measure and efficient. In
 addition, the use of cMetS in the metabolic assessment of a person was found to be more effective.

281

276

## 282 Conflict of interest - Disclose any potential conflict of interest appropriately.

283 The authors declare no conflict of interest.

#### 284 Acknowledgments

- 285 The authors would like to thank all the subjects who participated in this study. We would also like to
- 286 express our gratitude to The Ministry of Research, Technology and Higher Education, Indonesia" was
- 287 funded by the "Hibah Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) 2019.
- 288
- 289

Commented [A30]:

Commented [A31]: in the metabolic syndrome

#### 290 References

- 291 Al-Bachir, M. and Bakir, M. A. (2017). Predictive value of body mass index to metabolic syndrome risk factors in Syrian adolescents. Journal of Medical Case Reports, 11(1). doi: 10.1186/s13256-017-1315-292 2.
- 293

294 Ärnlöv, J., Sundström, J., Ingelsson, E., Lind, L. (2011). Impact of BMI and the metabolic syndrome on the 295 risk of diabetes in middle-aged men. Diabetes Care, 34(1), 61-65. doi: 10.2337/dc10-0955.

- 296 Aung, K. K., Lorenzo, C., Hinojosa, M. A., Haffner, S. M. (2014). Risk of developing diabetes and 297 cardiovascular disease in metabolically unhealthy normal-weight and metabolically healthy obese 298 individuals. Journal of Clinical Endocrinology and Metabolism, 99(2), 462-468. doi: 10.1210/jc.2013-299 2832
- 300 Badan Penelitian dan Pengembangan Kesehatan. (2018). Riset Kesehatan Dasar (RISKESDAS) 2018. 301 Jakarta, Indonesia.
- 302 Cameron, A. J., Magliano, D. J., Shaw, J. E., Zimmet, P. Z., Carstensen, B., Alberti, K. G. M. M., Tuomilehto, 303 J., Barr, E. L. M., Pauvaday, V. K., Kowlessur, S., Söderberg, S. (2012). The influence of hip circumference 304 on the relationship between abdominal obesity and mortality. International Journal of Epidemiology, 41(2), 484-494. doi: 10.1093/ije/dyr198. 305
- 306 Camhi, S. M., Whitney Evans, E., Hayman, L. L., Lichtenstein, A. H., Must, A. (2015). Healthy eating index 307 and metabolically healthy obesity in U.S. adolescents and adults. Preventive Medicine, 77, 23–27. doi: 308 10.1016/j.ypmed.2015.04.023.
- 309 Christijani, R. (2019). Determination of Diagnosis of Metabolic Syndrome based on Assessment of 310 Metabolic Syndrome and NCEP ATP-III Score in Adolescent. The Journal of Nutrition and Food Research, 311 42(1), 21-28. doi: 10.22435/pgm.v42i1.2418.
- 312 Devi, R., Manhas, S., Prasad, S., Sharma, S., Bhaskar, N., Mahajan, S. (2017). Short Review of Metabolic 313 Syndrome. International Journal of Research & Review, 4(2), p. 29.
- 314 Dieny, F. F., Setyaningsih, R. F., Fitranti, D. Y., Jauharany, F. F., Putra, Y. D., Tsani, A. F. A. (2020). Abdominal diameter profiles have relationship with insulin resistance in obese female adolescents. Electronic 315 316 Journal of General Medicine, 17(5), p. em219. doi: 10.29333/ejgm/7882.
- 317 Eckel, N., Mühlenbruch, K., Meidtner, K., Boeing, H., Stefan, N., Schulze, M. B. (2015). Characterization of 318 metabolically unhealthy normal-weight individuals: Risk factors and their associations with type 2 319 diabetes. Metabolism: Clinical and Experimental, 64(8), 862–871. doi: 10.1016/j.metabol.2015.03.009.
- 320 Eisenmann, J. C., Laurson, K. R., Dubose, K. D., Smith, B. K., Donnelly, J. E. (2010). Construct validity of a 321 continuous metabolic syndrome score in children. Diabetology and Metabolic Syndrome, 2(1). doi: 322 10.1186/1758-5996-2-8.
- 323 Firouzi, S. A., Tucker, L. A., LeCheminant, J. D., Bailey, B. W. (2018). Sagittal abdominal diameter, waist 324 circumference, and BMI as predictors of multiple measures of glucose metabolism: An NHANES investigation of US adults. Journal of Diabetes Research, 2018, 1–14. doi: 10.1155/2018/3604108. 325
- 326 Hadaegh, F., Bozorgmanesh, M., Safarkhani, M., Khalili, D., Azizi, F. (2011). Predictability of body mass 327 index for diabetes: Affected by the presence of metabolic syndrome?. BMC Public Health, 11(1), p. 383. 328 doi: 10.1186/1471-2458-11-383.
- 329 Heianza, Y., Kato, K., Kodama, S., Ohara, N., Suzuki, A., Tanaka, S., Hanyu, O., Sato, K., Sone, H. (2015). Risk 330 of the development of Type 2 diabetes in relation to overall obesity, abdominal obesity and the 331 clustering of metabolic abnormalities in Japanese individuals: Does metabolically healthy overweight 332 really exist? The Niigata Wellness Study. Diabetic Medicine, 32(5), 665-672. doi: 10.1111/dme.12646.
- 333 Herningtyas, E. H. and Ng, T. S. (2019). Prevalence and distribution of metabolic syndrome and its 334 components among provinces and ethnic groups in Indonesia. BMC Public Health, 19(1), p. 377. doi: 335 10.1186/s12889-019-6711-7.
- 336 Hinnouho, G. M., Czernichow, S., Dugravot, A., Nabi, H., Brunner, E. J., Kivimaki, M., Singh-Manoux, A.

- (2015). Metabolically healthy obesity and the risk of cardiovascular disease and type 2 diabetes: The
   Whitehall II cohort study. *European Heart Journal*, 36(9), 551–559. doi: 10.1093/eurheartj/ehu123.
- Jung, H. S., Chang, Y., Eun, Y. K., Kim, C. W., Choi, E. S., Kwon, M. J., Cho, J., Zhang, Y., Rampal, S., Zhao, D.,
   Soo, K. H., Shin, H., Guallar, E., Ryu, S. (2014). Impact of body mass index, metabolic health and weight
   change on incident diabetes in a Korean population. *Obesity*, 22(8), 1880–1887. doi:
   10.1002/oby.20751.
- Karimah, M. (2018). Rasio Lingkar Pinggal-panggul Memiliki Hubungan Paling Kuat dengan Kadar Glukosa
   Darah'. Jurnal Berkala Epidemiologi, 6(3), 219–226.
- Kim, M., Paik, J. K., Kang, R., Kim, S. Y., Lee, S. H., Lee, J. H. (2013). Increased oxidative stress in normalweight postmenopausal women with metabolic syndrome compared with metabolically healthy
  overweight/obese individuals. *Metabolism: Clinical and Experimental*, 62(4), 554–560. doi:
  10.1016/j.metabol.2012.10.006.
- Leone, A. *et al.* (2020). Evaluation of different adiposity indices and association with metabolic syndrome
   risk in obese children: Is there a winner?. *International Journal of Molecular Sciences*, 21(11), p. 4083.
   doi: 10.3390/ijms21114083.
- Li, Y. *et al.* (2018). Metabolic syndrome prevalence and its risk factors among adults in China: A nationally
   representative cross-sectional study. *PLoS ONE*, 13(6), p. e0199293. doi:
   10.1371/journal.pone.0199293.
- Moore, L. M. *et al.* (2015). Analysis of Pediatric Waist to Hip Ratio Relationship to Metabolic Syndrome
   Markers. *Journal of Pediatric Health Care*, 29(4), 319–324. doi: 10.1016/j.pedhc.2014.12.003.
- Ofer, K. *et al.* (2019). Normal body mass index (BMI) can rule out metabolic syndrome: An Israeli cohort
   study. *Medicine*, 98(9), p. e14712. doi: 10.1097/MD.00000000014712.
- Okosun, I. S., Boltri, J. M., *et al.* (2010). Continuous metabolic syndrome risk score, body mass index
   percentile, and leisure time physical activity in American children. *Journal of Clinical Hypertension*,
   12(8), 636–644. doi: 10.1111/j.1751-7176.2010.00338.x.
- Okosun, I. S., Lyn, R., *et al.* (2010). Validity of a Continuous Metabolic Risk Score as an Index for Modeling
   Metabolic Syndrome in Adolescents. *Annals of Epidemiology*, 20(11), 843–851. doi:
   10.1016/j.annepidem.2010.08.001.
- Okura, T. *et al.* (2018). Body mass index ≥23 is a risk factor for insulin resistance and diabetes in Japanese
   people: A brief report. *PLOS ONE*. Edited by P. Bjornstad, 13(7), p. e0201052. doi:
   10.1371/journal.pone.0201052.
- Pajunen, P. *et al.* (2013). Sagittal abdominal diameter as a new predictor for incident diabetes. *Diabetes Care*, 36(2), 283–288. doi: 10.2337/dc11-2451.
- Pratiwi, Z. A., Hasanbasri, M. and Huriyati, E. (2017). Penentuan titik potong skor sindroma metabolik
   remaja dan penilaian validitas diagnostik parameter antropometri: analisis Riskesdas 2013. Jurnal Gizi
   *Klinik Indonesia*, 14(2), p. 80. doi: 10.22146/ijcn.25590.
- Prybyla, O. (2020). *Metabolic phenotyping: is it so important?*. *Journal of Cognitive Neuropsychology*.
  iMedPub., 4(1), 1-3.
- Rodea-Montero, E. R., Evia-Viscarra, M. L. and Apolinar-Jiménez, E. (2014). Waist-to-height ratio is a better
   anthropometric index than waist circumference and BMI in predicting metabolic syndrome among
   obese mexican adolescents. *International Journal of Endocrinology*, 2014, 195407. doi:
   10.1155/2014/195407.
- Rokhmah, F. D., Handayani, D. and Al-Rasyid, H. (2015). Korelasi lingkar pinggang dan rasio lingkar
   pinggang-panggul terhadap kadar glukosa plasma menggunakan tes toleransi glukosa oral. Jurnal Gizi
   Klinik Indonesia, 12(1), 28–35. doi: 10.22146/ijcn.22425.
- Rose, S., Dieny, F. F., Nuryanto, N., Tsani, A. F. A. (2020). The correlation between waist-to-height ratio (wHtR) and second to fourth digit ratio (2D:4D) with an increase in metabolic syndrome scores in obese
- adolescent girls. *Electronic Journal of General Medicine*, 17(3), p. em211. doi: 10.29333/ejgm/7872.

- Samocha-Bonet, D., Dixit, V. D., Kahn, C. R., Leibel, R. L., Lin, X., Nieuwdorp, M., Pietiläinen, K. H., Rabasa Lhoret, R., Roden, M., Scherer, P. E., Klein, S., Ravussin, E. (2014). Metabolically healthy and unhealthy
   obese The 2013 stock conference report. *Obesity Reviews*, 15(9), 697–708. doi: 10.1111/obr.12199.
- Soewondo, P., Purnamasari, D., Oemardi, M., Waspadji, S., Soegondo, S. (2010). Prevalence of Metabolic
   Syndrome Using NCEP/ATP III Criteria in Jakarta, Indonesia: The Jakarta Primary Non-communicable
   Disease Risk Factors Surveillance 2006. Acta Med Indones., 42(4), 199–203.
- Sri Rahayu, M. and Maulina, M. (2017). Hubungan Rasio Lingkar Pinggang dan Lingkar Pinggul dengan
   Penyakit Jantung Koroner. Jurnal Aceh Medika, 1(1), 1–10. Available at:
   www.jurnal.abulyatama.ac.id/acehmedika (Accessed: 8 April 2021).
- Srikanthan, K., Feyh, A., Visweshwar, H., Shapiro, J. I., Sodhi, K.(2016). Systematic review of metabolic
   syndrome biomarkers: A panel for early detection, management, and risk stratification in the West
   Virginian population. *International Journal of Medical Sciences*, 13(1), 25–38. doi: 10.7150/ijms.13800.
- Suliga, E., Kozieł, D., Cieśla, E., Głuszek, S. (2015). Association between dietary patterns and metabolic
   syndrome in individuals with normal weight: A cross-sectional study. *Nutrition Journal*, 14(1), p. 55.
   doi: 10.1186/s12937-015-0045-9.
- Sumardiyono, S., Pamungkasari, E. P., Mahendra, A. G., Utomo, O. S., Mahajana, D., Cahyadi, W. R., Ulfia,
  M. (2018). Hubungan Lingkar Pinggang dan Lingkar Panggul dengan Tekanan Darah pada Pasien
  Program Pengelolaan Penyakit Kronis (Prolanis). *Smart Medical Journal*, 1(1), p. 26. doi:
  10.13057/smj.v1i1.24504.
- 404 Susetyowati, S. (2016). Gizi Remaja, in Ilmu Gizi: Teori dan Aplikasi. Jakarta, Indonesia: EGC, 160–164.
- Zhang, Y. X., Wang, Z. X., Chu, Z. H., Zhao, J. S. (2016). Profiles of body mass index and the nutritional
  status among children and adolescents categorized by waist-to-height ratio cut-offs. *International Journal of Cardiology*, 223, 529–533. doi: 10.1016/j.ijcard.2016.07.303.
- Zhou, D., Yang, M., Yuan, Z. P., Zhang, D. D., Liang, L., Wang, C. L., Zhang, S., Zhu, H. H., Lai, M. D., Zhu, Y.
   M. (2014). Waist-to-Height Ratio: A simple, effective and practical screening tool for childhood obesity
   and metabolic syndrome. *Preventive Medicine*, 67, 35–40. doi: 10.1016/j.ypmed.2014.06.025.
- 411 412

# 413 Tables and Figures – 1 PAGE 1 TABLE/FIGURE. PLACE ALL TABLES AND FIGURES AT THE END OF THE

## 414 MANUSCRIPT BODY AFTER THE REFERENCES

415

Variabel	Minimum	Maximum	Mean	SD
Anthropometric Indicators				
WHtR (rasio)	0.37	0.71	0.51	0.07
RLPP (rasio)	0.67	0.96	0.80	0.06
BMI (kg/m²)	15.81	39.30	24.04	4.72
Sagital Abdominal Diameter (cm)	11.35	25.50	16.79	2.42
Hip Circumference (cm)	80.60	138.45	98.96	9.30
Waist Circumference (cm)	58.00	112.10	79.44	10.78
Metabolic Profiles				
Blood Glucose Levels (mg/dL)	66.00	110.00	92.00	7.59
Trygliceride Levels (mg/dL)	29.00	309.00	88.35	44.68
Cholesterol Levels HDL (mg/dL)	36.00	109.00	61.73	26.43
Sistolic Blood Pressure (mmHg)	84.00	144.00	114.63	11.13
Diastolic Blood Pressure (mmHg)	55.00	178.00	82.40	55.52
cMetS (Score of Metabolic Syndrome)	-7.10	11.93	0.01	2.90

Commented [A32]: ?

haracteristics	n	%		
nthropometric				
Body Mass Index (BMI)				
Underweight (< 18.5 kg/m <sup>2</sup> )	6	3.7		
Normal (18.5 – 22.9 kg/m <sup>2</sup> )	71	43.6		
Overweight (23-24.9 kg/m <sup>2</sup> )	28	17.2		
Obese (≥25.0 kg/m <sup>2</sup> )	58	35.6		
Vaist Height Ratio (WHtR)				
Normal (<0.50)	45	27.6		
Risk (≥0.50)	118	72.4	_	Commented [A33]: at risk
Vaist Hip Ratio	-			commenter proof. at his
Normal (<0.85)	127	77.9		
Central Obesity (≥0.85)	36	22.1		
agital Abdominal Diameter (SAD)				
Normal (≤19.3 cm)	143	87.7		
Risk (>19.3 cm)	20	12.3	_	Commented [A34]: at risk
Vait Circumference	_•			commented [A34]. at this
Normal (<80 cm)	73	44.8		
Obese (≤80 cm)	90	55.2		
etabolic Profiles				
Blood Glucose Levels				
Normal (<110 mg/dL)	136	83.4		
High ( $\geq 110 \text{ mg/dL}$ )	27	16.6		
iglycerides	27	10.0		
Normal (<150 mg/dL)	149	914		
High ( $\geq 150 \text{ mg/dL}$ )	14	8.6		
nolesterol HDL		0.0		
Normal (≥150 mg/dL)	135	82.8		
Rendah (<150 mg/dL)	28	17.2		Commonted [A25]: 3
stolic Blood Pressure	20	11.6		Commented [A35]: ?
Normal (<130 mg/dL)	136	83.4		
High ( $\geq 130 \text{ mg/dL}$ )	27	16.6		
iastolic Blood Pressure	21	10.0		
Normal (<85 mg/dL)	128	78.5		
High ( $\geq$ 85 mg/dL)	35	21.5		
MetS (Score of Metabolic Syndrome)	55	21.3		
Normal (<2.21)	109	66.9		
Risk (≥2.21)	109 54	33.1		Commented [A26]
pe Metabolik	54	JJ.1		Commented [A36]: at ris
Metabolic Unhealthy Normal Weight (MUNW)	17	10.4		Commented [A37]: ?
Metabolic Officentity Normal Weight (MONW) Metabolic Healthy Normal Weight (MHNW)	88	54		
Metabolic Unhealthy Obese Weight (MUOW)	80 38	23.3		
Metabolic Healthy Obese Weight (MIOW) Metabolic Healthy Obese Weight (MHOW)	38 20	12.3		

437	mgiycenices, blood sugar, not and metabolic syndrome scores)											
Variable	Sistolic	BP	Distolic	BP	TG		Blood Glucose		llood Glucose HDL		cMetS	
	r	р	r	р	r	р	r	р	r	р	r	р
WHtR	0.358	<0.001	0.306	<0.001	0.289	<0.001	0.210	0.007	-0.266	0.001	0.599	<0.001
BMI	0.370	<0.001	0.313	<0.001	0.315	<0.001	0.221	0.005	-0.292	<0.001	0.600	<0.001
SAD	0.352	<0.001	0.284	<0.001	0.278	<0.001	0.191	0.015	-0.264	0.001	0.575	<0.001
WC	0.377	<0.001	0.284	<0.001	0.295	<0.001	0.212	0.005	-0.243	0.002	0.616	<0.001
HC	0.369	<0.001	0.332	<0.001	0.302	<0.001	0.179	0.002	-0.273	<0.001	0.581	<0.001
WHR	0.244	0.002	0.128	0.104	0.194	0.013	0.172	0.028	-0.149	0.048	0.415	<0.001
438												

Table 3.The Relationship between Anthropometric Indicators and Metabolic Profiles (Blood Pressure,
 Triglycerides, Blood Sugar, HDL and metabolic syndrome scores)

Sistolic BP					
Konstanta	USC <sup>a</sup>	p1 <sup>b</sup>	p2 <sup>c</sup>	<sup>d</sup> Adjusted R <sup>2</sup>	Commented [A38]: ?
91.759	0.951	<0.001	<0.001	0.158	
Blood Glucos	e Levels				
Konstanta	USC <sup>°</sup>	<b>р1</b> <sup>ь</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>	
83.454	0.355	0.005	<0.001	0.043	
HDL					
Konstanta	USC⁰	<b>р1</b> <sup>ь</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>	
81.429	-0.819	<0.001	<0.001	0.080	
Triglycerides					
Konstanta	USC <sup>a</sup>	<b>р1</b> <sup>ь</sup>	р2 <sup>с</sup>	Adjusted R <sup>2</sup>	
-6.614	1.195	<0.001	<0.001	0.078	
Score of Mete	abolic Syndro	ome			
Konstanta	USC <sup>a</sup>	<b>р1</b> <sup>ь</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>	Commented [A39]: ?
-13.163	0.166	<0.001	<0.001	0.375	
	Konstanta 91.759 Blood Glucos Konstanta 83.454 HDL Konstanta 81.429 Triglycerides Konstanta -6.614 Score of Meta Konstanta	KonstantaUSC°91.7590.951Blood Glucose LevelsKonstantaUSC°83.4540.355HDLKonstantaUSC°81.429-0.819TriglyceridesKonstantaUSC°-6.6141.195Score of Metabolic SyndroKonstantaUSC°	Konstanta         USC <sup>a</sup> p1 <sup>b</sup> 91.759         0.951         <0.001	Konstanta         USC° $p1^b$ $p2^c$ 91.759         0.951         <0.001	$\begin{tabular}{ c c c c c } \hline Konstanta & USC^\circ & p1^b & p2^c & {}^dAdjusted R^2 \\ \hline g1.759 & 0.951 & <0.001 & <0.001 & 0.158 \\ \hline Blood Glucose Levels & & & & \\ \hline Konstanta & USC^\circ & p1^b & p2^c & Adjusted R^2 \\ \hline 83.454 & 0.355 & 0.005 & <0.001 & 0.043 \\ \hline HDL & & & & \\ \hline Konstanta & USC^\circ & p1^b & p2^c & Adjusted R^2 \\ \hline 81.429 & -0.819 & <0.001 & <0.001 & 0.080 \\ \hline Triglycerides & & & \\ \hline Konstanta & USC^\circ & p1^b & p2^c & Adjusted R^2 \\ \hline -6.614 & 1.195 & <0.001 & <0.001 & 0.078 \\ \hline Score of Metabolic Syndrome & & \\ \hline Konstanta & USC^\circ & p1^b & p2^c & Adjusted R^2 \\ \hline \end{tabular}$

Table 4. Anthropometric indicators most associated with metabolic components and metabolic

442 <sup>a</sup>U

440

1	Anthropometry indicators that are most related to metabolic profiles in female college	
2	stu <mark>dents</mark>	Commented [acer1]: Include author information
3		
4	Abstract	
5 6 7 9 10 11 12 13 14 15 16	Metabolic syndrome is not a disease, but is a set of several disorders and causes an increased risk of cardiovascular disease and diabetes mellitus complications. Several studies have shown that non-invasive approaches such as anthropometric measurements can be used for early detection of metabolic syndrome. This study aims to analyze the anthropometric indicators related to metabolic syndrome in female college students. This cross-sectional study with a total of 163 female college students, aged between 19 and 24 years old. Purposive sampling was used in this study. The independent variables in this study were the Waist-to-Height Ratio (WHR), Waist-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference. The dependent variable in this study is the metabolic syndrome component that has been converted into a metabolic syndrome score (cMetS). The analysis results showed that all anthropometric indicators, namely WHtR, BMI, SAD, waist circumference, hip circumference and WHR have a strong positive relationship with the metabolic syndrome score (p<0.001). BMI was the anthropometric indicator	Commented [A2]: revised
17	that is most associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood	
18	sugar (p<0.05), and HDL (p<0.001). Waist circumference was the anthropometric indicator that is	
19	most associated with triglycerides and metabolic syndrome score (p<0.001). Metabolic syndrome in	
20	female college students can be identified using anthropometric measurements, one of which is BMI	 Commented [A3]: revised
21	and WHR which are very easy to measure and efficient. BMI and WHR have the strongest relationship	

22 and can be used to detect early risk of metabolic syndrome in female college students.

23 Keywords: Adolescent; Anthropometric Indicator; Female; Metabolic Profile; Metabolic Syndrome.

- 24
- 25

## 26 1. Introduction

27 Metabolic syndrome is a set of body metabolic disorders such as dyslipidemia, hyperglycemia, 28 hypertension, and central obesity (Srikanthan *et al.*, 2016; Devi *et al.*, 2017; Christijani, 2019). 29 Metabolic syndrome is not a disease, but is a set of several disorders and causes an increased risk of 30 cardiovascular disease and diabetes mellitus complications. Some epidemiological studies have 31 shown that metabolic syndrome doubles the risk of cardiovascular diseases (Sri Rahayu and Maulina, 32 2017).

Indonesia as a developing country cannot be separated from the existing nutritional problems in the world, including the incidence of obesity and metabolic syndrome. Several studies found that the prevalence of metabolic syndrome keeps increasing every year. A study in China showed the prevalence of metabolic syndrome in adults was 24.2% (Li *et al.*, 2018). Another study indicated that the prevalence of metabolic syndrome in Indonesia was 21.66% (Herningtyas and Ng, 2019). In recent studies metabolic syndrome can be assessed using the continuous value of metabolic syndrome (CMets) or the metabolic syndrome score recommended by the American Diabetic Association of Commented [A4]: revised

Commented [A5]: revised

Diabetes. The metabolic syndrome score is a z-score resulting from the assessment of all components
 of the metabolic syndrome (Pratiwi, *et al.*, 2017). The advantages of using cMetS are (1) reducing
 dichotomization factors because cardiovascular disease is a progression of several components of
 the metabolic syndrome, (2) cMetS is more sensitive and less error-prone than categoric metabolic
 syndrome assessments, (3) increasing the statistical power (Okosun, Lyn, *et al.*, 2010).

45 Central obesity is one of the components of metabolic syndrome parameters. Central obesity is 46 associated with increased blood pressure, serum triglycerides, decreased HDL, and glucose 47 intolerance. Based on the National Basic Health Research (Riskesdas) in 2018, the prevalence of 48 obesity in adults was 21.8%, and the prevalence of central obesity at age of more than 15 years 49 increased from 26.6% in 2013 to 31% in 2018 (Badan Penelitian dan Pengembangan Kesehatan, 50 2018). Obesity is closely related to degenerative diseases. The Riskesdas 2018 showed that the 51 prevalence of stroke, diabetes mellitus, heart disease, and hypertension is higher in women than 52 men.

53 Several studies have shown that non-invasive approaches such as anthropometric measurements 54 can be used for the early detection of metabolic syndrome (Pratiwi, *et al.,* 2017). Anthropometric 55 measurements are described as the measurements of body dimensions and body composition to 56 assess nutritional status. The advantages of anthropometric measurements are relatively fast and 57 easy, as it can be performed using portable and calibrated instruments with standardized methods 58 (Rokhmah, et al., 2015). Some anthropometric measurements that can be used for early detection 59 of metabolic syndrome are Waist-to-Height Ratio (WHtR), waist-to-hip ratio (WHR), hip 60 circumference, Body Mass Index (BMI), Sagital Abdominal Diameter (SAD).

61 One of the anthropometric measurements which can be a parameter for central obesity is the ratio of waist circumference to height (WHtR). The instruments used in the measurement are 62 63 microtoise and measuring tape so that it takes a longer time. Studies on waist circumference have 64 been shown to have a strong correlation with abdominal fat deposits (Zhou et al., 2014). The 65 distribution of abdominal adipose tissue (central obesity) in adults is associated with a component of the metabolic syndrome (Rodea-Montero, et al., 2014). A study on adult subjects has shown that 66 67 people who have the same waist circumference but are shorter in height have a greater risk of developing metabolic syndrome than taller people (Zhou et al., 2014). Therefore, WHtR can be used 68 69 as a simple and effective anthropometric index to identify the metabolic risk associated with obesity 70 (Rodea-Montero, et al., 2014).

71 The Waist-To-Hip Ratio (WHR) is a measurement that may indicate central obesity (Karimah, 72 2018). The higher the WHR value, the higher the risk level for several metabolic diseases. The Waist-73 To-Hip Ratio is calculated by dividing the measurement of the waist circumference by the circumference of the hip. The cut-off points for WHR are  $\geq$ 1.0 for men and  $\geq$ 0.85 for women 74 75 (Rokhmah, et al., 2015). Individuals with a high waist and hip circumference will also have a higher 76 distribution of fat in their abdominal area. Irregular fats distribution in the abdominal area indirectly 77 causes higher triglyceride levels circulating in the blood, which will affect blood pressure 78 (Sumardiyono et al., 2018). WHR measurement is more sensitive in assessing the distribution of fat 79 in the body, especially in the abdomen. This measurement is three times better than BMI in reflecting the presence of harmful fats in the abdomen. Measurement of waist circumference is performed by 80 81 determining the lower part of arcus costae and crista iliaca (Sri Rahayu and Maulina, 2017).

Commented [A6]: revised

Commented [A7]: revised

Commented [A8]: revised

82 Body Mass Index (BMI) is a practical and easy measurement to perform, but it cannot distinguish 83 between fat mass, bone mass and muscle mass. BMI is calculated as body weight (kg) / height 84 squared (m<sup>2</sup>) (Okura et al., 2018). BMI can be used as the first measurement before any other 85 anthropometric measurements.

Sagittal Abdominal Diameter (SAD) or the height of the abdomen while the subjects are in a lying 86 87 position. This anthropometric measurement has not been widely used to measure fat tissue in the 88 abdominal area. SAD measurements using computed tomography or magnetic resonance imaging, 89 and are associated with components of metabolic syndrome. The measurements of SAD are taken 90 when the subject is lying down on the examination table with a naked upper body. SAD is related to 91 central obesity in individuals with obese and normal nutritional status. Furthermore, SAD is 92 associated with diabetes mellitus and a predictor of cardiovascular disease incidence, even when SAD 93 is measured in a standing position (Pajunen et al., 2013). Based on the above mentioned problems, 94 our study aims to analyze the anthropometric indicators related to metabolic syndrome in female 95 college students.

#### 96

101

104 105

#### 97 2. Materials and methods

#### 98 2.1 Design, location, and time

99 A cross-sectional study design and this research wasc onducted from March to July 2020. 100 Anthropometric and biochemical data were collected at the Cito Laboratory, Banyumanik Semarang with health protocols applied. This study was approved by the Medical/Health Research Bioethics 102 Commission, Faculty of Medicine, Sultan Agung Islamic University Semarang with Number No.296 /IX 103 /2020 /Bioethical Commission.

#### 2.2 Samplinas

106 This study was conducted during the SARS-CoV-2 outbreak, which later was named COVID-19 by 107 the WHO, so the registration for study participants was done online. Purposive sampling was used in 108 this study and the total number of subjects required was 163. Samples are selected based on 109 inclusion criteria, such as willing to be research subjects, female college students in Semarang City, aged 19-24 years in Semarang, not consuming alcohol, not smoking, willing to be a study participant 110 111 and willing to follow a series of study instructions. Exclusion criteria are subjects who withdraw and 112 those who are ill during the research study. Based on the exclusion criteria mentioned, no subjects 113 are included in the exclusion criteria. Subjects were asked to fill in personal data using a Google form; 114 and eligible subjects will be contacted by the researchers to plan a direct meeting.

115 The health protocol applied during the anthropometric and biochemical data collection process, 116 consist of the subject filled out a Covid sign/symptom screening questionnaire, the subject was 117 checked for temperature, washed his hands before entering the room, the distance between subjects was at least 1 meter, the subject and researcher used a mask and face shield. Researchers used gloves 118 119 and protective clothing. During the study, hand sanitizers were provided, anthropometric tools that 120 were on the subject's skin were wiped with alcohol. 121

122 2.3 Data collected

123 The independent variables in this study were the Waist-to-Height Ratio (WHtR), Waist-Hip Ratio 124 (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference. Weight Commented [A9]: revised

Commented [A10]: revised

Commented [A11]: revised Commented [ASUS12]: space Commented [A13R12]: revised Commented [A14]: revised

Commented [A15]: revised

125and height data were obtained through direct measurements using a digital stamp scale GEA brand126with an accuracy of 0.1 kg and microtoise with an accuracy of 0.1 cm.127circumference was measured using a measuring tape (Medline) to the nearest 1 mm and abdominal128height was measured using the Abawerk Schaffenburg abdominal129measurements were performed with the subject in a supine position on a flat surface with both knees130forming an angle of 90° (Firouzi *et al.,* 2018).131enumerators.

132The cut-off point used in this study refers to previous studies because it had been adjusted for the133Asian race (Rose *et al.*, 2020). Each anthropometric measurement is stated as "at risk" if the134individuals have  $\geq 0.50$  for WHtR (Zhang *et al.*, 2016),  $\geq 0.85$  for WHR (Rokhmah, *et al.*, 2015), > 19.3135cm for Sagital Abdominal Diameter (SAD) (Dieny *et al.*, 2020), and have the normal to overweight136BMI (18.5 - 25 kg/m²) or obese BMI ( $\geq 25.0$  kg/m²) (Susetyowati, 2016).

137 The dependent variable in this study is the metabolic syndrome component that has been 138 converted into a metabolic syndrome score (cMetS) with the cut-off point on cMetS> 2.21 (Rose et 139 al., 2020). The guidelines for metabolic syndrome in this study are taken from the National 140 Cholesterol Education Program-Adult Treatment Panel (NCEP-ATP III) 2005 which has been 141 frequently used in Indonesia. There are 5 parameters to assess metabolic syndrome: (1) fasting blood 142 glucose levels  $\geq$ 110 mg/dL, (2) triglyceride levels  $\geq$ 150 mg/dL (3) HDL cholesterol levels <50 mg/dL, 143 (4) central obesity in women with waist circumference ≥80 cm, and (5) systolic and diastolic blood 144 pressures  $\geq$ 130 mmHg and  $\geq$ 85 mmHg, respectively (Soewondo *et al.*, 2010). The calculation of the 145 metabolic syndrome score (cMetS) was done in the following steps: (1) after measuring all 146 parameters of the metabolic syndrome, standardisation was carried out to obtain a Z-score; (2) the blood pressure must be converted into Mean Arterial Blood (MAP) by dividing the difference 147 148 between systolic and diastolic blood pressure by three and summed with the diastolic blood 149 pressure; (3) the HDL cholesterol standardization results were multiplied by (-1) because the 150 parameter was inversely related to the risk of metabolic syndrome; (4) All Z-scores were added to 151 obtain the cMetS values; (5) The final step was to compare the cMetS values with the cut-off point 152 of ≥2,21 (Eisenmann et al., 2010; Okosun, Boltri, et al., 2010; Rose et al., 2020). The subjects were 153 instructed to do fasting for at least 8 hours; only drinking water was permitted.

154 Other than the cMetS score, metabolic syndrome risk can also be assessed from the classification 155 of metabolic types. This classification combines the internal and external signs of the body such as 156 biochemical parameters, the ratio of subcutaneous fat to abdominal fat, and blood pressure (Prybyla 157 O, 2020). The main phenotypes that reflect the possible combination of metabolic profile and the 158 degree of obesity are metabolic healthy obese weight, metabolic healthy normal weight, metabolic 159 unhealthy normal weight, and metabolic unhealthy normal weight.

#### 2.4 Data analysis

160 161

All data were analyzed using computer programs and statistical analyses were performed using SPSS Statistical software version 22. Univariate analysis was used to describe subjects characteristic. The distribution of data for normality was assessed using the Kolmogorov Smirnov test before statistical. The relationship of anthropometric indicators with metabolic profile (Blood Pressure, Triglycerides, Blood Sugar, HDL and metabolic syndrome scores) were determined using the Person correlation test. Furthermore, Anthropometric indicators that are most related to the metabolic component and metabolic syndrome score were analyzed using the Multiple Linear Regression test. Commented [A16]: revised

Commented [ASUS17]: For what? Commented [A18R17]: revised Commented [A19]: revised

Commented [A20]: revised

Commented [A21]: revised

#### 170 3. Results and Discussion

169

171The subject characteristics measured in female student aged 19-24 years include age,172anthropometric indicators, and metabolic syndromes. Table 1 shows the characteristics of the study173subjects. The mean of WHtR value in this study was 0.51. Meanwhile, the mean of WHR was 0.80; the174mean of BMI was 24.04 kg/m²; the mean of SAD was 16.79 cm; and the mean of waist circumference175was 79.44 cm.

176 Table 2 shows various nutritional status of the subjects based on BMI. We found that 43.6% of the 177 subjects had normal BMI, 17.2% were overweight and 35.6% were obese. Based on the WHtR 178 anthropometric indicator, 72.4% of subjects were at risk of having obesity; based on WHR, 22.1% had 179 central obesity; based on BMI, 35.6% were obese; based on SAD 12.3% of the subjects were at risk; 180 and based on waist circumference 55.2% had central obesity. According to the metabolic profile that 181 was assessed, 16.6% had high Fasting Blood Glucose levels, 8.6% had hypertriglycerides, 17.2% had 182 low HDL, 16.6% had high systolic blood pressure, and 21.5% had high diastolic blood pressure. In 183 addition, we found 33.1% of the subjects had high metabolic syndrome (cMetS) scores. This 184 proportion was similar to the assessment based on the metabolic type of unhealthy subjects (subjects 185 who had  $\geq$  3 risk factors of the metabolic profile), which was 33.7%. Moreover, two subjects had five 186 risk factors: abdominal obesity, hypertension, hyperglycemia, hypertriglycerides, and low HDL.

187 The objective of this study was to determine the anthropometric indicators associated with 188 metabolic syndromes in female students. The study included 163 female students aged 19-24 years. 189 The students are in their late adolescents who begin to have an independent life. Inappropriate and 190 unhealthy eating behavior will have an impact on the student's nutritional status. Excessive nutritional 191 status and obesity will affect student's body metabolism. Based on the study results, 33.1% of the 192 subjects had a high metabolic syndrome (cMetS) score. In line with the previous study conducted in 193 2019 on 18-to-21-year-old students at Universitas Diponegoro, 20% of the subjects had high cMetS 194 (Rose et al., 2020). Meanwhile, a study conducted by Pratiwi et al in 2017 using secondary data from 195 the National Basic Health Research 2013 found that 19.98% of adolescents aged 15-24 years had high 196 cMetS (Pratiwi, et al., 2017). Therefore, we conclude that there is a trend of Metabolic Syndrome 197 Score (cMetS) among young women in Semarang.

198 The assessment of metabolic syndrome using a continuous type (scoring) rather than using a 199 dichotomy or binary ("yes" and "no") is recommended (Christijani, 2019). An adolescent can be 200 diagnosed with metabolic syndrome if their Metabolic Syndrome Score (cMetS) >2.21 (Pratiwi, et al., 201 2017). Anthropometric indicators used in this study are Waist and Height Ratio (WHtR), Waist-to-Hip 202 Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and Waist Circumference. 203 Based on the correlation analyses, all anthropometric indicators have a significant positive 204 relationship with the Metabolic Syndrome Score (cMetS). Furthermore, the multivariate analyses 205 show that the anthropometric indicators of BMI and WHR are strongly associated with cMetS.

206If we are considering metabolic type based on nutritional status (subjects with non-obese BMI207(<25kg/m²) with metabolic healthy and metabolic unhealthy and subjects with obese BMI (>25kg/m²)208with metabolic healthy and metabolic unhealthy), subjects are categorized as metabolic unhealthy209(experiencing metabolic syndrome) if they fulfil ≥ 3 risk factors including high waist circumference,210blood pressure, GDP Fasting blood glucose and triglyceride levels, and low HDL levels. Based on these211criteria, we found that 10.4% of the subjects had metabolic unhealthy normal weight (MUNW) and21223.3% of the subjects had metabolic unhealthy obesity weight (MUOW). In non-obese subjects, 54%

Commented [A22]: revised

Commented [A23]: revised

Commented [A24]: revised
Commented [A25]: revised

213 of them were metabolic healthy. Our study also shows that 10.4% of the subjects were classified as 214 metabolic unhealthy normal weight (MUNW). The subjects' BMI in this category is in the normal range 215 but has a high percentage of body fat that makes them at high risk of developing metabolic disorders (Eckel et al., 2015; Suliga et al., 2015). Several recent cohort studies have shown a greater risk of type 216 217 II diabetes mellitus in individuals with MUNW compared to individuals with MHNW (Ärnlöv et al., 218 2011; Hadaegh et al., 2011; Aung et al., 2014; Jung et al., 2014; Hinnouho et al., 2015). Other studies 219 have shown that women with the MUNW type have a long-term impact of an increased risk of cardiovascular diseases such as higher blood pressure, triglyceride and glucose levels as well as lower 220 221 levels of adiponectin, HDL, and LDL compared to women with the MHNW type (Kim et al., 2013).

In this study, 23.3% of the subjects belonged to the Metabolic Unhealthy Obese Weight (MUOW)
 type. Subjects with this metabolic type have an obese BMI and have a high risk of developing
 metabolic disorders. A study conducted in Japan on 29,564 subjects showed that individuals with
 MUOW had a greater risk of developing type II diabetes mellitus compared to individuals with MHOW
 (Heianza et al., 2015).

227 We also found that 12.3% of the subjects were categorized as metabolic healthy obese weight 228 (MHOW). Individuals in this metabolic type have an obese BMI but do not show any metabolic risks. 229 Given the impact of obesity in relation to the risk of metabolic diseases, various studies have been 230 conducted to examine the long-term effects of MHOW. Individuals with MHOW had a different fat 231 distribution pattern (less ectopic and visceral fat), and lower inflammatory markers (Samocha-Bonet 232 et al., 2014). Other studies also have shown that women with MHOW had lower blood pressure, 233 triglyceride levels, and glucose levels, but higher levels of HDL, adiponectin, and LDL compared to 234 women with MUNW (Kim et al., 2013). This condition was associated with good diet quality in individuals with MHOW. Based on National Health and Nutrition Examination Surveys (NHANES) 235 236 data, Camhi et al. (2015) examined the quality of diet in obese subjects, and found that adolescents 237 and adult women with the MHOW metabolic type had higher diet quality scores due to high intake 238 of fruit, whole grains, meat, and nuts.

239 Table 3 and Table 4 show the results of statistical analyses on anthropometric indicators related 240 to the metabolic syndromes. Table 3 shows the bivariate statistical analysis using the Pearson 241 correlation test. The analysis results showed that all anthropometric indicators, namely WHtR, BMI, 242 SAD, waist circumference, hip circumference and WHR have a strong positive relationship with the 243 metabolic syndrome score (p<0.001), which means that the higher the anthropometric value, the 244 higher the metabolic syndrome score. In addition, the analysis on the relationship between 245 anthropometric indicators and each metabolic profile revealed that almost all of the independent 246 variables (WHtR, waist and hip circumference, WHR, BMI, and SAD) were associated with each 247 metabolic profile, such as baseline systolic pressure, diastolic blood pressure, triglyceride levels, blood sugar levels, and HDL. Only WHR-that was not associated with diastolic blood pressure (p>0.005). 248

Table 4 shows the results of the analysis using multiple linear regression to determine anthropometric indicators that are most associated with each metabolic profile and metabolic syndrome score. The results showed that BMI was the anthropometric indicator that is most associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood sugar (p<0.05), and HDL (p<0.001). In addition, waist circumference was the anthropometric indicator that is most associated with triglycerides and metabolic syndrome score (p<0.001). Based on the Adjusted R<sup>2</sup> value on the metabolic syndrome score, we found that 37.5% of the metabolic syndrome score was

Commented [A26]: revised

related to anthropometric indicators, such as WHtR, waist and hip circumference, WHR, BMI, and
 SAD. The rest may be influenced by other variables that are not included in this study.

The correlation test results indicated that all anthropometric indicators had a positive 258 259 relationship with the metabolic syndrome scores with p <0.001. Meanwhile, the regression analyses 260 show that BMI and WHR were inversely related to cMetS. This is in line with research who stated that 261 an increase in the WHR value could be associated with the risk of metabolic syndrome in children 262 and adolescents in Florida (Moore et al., 2015). Another study stated that there was a strong 263 relationship between overweight and obese adolescents with metabolic syndrome (Al-Bachir and 264 Bakir, 2017). Furthermore, a study on the adolescents in South Africa found that central obesity as 265 measured by the hip circumference could lead to an increased risk of cardiovascular diseases and 266 death. Therefore, hip circumference and waist circumference can be used to predict the risk of 267 cardiovascular diseases and death in the future (Cameron et al., 2012).

268 Body Mass Index (BMI) is the most widely used indicator of measurement in epidemiological 269 studies and is used as a substitute for evaluating body composition. However, BMI cannot distinguish 270 fat from fat mass and lean mass, and it fails to show the presence of adipose and body fat distribution 271 (Ofer et al., 2019; Leone et al., 2020). However, the BMI cut-offs for metabolic syndrome has not yet 272 been determined (Ofer et al., 2019). Obesity in adolescents is generally assessed using a BMI of ≥25.0 273 kg/m<sup>2</sup>. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m<sup>2</sup>) and 274 obesity (≥25.0 kg/m<sup>2</sup>), and we found that 35.6% of the subjects were obese. The finding is in line with 275 the research on the subject of students at Universitas Diponegoro aged 18-21 years. They found that 276 40% of their study population had obesity level I and 36.3% had obesity level II (Rose et al., 2020).

277 Abdominal obesity is often assessed to determine a metabolic syndrome in people. One of the 278 indicators used to measure abdominal obesity is the Waist-to-Hip Ratio (WHR) which is calculated by 279 dividing the waist circumference and the hip circumference. Measurement of waist circumference is 280 more sensitive in assessing the distribution of body fat in the abdominal wall, which is also a 281 component in the metabolic syndrome. The limit of the WHR value for female is ≥ 0.85 (Rokhmah, *et* 282 al., 2015). This study shows that every 1% increase in the WHR value will increase the cMetS value 283 by 10.411. Hip circumference is also an indicator that has a strong correlation with cMetS, but many 284 studies have used it as a ratio along with waist circumference for assessing a person's central obesity 285 status.

#### 287 4. Conclusion

288 Metabolic syndrome in female students can be identified using anthropometric measurements, one 289 of which is BMI and WHR which are very easy to measure and efficient. BMI and WHR have the 290 strongest relationship and can be used to detect early risk of metabolic syndrome in female college 291 students.

292

286

293 Conflict of interest - Disclose any potential conflict of interest appropriately.

294 The authors declare no conflict of interest.

295 Acknowledgments

Commented [A27]: revised

Commented [A28]: revised

Commented [A29]: revised

- 296 The authors would like to thank all the subjects who participated in this study. We would also like to
- 297 express our gratitude to The Ministry of Research, Technology and Higher Education, Indonesia" was
- 298 funded by the "Hibah Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) 2019.

#### 299 References

- Al-Bachir, M. and Bakir, M. A. (2017). Predictive value of body mass index to metabolic syndrome risk
   factors in Syrian adolescents. *Journal of Medical Case Reports*, 11(1). doi: 10.1186/s13256-017-1315 2.
- Ärnlöv, J., Sundström, J., Ingelsson, E. and Lind, L. (2011). Impact of BMI and the metabolic syndrome on
   the risk of diabetes in middle-aged men. *Diabetes Care*, 34(1), 61–65. doi: 10.2337/dc10-0955.
- Aung, K. K., Lorenzo, C., Hinojosa, M. A. and Haffner, S. M. (2014). Risk of developing diabetes and
   cardiovascular disease in metabolically unhealthy normal-weight and metabolically healthy obese
   individuals. *Journal of Clinical Endocrinology and Metabolism*, 99(2), 462–468. doi: 10.1210/jc.2013 2832.
- Badan Penelitian dan Pengembangan Kesehatan. (2018). *Riset Kesehatan Dasar (RISKESDAS) 2018*.
  Jakarta, Indonesia.
- Cameron, A. J., Magliano, D. J., Shaw, J. E., Zimmet, P. Z., Carstensen, B., Alberti, K. G. M. M., Tuomilehto,
   J., Barr, E. L. M., Pauvaday, V. K., Kowlessur, S. and Söderberg, S. (2012). The influence of hip
   circumference on the relationship between abdominal obesity and mortality. *International Journal of Epidemiology*, 41(2), 484–494. doi: 10.1093/ije/dyr198.
- Camhi, S. M., Whitney Evans, E., Hayman, L. L., Lichtenstein, A. H. and Must, A. (2015). Healthy eating
   index and metabolically healthy obesity in U.S. adolescents and adults. *Preventive Medicine*, 77, 23–
   27. doi: 10.1016/j.ypmed.2015.04.023.
- Christijani, R. (2019). Determination of Diagnosis of Metabolic Syndrome based on Assessment of
   Metabolic Syndrome and NCEP ATP-III Score in Adolescent. *The Journal of Nutrition and Food Research*,
   42(1), 21–28. doi: 10.22435/pgm.v42i1.2418.
- Devi, R., Manhas, S., Prasad, S., Sharma, S., Bhaskar, N. and Mahajan, S. (2017). Short Review of Metabolic
   Syndrome. *International Journal of Research and Review*, 4(2), p. 29.
- Dieny, F. F., Setyaningsih, R. F., Fitranti, D. Y., Jauharany, F. F., Putra, Y. D. and Tsani, A. F. A. (2020).
   Abdominal diameter profiles have relationship with insulin resistance in obese female adolescents.
   *Electronic Journal of General Medicine*, 17(5), p. em219. doi: 10.29333/ejgm/7882.
- Eckel, N., Mühlenbruch, K., Meidtner, K., Boeing, H., Stefan, N. and Schulze, M. B. (2015). Characterization
   of metabolically unhealthy normal-weight individuals: Risk factors and their associations with type 2
   diabetes. *Metabolism: Clinical and Experimental*, 64(8), 862–871. doi: 10.1016/j.metabol.2015.03.009.
- Eisenmann, J. C., Laurson, K. R., Dubose, K. D., Smith, B. K. and Donnelly, J. E. (2010). Construct validity of
   a continuous metabolic syndrome score in children. *Diabetology and Metabolic Syndrome*, 2(1). doi:
   10.1186/1758-5996-2-8.
- Firouzi, S. A., Tucker, L. A., LeCheminant, J. D. and Bailey, B. W. (2018). Sagittal abdominal diameter, waist
   circumference, and BMI as predictors of multiple measures of glucose metabolism: An NHANES
   investigation of US adults. *Journal of Diabetes Research*, 2018, 1–14. doi: 10.1155/2018/3604108.
- Hadaegh, F., Bozorgmanesh, M., Safarkhani, M., Khalili, D. and Azizi, F. (2011). Predictability of body mass
   index for diabetes: Affected by the presence of metabolic syndrome?. *BMC Public Health*, 11(1), p. 383.
   doi: 10.1186/1471-2458-11-383.
- Heianza, Y., Kato, K., Kodama, S., Ohara, N., Suzuki, A., Tanaka, S., Hanyu, O., Sato, K. and Sone, H. (2015).
   Risk of the development of Type 2 diabetes in relation to overall obesity, abdominal obesity and the
- 340 clustering of metabolic abnormalities in Japanese individuals: Does metabolically healthy overweight
- really exist? The Niigata Wellness Study. *Diabetic Medicine*, 32(5), 665–672. doi: 10.1111/dme.12646.

242	Herningtway F. H. and Ng. T. S. (2010). Dravalance and distribution of matchalic condrama and its		
342 343	Herningtyas, E. H. and Ng, T. S. (2019). Prevalence and distribution of metabolic syndrome and its components among provinces and ethnic groups in Indonesia. <i>BMC Public Health</i> , 19(1), p. 377. doi:		
344	10.1186/s12889-019-6711-7.		
345	Hinnouho, G. M., Czernichow, S., Dugravot, A., Nabi, H., Brunner, E. J., Kivimaki, M. and Singh-Manoux, A.		
346	(2015). Metabolically healthy obesity and the risk of cardiovascular disease and type 2 diabetes: The		
347	Whitehall II cohort study. European Heart Journal, 36(9), 551–559. doi: 10.1093/eurheartj/ehu123.		
348	Jung, H. S., Chang, Y., Eun, Y. K., Kim, C. W., Choi, E. S., Kwon, M. J., Cho, J., Zhang, Y., Rampal, S., Zhao, D.,		
349	Soo, K. H., Shin, H., Guallar, E. and Ryu, S. (2014). Impact of body mass index, metabolic health and		
350	weight change on incident diabetes in a Korean population. <i>Obesity</i> , 22(8), 1880–1887. doi:		
351	10.1002/oby.20751.		
352	Karimah, M. (2018). Rasio Lingkar Pinggal-panggul Memiliki Hubungan Paling Kuat dengan Kadar Glukosa		
353	Darah'. Jurnal Berkala Epidemiologi, 6(3), 219–226.		
354	Kim, M., Paik, J. K., Kang, R., Kim, S. Y., Lee, S. H. and Lee, J. H. (2013). Increased oxidative stress in normal-		
355	weight postmenopausal women with metabolic syndrome compared with metabolically healthy		
356	overweight/obese individuals. <i>Metabolism: Clinical and Experimental</i> , 62(4), 554–560. doi:		
357	10.1016/j.metabol.2012.10.006.	C	
358	Leone, A. <i>et al.</i> (2020). Evaluation of different adiposity indices and association with metabolic syndrome		Commented [acer30]: please list all the authors
359	risk in obese children: Is there a winner?. <i>International Journal of Molecular Sciences</i> , 21(11), p. 4083.		
360	doi: 10.3390/ijms21114083.	ſ	
361 362	Li, Y. <i>et al.</i> (2018). Metabolic syndrome prevalence and its risk factors among adults in China: A nationally representative cross-sectional study. <i>PLoS ONE</i> , 13(6), p. e0199293. doi:		Commented [acer31]: list all authors
363	10.1371/journal.pone.0199293.		
364	Moore, L. M. <i>et al.</i> (2015). Analysis of Pediatric Waist to Hip Ratio Relationship to Metabolic Syndrome	_	Commented [acer32]: list all authors
365	Markers. Journal of Pediatric Health Care, 29(4), 319–324. doi: 10.1016/j.pedhc.2014.12.003.		commented [acersz]: list all authors
366	Ofer, K. <i>et al.</i> (2019). Normal body mass index (BMI) can rule out metabolic syndrome: An Israeli cohort		
367	study. <i>Medicine</i> , 98(9), p. e14712. doi: 10.1097/MD.000000000014712.		
368	Okosun, I. S., Boltri, J. M., et al. (2010). Continuous metabolic syndrome risk score, body mass index		
369	percentile, and leisure time physical activity in American children. Journal of Clinical Hypertension,		
370	12(8), 636–644. doi: 10.1111/j.1751-7176.2010.00338.x.		
371	Okosun, I. S., Lyn, R., et al. (2010). Validity of a Continuous Metabolic Risk Score as an Index for Modeling		
372	Metabolic Syndrome in Adolescents. Annals of Epidemiology, 20(11), 843-851. doi:		
373	10.1016/j.annepidem.2010.08.001.		
374	Okura, T. et al. (2018). Body mass index ≥23 is a risk factor for insulin resistance and diabetes in Japanese		
375	people: A brief report. <i>PLOS ONE</i> . Edited by P. Bjornstad, 13(7), p. e0201052. doi:		
376	10.1371/journal.pone.0201052.		
377	Pajunen, P. et al. (2013). Sagittal abdominal diameter as a new predictor for incident diabetes. Diabetes	C	
378	<i>Care</i> , 36(2), 283–288. doi: 10,2337/dc11-2451.		Commented [acer33]: list all authors
379	Pratiwi, Z. A., Hasanbasri, M. and Huriyati, E. (2017). Penentuan titik potong skor sindroma metabolik		
380	remaja dan penilaian validitas diagnostik parameter antropometri: analisis Riskesdas 2013. Jurnal Gizi		
381	Klinik Indonesia, 14(2), p. 80. doi: 10.22146/ijcn.25590.		
382	Prybyla, O. (2020). Metabolic phenotyping: is it so important?. Journal of Cognitive Neuropsychology.		
383	iMedPub., 4(1), 1-3.		
384 385	Rodea-Montero, E. R., Evia-Viscarra, M. L. and Apolinar-Jiménez, E. (2014). Waist-to-height ratio is a better anthropometric index than waist circumference and BMI in predicting metabolic syndrome among		
386	obese mexican adolescents. International Journal of Endocrinology, 2014, 195407. doi:		
387	10.1155/2014/195407.		
388	Rokhmah, F. D., Handayani, D. and Al-Rasyid, H. (2015). Korelasi lingkar pinggang dan rasio lingkar		

pinggang-panggul terhadap kadar glukosa plasma menggunakan tes toleransi glukosa oral. Jurnal Gizi

#### 390 *Klinik Indonesia*, 12(1), 28–35. doi: 10.22146/ijcn.22425.

- Rose, S., Dieny, F. F., Nuryanto, N., Tsani, A. F. A. (2020). The correlation between waist-to-height ratio
   (wHtR) and second to fourth digit ratio (2D:4D) with an increase in metabolic syndrome scores in obese
   adolescent girls. *Electronic Journal of General Medicine*, 17(3), p. em211. doi: 10.29333/ejgm/7872.
- Samocha-Bonet, D., Dixit, V. D., Kahn, C. R., Leibel, R. L., Lin, X., Nieuwdorp, M., Pietiläinen, K. H., Rabasa Lhoret, R., Roden, M., Scherer, P. E., Klein, S., Ravussin, E. (2014). Metabolically healthy and unhealthy
   obese The 2013 stock conference report. *Obesity Reviews*, 15(9), 697–708. doi: 10.1111/obr.12199.
- Soewondo, P., Purnamasari, D., Oemardi, M., Waspadji, S., Soegondo, S. (2010). Prevalence of Metabolic
   Syndrome Using NCEP/ATP III Criteria in Jakarta, Indonesia: The Jakarta Primary Non-communicable
   Disease Risk Factors Surveillance 2006. Acta Med Indones, 42(4), 199–203.
- Sri Rahayu, M. and Maulina, M. (2017). Hubungan Rasio Lingkar Pinggang dan Lingkar Pinggul dengan
   Penyakit Jantung Koroner. Jurnal Aceh Medika, 1(1), 1–10. Available at:
   www.jurnal.abulyatama.ac.id/acehmedika (Accessed: 8 April 2021).
- Srikanthan, K., Feyh, A., Visweshwar, H., Shapiro, J. I., Sodhi, K.(2016). Systematic review of metabolic
  syndrome biomarkers: A panel for early detection, management, and risk stratification in the West
  Virginian population. *International Journal of Medical Sciences*, 13(1), 25–38. doi: 10.7150/ijms.13800.
- Suliga, E., Kozieł, D., Cieśla, E., Głuszek, S. (2015). Association between dietary patterns and metabolic
  syndrome in individuals with normal weight: A cross-sectional study. *Nutrition Journal*, 14(1), p. 55.
  doi: 10.1186/s12937-015-0045-9.
- Sumardiyono, S., Pamungkasari, E. P., Mahendra, A. G., Utomo, O. S., Mahajana, D., Cahyadi, W. R., Ulfia,
  M. (2018). Hubungan Lingkar Pinggang dan Lingkar Panggul dengan Tekanan Darah pada Pasien
  Program Pengelolaan Penyakit Kronis (Prolanis). *Smart Medical Journal*, 1(1), p. 26. doi:
  10.13057/smj.v1i1.24504.
- 413 Susetyowati, S. (2016). Gizi Remaja, in *Ilmu Gizi: Teori dan Aplikasi*. Jakarta, Indonesia: EGC, 160–164.
- Zhang, Y. X., Wang, Z. X., Chu, Z. H., Zhao, J. S. (2016). Profiles of body mass index and the nutritional
  status among children and adolescents categorized by waist-to-height ratio cut-offs. *International Journal of Cardiology*, 223, 529–533. doi: 10.1016/j.ijcard.2016.07.303.
- Zhou, D., Yang, M., Yuan, Z. P., Zhang, D. D., Liang, L., Wang, C. L., Zhang, S., Zhu, H. H., Lai, M. D., Zhu, Y.
  M. (2014) . Waist-to-Height Ratio: A simple, effective and practical screening tool for childhood obesity
  and metabolic syndrome. *Preventive Medicine*, 67, 35–40. doi: 10.1016/j.ypmed.2014.06.025.
- 421

**Commented [acer34]:** replace with 'and' a lot of the 'and' are missing from the authors list. Please include to the references below

Commented [acer35]: Journal names should be written in full Apply to all references

# Tables and Figures – 1 PAGE 1 TABLE/FIGURE. PLACE ALL TABLES AND FIGURES AT THE END OF THE

## 423 MANUSCRIPT BODY AFTER THE REFERENCES

Table 1. Minimum, Maximu	ım, Average a	and Standard	Deviation			
Variabel	Minimum	Maximum	Mean	SD	_	
Anthropometric Indicators					_	
WHtR <mark>(ratio)</mark>	0.37	0.71	0.51	0.07		
WHR (ratio <mark>)</mark>	0.67	0.96	0.80	0.06	Commented [A36]:	REVISE
BMI (kg/m²)	15.81	39.30	24.04	4.72		
Sagital Abdominal Diameter (cm)	11.35	25.50	16.79	2.42		
Hip Circumference (cm)	80.60	138.45	98.96	9.30		
Waist Circumference (cm)	58.00	112.10	79.44	10.78		
Metabolic Profiles						
Blood Glucose Levels (mg/dL)	66.00	110.00	92.00	7.59		
Trygliceride Levels (mg/dL)	29.00	309.00	88.35	44.68		
Cholesterol HDL Levels (mg/dL)	36.00	109.00	61.73	26.43		
Sistolic Blood Pressure (mmHg)	84.00	144.00	114.63	11.13		
Diastolic Blood Pressure (mmHg)	55.00	178.00	82.40	55.52		
cMetS (Score of Metabolic Syndrome)	-7.10	11.93	0.01	2.90		

Characteristics	n	%		
Anthropometric				
Body Mass Index (BMI)				
Underweight (< 18.5 kg/m <sup>2</sup> )	6	3.7		
Normal (18.5 – 22.9 kg/m <sup>2</sup> )	71	43.6		
Overweight (23-24.9 kg/m <sup>2</sup> )	28	17.2		
Obese ( $\geq 25.0 \text{ kg/m}^2$ )	58	35.6		
Waist Height Ratio (WHtR)				
Normal (<0.50)	45	27.6		
At Risk (≥0.50)	118	72.4	_	Commented [A37]: revised
Waist Hip Ratio				commented [AS7]. revised
Normal (<0.85)	127	77.9		
Central Obesity (≥0.85)	36	22.1		
Sagital Abdominal Diameter (SAD)				
Normal (≤19.3 cm)	143	87.7		
At Risk (>19.3 cm)	20	12.3		Commented [A38]: revised
Wait Circumference				commented [ASO]. revised
Normal (<80 cm)	73	44.8		
Obese (≤80 cm)	90	55.2		
Metabolic Profiles				
Blood Glucose Levels				
Normal (<110 mg/dL)	136	83.4		
High (≥110 mg/dL)	27	16.6		
Triglycerides	27	10.0		
Normal (<150 mg/dL)	149	914		
High ( $\geq 150 \text{ mg/dL}$ )	14	8.6		
Cholesterol HDL	1.	0.0		
Normal (≥150 mg/dL)	135	82.8		
Low (<150 mg/dL)	28	17.2		Commented [A39]: revised
Sistolic Blood Pressure			<	
Normal (<130 mg/dL)	136	83.4		Commented [A40]: revised
High ( $\geq 130 \text{ mg/dL}$ )	27	16.6		
Diastolic Blood Pressure		2010		
Normal (<85 mg/dL)	128	78.5		
High ( $\geq$ 85 mg/dL)	35	21.5		
cMetS (Score of Metabolic Syndrome)				
Normal (<2.21)	109	66.9		
At Risk (≥2.21)	54	33.1		
Metabolic Types	2.			Commented [A41]: revised
Metabolic Unhealthy Normal Weight (MUNW)	17	10.4		Commented [A41]. Tevised
Metabolic Healthy Normal Weight (MHNW)	88	54		
Metabolic Unhealthy Obese Weight (MUOW)	38	23.3		
Metabolic Healthy Obese Weight (MHOW)	20	12.3		

440	ingryceniues, Blood Sugar, HDL and metabolic syndrome scores)											
Variable	Sistolic	BP	Distolic	BP	TG		Blood Glucose		lood Glucose HDL		cMetS	
	r	р	r	р	r	р	r	р	r	р	r	р
WHtR	0.358	<0.001	0.306	<0.001	0.289	<0.001	0.210	0.007	-0.266	0.001	0.599	<0.001
BMI	0.370	<0.001	0.313	<0.001	0.315	<0.001	0.221	0.005	-0.292	<0.001	0.600	<0.001
SAD	0.352	<0.001	0.284	<0.001	0.278	<0.001	0.191	0.015	-0.264	0.001	0.575	<0.001
WC	0.377	<0.001	0.284	<0.001	0.295	<0.001	0.212	0.005	-0.243	0.002	0.616	<0.001
HC	0.369	<0.001	0.332	<0.001	0.302	<0.001	0.179	0.002	-0.273	<0.001	0.581	<0.001
WHR	0.244	0.002	0.128	0.104	0.194	0.013	0.172	0.028	-0.149	0.048	0.415	<0.001
447												

Table 3.The Relationship between Anthropometric Indicators and Metabolic Profiles (Blood Pressure,
 Triglycerides, Blood Sugar, HDL and metabolic syndrome scores)

		syndrome	scores		
Variable	Sistolic BP				
	<mark>Constant</mark>	USC <sup>a</sup>	<b>р1</b> <sup>ь</sup>	р2 <sup>с</sup>	<sup>d</sup> Adjusted R <sup>2</sup>
BMI	91.759	0.951	<0.001	<0.001	0.158
	Blood Gluce	ose Levels			
	Constant	USC <sup>a</sup>	<b>р1</b> <sup>ь</sup>	р2 <sup>с</sup>	Adjusted R <sup>2</sup>
BMI	83.454	0.355	0.005	<0.001	0.043
	HDL				
	Constant	USC <sup>a</sup>	<b>р1</b> <sup>ь</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>
BMI	81.429	-0.819	<0.001	<0.001	0.080
	Triglyceride	25			
	Constant	USC <sup>a</sup>	<b>р1</b> <sup>ь</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>
WC	-6.614	1.195	<0.001	<0.001	0.078
	Score of Me	etabolic Syna	Irome		
	Constant	USC <sup>a</sup>	<i>р</i> 1 <sup>ь</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>
WC	-13.163	0.166	<0.001	<0.001	0.375
<sup>a</sup> Unstandardiz	ed Coefficient, <sup>b</sup> p-v	alue, <sup>c</sup> p F-Te	st (ANOVA), <sup>d</sup>	coefficient of	determination

Table 4. Anthropometric indicators most associated with metabolic components and metabolic

451

449

450

eff

Commented [ASUS42]: Translate in english

Commented [A43R42]: revised

1	Anthropometry indicators that are most related to metabolic profiles in female college	
2	stu <mark>dents</mark>	Commented [acer1]: Include author information
3	<sup>1,2</sup> *Dieny, F.F., <sup>1</sup> Rose S., <sup>1,2</sup> Tsani, A.F.A., <sup>1</sup> Jauharany, F.F., <sup>1,2</sup> Fitranti, D.Y.	Commented [A2R1]: what does this revision mean?
4	<sup>1</sup> Department of Nutrition Science, Faculty of Medicine, Universitas Diponegoro, Indonesia	
5	<sup>2</sup> Center of Nutrition Research (CENURE), Faculty of Medicine, Universitas Diponegoro, Indonesia	
6		
7	*Corresponding author: <u>fillahdieny@gmail.com</u>	
8		
9	ORCID ID Author 1: 0000-0001-6071-8901	
10	ORCID ID Author 2: 0000-0002-1898-1842	
11	ORCID ID Author 3: 0000-0002-3407-5188	
12	ORCID ID Author 4: 0000-0001-9471-9419	
13	ORCID ID Author 5: 0000-0002-1656-9563	Commented [A3]: revised
14		
15	Abstract	
16	Metabolic syndrome is not a disease, but is a set of several disorders and causes an increased risk of	

17 cardiovascular disease and diabetes mellitus complications. Several studies have shown that non-18 invasive approaches such as anthropometric measurements can be used for early detection of 19 metabolic syndrome. This study aims to analyze the anthropometric indicators related to metabolic 20 syndrome in female college students. This cross-sectional study with a total of 163 female college 21 students, aged between 19 and 24 years old. Purposive sampling was used in this study. The 22 independent variables in this study were the Waist-to-Height Ratio (WHR), Waist-Hip Ratio (WHR), 23 Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference. The dependent 24 variable in this study is the metabolic syndrome component that has been converted into a metabolic 25 syndrome score (cMetS). The analysis results showed that all anthropometric indicators, namely 26 WHtR, BMI, SAD, waist circumference, hip circumference and WHR have a strong positive 27 relationship with the metabolic syndrome score (p<0.001). BMI was the anthropometric indicator 28 that is most associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood 29 sugar (p<0.05), and HDL (p<0.001). Waist circumference was the anthropometric indicator that is 30 most associated with triglycerides and metabolic syndrome score (p<0.001). Metabolic syndrome in 31 female college students can be identified using anthropometric measurements, one of which is BMI 32 and WHR which are very easy to measure and efficient. BMI and WHR have the strongest relationship 33 and can be used to detect early risk of metabolic syndrome in female college students.

34 **Keywords:** Adolescent; Anthropometric Indicator; Female; Metabolic Profile; Metabolic Syndrome.

35

Commented [A4]: revised

#### 37 1. Introduction

36

Metabolic syndrome is a set of body metabolic disorders such as dyslipidemia, hyperglycemia, hypertension, and central obesity (Srikanthan *et al.*, 2016; Devi *et al.*, 2017; Christijani, 2019). Metabolic syndrome is not a disease, but is a set of several disorders and causes an increased risk of cardiovascular disease and diabetes mellitus complications. Some epidemiological studies have shown that metabolic syndrome doubles the risk of cardiovascular diseases (Sri Rahayu and Maulina, 2017).

44 Indonesia as a developing country cannot be separated from the existing nutritional problems in 45 the world, including the incidence of obesity and metabolic syndrome. Several studies found that the 46 prevalence of metabolic syndrome keeps increasing every year. A study in China showed the 47 prevalence of metabolic syndrome in adults was 24.2% (Li et al., 2018). Another study indicated that 48 the prevalence of metabolic syndrome in Indonesia was 21.66% (Herningtyas and Ng, 2019). In recent 49 studies metabolic syndrome can be assessed using the continuous value of metabolic syndrome 50 (cMets) or the metabolic syndrome score recommended by the American Diabetic Association of 51 Diabetes. The metabolic syndrome score is a z-score resulting from the assessment of all components 52 of the metabolic syndrome (Pratiwi, et al., 2017). The advantages of using cMetS are (1) reducing 53 dichotomization factors because cardiovascular disease is a progression of several components of 54 the metabolic syndrome, (2) cMetS is more sensitive and less error-prone than categoric metabolic 55 syndrome assessments, (3) increasing the statistical power (Okosun, Lyn, et al., 2010).

56 Central obesity is one of the components of metabolic syndrome parameters. Central obesity is associated with increased blood pressure, serum triglycerides, decreased HDL, and glucose 57 58 intolerance. Based on the National Basic Health Research (Riskesdas) in 2018, the prevalence of 59 obesity in adults was 21.8%, and the prevalence of central obesity at age of more than 15 years 60 increased from 26.6% in 2013 to 31% in 2018 (Badan Penelitian dan Pengembangan Kesehatan, 61 2018). Obesity is closely related to degenerative diseases. The Riskesdas (2018) showed that the 62 prevalence of stroke, diabetes mellitus, heart disease, and hypertension is higher in women than 63 men.

64 Several studies have shown that non-invasive approaches such as anthropometric measurements 65 can be used for the early detection of metabolic syndrome (Pratiwi, et al., 2017). Anthropometric measurements are described as the measurements of body dimensions and body composition to 66 assess nutritional status. The advantages of anthropometric measurements are relatively fast and 67 68 easy, as it can be performed using portable and calibrated instruments with standardized methods 69 (Rokhmah, et al., 2015). Some anthropometric measurements that can be used for early detection of metabolic syndrome are Waist-to-Height Ratio (WHtR), waist-to-hip ratio (WHR), hip 70 71 circumference, Body Mass Index (BMI), Sagital Abdominal Diameter (SAD).

72 One of the anthropometric measurements which can be a parameter for central obesity is the 73 ratio of waist circumference to height (WHtR). The instruments used in the measurement are 74 microtoise and measuring tape so that it takes a longer time. Studies on waist circumference have 75 been shown to have a strong correlation with abdominal fat deposits (Zhou *et al.*, 2014). The 76 distribution of abdominal adipose tissue (central obesity) in adults is associated with a component of the metabolic syndrome (Rodea-Montero, *et al.*, 2014). A study on adult subjects has shown that
people who have the same waist circumference but are shorter in height have a greater risk of
developing metabolic syndrome than taller people (Zhou *et al.*, 2014). Therefore, WHtR can be used
as a simple and effective anthropometric index to identify the metabolic risk associated with obesity
(Rodea-Montero, *et al.*, 2014).

The Waist-To-Hip Ratio (WHR) is a measurement that may indicate central obesity (Karimah, 82 83 2018). The higher the WHR value, the higher the risk level for several metabolic diseases. The Waist-84 To-Hip Ratio is calculated by dividing the measurement of the waist circumference by the 85 circumference of the hip. The cut-off points for WHR are ≥1.0 for men and ≥0.85 for women 86 (Rokhmah, et al., 2015). Individuals with a high waist and hip circumference will also have a higher 87 distribution of fat in their abdominal area. Irregular fats distribution in the abdominal area indirectly 88 causes higher triglyceride levels circulating in the blood, which will affect blood pressure 89 (Sumardiyono et al., 2018). WHR measurement is more sensitive in assessing the distribution of fat 90 in the body, especially in the abdomen. This measurement is three times better than BMI in reflecting 91 the presence of harmful fats in the abdomen. Measurement of waist circumference is performed by 92 determining the lower part of arcus costae and crista iliaca (Sri Rahayu and Maulina, 2017).

Body Mass Index (BMI) is a practical and easy measurement to perform, but it cannot distinguish
 between fat mass, bone mass and muscle mass. BMI is calculated as body weight (kg) / height
 squared (m<sup>2</sup>) (Okura *et al.*, 2018). BMI can be used as the first measurement before any other
 anthropometric measurements.

97 Sagittal Abdominal Diameter (SAD) or the height of the abdomen while the subjects are in a lying 98 position. This anthropometric measurement has not been widely used to measure fat tissue in the 99 abdominal area. SAD measurements using computed tomography or magnetic resonance imaging, 100 and are associated with components of metabolic syndrome. The measurements of SAD are taken 101 when the subject is lying down on the examination table with a naked upper body. SAD is related to 102 central obesity in individuals with obese and normal nutritional status. Furthermore, SAD is 103 associated with diabetes mellitus and a predictor of cardiovascular disease incidence, even when SAD 104 is measured in a standing position (Pajunen et al., 2013). Based on the above mentioned problems, 105 our study aims to analyze the anthropometric indicators related to metabolic syndrome in female 106 college students.

107

115

## 108 **2.** Materials and methods

## 109 2.1 Design, location, and time

110A cross-sectional study design and this research wasc onducted from March to July 2020.111Anthropometric and biochemical data were collected at the Cito Laboratory, Banyumanik Semarang112with health protocols applied. This study was approved by the Medical/Health Research Bioethics113Commission, Faculty of Medicine, Sultan Agung Islamic University Semarang with Number No.296 /IX114/2020 /Bioethical Commission.

116 2.2 Samplings

117This study was conducted during the SARS-CoV-2 outbreak, which later was named COVID-19 by118the WHO, so the registration for study participants was done online. Purposive sampling was used in

this study and the total number of subjects required was 163. Samples are selected based on inclusion criteria, such as willing to be research subjects, female college students in Semarang City, aged 19-24 years in Semarang, not consuming alcohol, not smoking, willing to be a study participant and willing to follow a series of study instructions. Exclusion criteria are subjects who withdraw and those who are ill during the research study. Based on the exclusion criteria mentioned, no subjects are included in the exclusion criteria. Subjects were asked to fill in personal data using a Google form; and eligible subjects will be contacted by the researchers to plan a direct meeting.

The health protocol applied during the anthropometric and biochemical data collection process, consist of the subject filled out a Covid sign/symptom screening questionnaire, the subject was checked for temperature, washed his hands before entering the room, the distance between subjects was at least 1 meter, the subject and researcher used a mask and face shield. Researchers used gloves and protective clothing. During the study, hand sanitizers were provided, anthropometric tools that were on the subject's skin were wiped with alcohol.

#### 133 2.3 Data collected

132

134 The independent variables in this study were the Waist-to-Height Ratio (WHtR), Waist-Hip Ratio 135 (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference. Weight and height data were obtained through direct measurements using a digital stamp scale GEA brand 136 137 with an accuracy of 0.1 kg and microtoise with an accuracy of 0.1 cm. Waist circumference and hip 138 circumference was measured using a measuring tape (Medline) to the nearest 1 mm and abdominal 139 height was measured using the Abawerk Schaffenburg abdominal caliper to the nearest 1 mm. SAD 140 measurements were performed with the subject in a supine position on a flat surface with both knees 141 forming an angle of 90° (Firouzi et al., 2018). Anthropometric data were collected by trained 142 enumerators.

143The cut-off point used in this study refers to previous studies because it had been adjusted for the144Asian race (Rose *et al.*, 2020). Each anthropometric measurement is stated as "at risk" if the145individuals have  $\geq 0.50$  for WHtR (Zhang *et al.*, 2016),  $\geq 0.85$  for WHR (Rokhmah, *et al.*, 2015), > 19.3146cm for Sagital Abdominal Diameter (SAD) (Dieny *et al.*, 2020), and have the normal to overweight147BMI (18.5 - 25 kg/m²) or obese BMI ( $\geq 25.0$  kg/m²) (Susetyowati, 2016).

148 The dependent variable in this study is the metabolic syndrome component that has been 149 converted into a metabolic syndrome score (cMetS) with the cut-off point on cMetS> 2.21 (Rose et 150 al., 2020). The guidelines for metabolic syndrome in this study are taken from the National 151 Cholesterol Education Program-Adult Treatment Panel (NCEP-ATP III) 2005 which has been 152 frequently used in Indonesia. There are 5 parameters to assess metabolic syndrome: (1) fasting blood 153 glucose levels ≥110 mg/dL, (2) triglyceride levels ≥150 mg/dL (3) HDL cholesterol levels <50 mg/dL, 154 (4) central obesity in women with waist circumference ≥80 cm, and (5) systolic and diastolic blood 155 pressures ≥130 mmHg and ≥85 mmHg, respectively (Soewondo et al., 2010). The calculation of the metabolic syndrome score (cMetS) was done in the following steps: (1) after measuring all 156 parameters of the metabolic syndrome, standardisation was carried out to obtain a Z-score; (2) the 157 blood pressure must be converted into Mean Arterial Blood (MAP) by dividing the difference 158 between systolic and diastolic blood pressure by three and summed with the diastolic blood 159 160 pressure; (3) the HDL cholesterol standardization results were multiplied by (-1) because the 161 parameter was inversely related to the risk of metabolic syndrome; (4) All Z-scores were added to 162 obtain the cMetS values; (5) The final step was to compare the cMetS values with the cut-off point Commented [A5]: revised

Commented [A6]: revised

of ≥2,21 (Eisenmann *et al.*, 2010; Okosun, Boltri, *et al.*, 2010; Rose *et al.*, 2020). The subjects were
 instructed to do fasting for at least 8 hours; only drinking water was permitted.

165Other than the cMetS score, metabolic syndrome risk can also be assessed from the classification166of metabolic types. This classification combines the internal and external signs of the body such as167biochemical parameters, the ratio of subcutaneous fat to abdominal fat, and blood pressure (Prybyla168O, 2020). The main phenotypes that reflect the possible combination of metabolic profile and the169degree of obesity are metabolic healthy obese weight, metabolic healthy normal weight, metabolic170unhealthy normal weight, and metabolic unhealthy normal weight.

#### 172 2.4 Data analysis

171

180

All data were analyzed using computer programs and statistical analyses were performed using SPSS Statistical software version 22. Univariate analysis was used to describe subjects characteristic. The distribution of data for normality was assessed using the Kolmogorov Smirnov test before statistical. The relationship of anthropometric indicators with metabolic profile (Blood Pressure, Triglycerides, Blood Sugar, HDL and metabolic syndrome scores) were determined using the Person correlation test. Furthermore, Anthropometric indicators that are most related to the metabolic component and metabolic syndrome score were analyzed using the Multiple Linear Regression test.

#### 181 3. Results and Discussion

The subject characteristics measured in female student aged 19-24 years include age, anthropometric indicators, and metabolic syndromes. Table 1 shows the characteristics of the study subjects. The mean of WHtR value in this study was 0.51. Meanwhile, the mean of WHR was 0.80; the mean of BMI was 24.04 kg/m<sup>2</sup>; the mean of SAD was 16.79 cm; and the mean of waist circumference was 79.44 cm.

187 Table 2 shows various nutritional status of the subjects based on BMI. We found that 43.6% of the 188 subjects had normal BMI, 17.2% were overweight and 35.6% were obese. Based on the WHtR 189 anthropometric indicator, 72.4% of subjects were at risk of having obesity; based on WHR, 22.1% had 190 central obesity; based on BMI, 35.6% were obese; based on SAD 12.3% of the subjects were at risk; 191 and based on waist circumference 55.2% had central obesity. According to the metabolic profile that 192 was assessed, 16.6% had high Fasting Blood Glucose levels, 8.6% had hypertriglycerides, 17.2% had 193 low HDL, 16.6% had high systolic blood pressure, and 21.5% had high diastolic blood pressure. In 194 addition, we found 33.1% of the subjects had high metabolic syndrome (cMetS) scores. This 195 proportion was similar to the assessment based on the metabolic type of unhealthy subjects (subjects 196 who had  $\geq$  3 risk factors of the metabolic profile), which was 33.7%. Moreover, two subjects had five 197 risk factors: abdominal obesity, hypertension, hyperglycemia, hypertriglycerides, and low HDL.

198 The objective of this study was to determine the anthropometric indicators associated with 199 metabolic syndromes in female students. The study included 163 female students aged 19-24 years. 200 The students are in their late adolescents who begin to have an independent life. Inappropriate and 201 unhealthy eating behavior will have an impact on the student's nutritional status. Excessive nutritional 202 status and obesity will affect student's body metabolism. Based on the study results, 33.1% of the 203 subjects had a high metabolic syndrome (cMetS) score. In line with the previous study conducted in 204 2019 on 18-to-21-year-old students at Universitas Diponegoro, 20% of the subjects had high cMetS 205 (Rose et al., 2020). Meanwhile, a study conducted by Pratiwi et al in 2017 using secondary data from 206 the National Basic Health Research 2013 found that 19.98% of adolescents aged 15-24 years had high cMetS (Pratiwi, *et al.*, 2017). Therefore, we conclude that there is a trend of Metabolic Syndrome
 Score (cMetS) among young women in Semarang.

209 The assessment of metabolic syndrome using a continuous type (scoring) rather than using a 210 dichotomy or binary ("yes" and "no") is recommended (Christijani, 2019). An adolescent can be 211 diagnosed with metabolic syndrome if their Metabolic Syndrome Score (cMetS) >2.21 (Pratiwi, et al., 212 2017). Anthropometric indicators used in this study are Waist and Height Ratio (WHtR), Waist-to-Hip 213 Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and Waist Circumference. 214 Based on the correlation analyses, all anthropometric indicators have a significant positive 215 relationship with the Metabolic Syndrome Score (cMetS). Furthermore, the multivariate analyses show that the anthropometric indicators of BMI and WHR are strongly associated with cMetS. 216

217 If we are considering metabolic type based on nutritional status (subjects with non-obese BMI 218 (<25kg/m<sup>2</sup>) with metabolic healthy and metabolic unhealthy and subjects with obese BMI (> 25kg/m<sup>2</sup>) 219 with metabolic healthy and metabolic unhealthy), subjects are categorized as metabolic unhealthy 220 (experiencing metabolic syndrome) if they fulfil  $\geq$  3 risk factors including high waist circumference, 221 blood pressure, GDP Fasting blood glucose and triglyceride levels, and low HDL levels. Based on these 222 criteria, we found that 10.4% of the subjects had metabolic unhealthy normal weight (MUNW) and 223 23.3% of the subjects had metabolic unhealthy obesity weight (MUOW). In non-obese subjects, 54% 224 of them were metabolic healthy. Our study also shows that 10.4% of the subjects were classified as 225 metabolic unhealthy normal weight (MUNW). The subjects' BMI in this category is in the normal range 226 but has a high percentage of body fat that makes them at high risk of developing metabolic disorders 227 (Eckel et al., 2015; Suliga et al., 2015). Several recent cohort studies have shown a greater risk of type 228 II diabetes mellitus in individuals with MUNW compared to individuals with MHNW (Ärnlöv et al., 229 2011; Hadaegh et al., 2011; Aung et al., 2014; Jung et al., 2014; Hinnouho et al., 2015). Other studies 230 have shown that women with the MUNW type have a long-term impact of an increased risk of 231 cardiovascular diseases such as higher blood pressure, triglyceride and glucose levels as well as lower 232 levels of adiponectin, HDL, and LDL compared to women with the MHNW type (Kim et al., 2013).

In this study, 23.3% of the subjects belonged to the Metabolic Unhealthy Obese Weight (MUOW)
 type. Subjects with this metabolic type have an obese BMI and have a high risk of developing
 metabolic disorders. A study conducted in Japan on 29,564 subjects showed that individuals with
 MUOW had a greater risk of developing type II diabetes mellitus compared to individuals with MHOW
 (Heianza *et al.*, 2015).

238 We also found that 12.3% of the subjects were categorized as metabolic healthy obese weight 239 (MHOW). Individuals in this metabolic type have an obese BMI but do not show any metabolic risks. 240 Given the impact of obesity in relation to the risk of metabolic diseases, various studies have been 241 conducted to examine the long-term effects of MHOW. Individuals with MHOW had a different fat 242 distribution pattern (less ectopic and visceral fat), and lower inflammatory markers (Samocha-Bonet 243 et al., 2014). Other studies also have shown that women with MHOW had lower blood pressure, triglyceride levels, and glucose levels, but higher levels of HDL, adiponectin, and LDL compared to 244 245 women with MUNW (Kim et al., 2013). This condition was associated with good diet quality in individuals with MHOW. Based on National Health and Nutrition Examination Surveys (NHANES) 246 data, Camhi et al. (2015) examined the quality of diet in obese subjects, and found that adolescents 247 248 and adult women with the MHOW metabolic type had higher diet quality scores due to high intake 249 of fruit, whole grains, meat, and nuts.

Commented [A7]: revised

250 Table 3 and Table 4 show the results of statistical analyses on anthropometric indicators related 251 to the metabolic syndromes. Table 3 shows the bivariate statistical analysis using the Pearson 252 correlation test. The analysis results showed that all anthropometric indicators, namely WHtR, BMI, 253 SAD, waist circumference, hip circumference and WHR have a strong positive relationship with the 254 metabolic syndrome score (p<0.001), which means that the higher the anthropometric value, the 255 higher the metabolic syndrome score. In addition, the analysis on the relationship between 256 anthropometric indicators and each metabolic profile revealed that almost all of the independent 257 variables (WHtR, waist and hip circumference, WHR, BMI, and SAD) were associated with each 258 metabolic profile, such as baseline systolic pressure, diastolic blood pressure, triglyceride levels, blood 259 sugar levels, and HDL. Only WHR that was not associated with diastolic blood pressure (p>0.005).

260 Table 4 shows the results of the analysis using multiple linear regression to determine 261 anthropometric indicators that are most associated with each metabolic profile and metabolic 262 syndrome score. The results showed that BMI was the anthropometric indicator that is most 263 associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood sugar 264 (p<0.05), and HDL (p<0.001). In addition, waist circumference was the anthropometric indicator that 265 is most associated with triglycerides and metabolic syndrome score (p<0.001). Based on the Adjusted 266 R<sup>2</sup> value on the metabolic syndrome score, we found that 37.5% of the metabolic syndrome score was 267 related to anthropometric indicators, such as WHtR, waist and hip circumference, WHR, BMI, and 268 SAD. The rest may be influenced by other variables that are not included in this study.

269 The correlation test results indicated that all anthropometric indicators had a positive 270 relationship with the metabolic syndrome scores with p <0.001. Meanwhile, the regression analyses 271 show that BMI and WHR were inversely related to cMetS. This is in line with research who stated that 272 an increase in the WHR value could be associated with the risk of metabolic syndrome in children 273 and adolescents in Florida (Moore et al., 2015). Another study stated that there was a strong 274 relationship between overweight and obese adolescents with metabolic syndrome (Al-Bachir and 275 Bakir, 2017). Furthermore, a study on the adolescents in South Africa found that central obesity as 276 measured by the hip circumference could lead to an increased risk of cardiovascular diseases and 277 death. Therefore, hip circumference and waist circumference can be used to predict the risk of 278 cardiovascular diseases and death in the future (Cameron et al., 2012).

279 Body Mass Index (BMI) is the most widely used indicator of measurement in epidemiological 280 studies and is used as a substitute for evaluating body composition. However, BMI cannot distinguish 281 fat from fat mass and lean mass, and it fails to show the presence of adipose and body fat distribution 282 (Ofer et al., 2019; Leone et al., 2020). However, the BMI cut-offs for metabolic syndrome has not yet 283 been determined (Ofer et al., 2019). Obesity in adolescents is generally assessed using a BMI of ≥25.0 284 kg/m<sup>2</sup>. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m<sup>2</sup>) and 285 obesity (≥25.0 kg/m<sup>2</sup>), and we found that 35.6% of the subjects were obese. The finding is in line with 286 the research on the subject of students at Universitas Diponegoro aged 18-21 years. They found that 287 40% of their study population had obesity level I and 36.3% had obesity level II (Rose et al., 2020).

Abdominal obesity is often assessed to determine a metabolic syndrome in people. One of the indicators used to measure abdominal obesity is the Waist-to-Hip Ratio (WHR) which is calculated by dividing the waist circumference and the hip circumference. Measurement of waist circumference is more sensitive in assessing the distribution of body fat in the abdominal wall, which is also a component in <del>the</del>-metabolic syndrome. The limit of the WHR value for female is  $\geq$  0.85 (Rokhmah, *et al.*, 2015). This study shows that every 1% increase in the WHR value will increase the cMetS value Commented [A8]: revised

by 10.411. Hip circumference is also an indicator that has a strong correlation with cMetS, but many
 studies have used it as a ratio along with waist circumference for assessing a person's central obesity
 status.

## 298 4. Conclusion

299 Metabolic syndrome in female students can be identified using anthropometric measurements, one 300 of which is BMI and WHR which are very easy to measure and efficient. BMI and WHR have the 301 strongest relationship and can be used to detect early risk of metabolic syndrome in female college 302 students.

303

297

#### 304 Conflict of interest - Disclose any potential conflict of interest appropriately.

- 305 The authors declare no conflict of interest.
- 306 Acknowledgments

The authors would like to thank all the subjects who participated in this study. We would also like to express our gratitude to The Ministry of Research, Technology and Higher Education, Indonesia" was funded by the "Hibah Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) 2019.

#### 310 References

- Al-Bachir, M. and Bakir, M. A. (2017). Predictive value of body mass index to metabolic syndrome risk factors in Syrian adolescents. *Journal of Medical Case Reports*, 11(1). doi: 10.1186/s13256-017-1315-2.
   Ärnlöv, J., Sundström, J., Ingelsson, E. and Lind, L. (2011). Impact of BMI and the metabolic syndrome on the risk of diabetes in middle-aged men. *Diabetes Care*, 34(1), 61–65. doi: 10.2337/dc10-0955.
   Aung, K. K., Lorenzo, C., Hinojosa, M. A. and Haffner, S. M. (2014). Risk of developing diabetes and cardiovascular disease in metabolically unhealthy normal-weight and metabolically healthy obese
- individuals. Journal of Clinical Endocrinology and Metabolism, 99(2), 462–468. doi: 10.1210/jc.2013 2832.
   Badan Penelitian dan Pengembangan Kesehatan. (2018). Riset Kesehatan Dasar (RISKESDAS) 2018.
- 320 Badan Penentian dan Pengembangan Kesenatan. (2018). *Riset Kesenatan Dasar (RiskesDAs) 2018*. 321 Jakarta, Indonesia.
- Cameron, A. J., Magliano, D. J., Shaw, J. E., Zimmet, P. Z., Carstensen, B., Alberti, K. G. M. M., Tuomilehto,
   J., Barr, E. L. M., Pauvaday, V. K., Kowlessur, S. and Söderberg, S. (2012). The influence of hip
   circumference on the relationship between abdominal obesity and mortality. *International Journal of Epidemiology*, 41(2), 484–494. doi: 10.1093/ije/dyr198.
- Camhi, S. M., Whitney Evans, E., Hayman, L. L., Lichtenstein, A. H. and Must, A. (2015). Healthy eating
   index and metabolically healthy obesity in U.S. adolescents and adults. *Preventive Medicine*, 77, 23–
   27. doi: 10.1016/j.ypmed.2015.04.023.
- Christijani, R. (2019). Determination of Diagnosis of Metabolic Syndrome based on Assessment of
   Metabolic Syndrome and NCEP ATP-III Score in Adolescent. *The Journal of Nutrition and Food Research*,
   42(1), 21–28. doi: 10.22435/pgm.v42i1.2418.
- Devi, R., Manhas, S., Prasad, S., Sharma, S., Bhaskar, N. and Mahajan, S. (2017). Short Review of Metabolic
   Syndrome. International Journal of Research and Review, 4(2), p. 29.
- Dieny, F. F., Setyaningsih, R. F., Fitranti, D. Y., Jauharany, F. F., Putra, Y. D. and Tsani, A. F. A. (2020).
   Abdominal diameter profiles have relationship with insulin resistance in obese female adolescents.

Commented [A9]: revised

336	Electronic Journal of General Medicine, 17(5), p. em219. doi: 10.29333/ejgm/7882.	
337	Eckel, N., Mühlenbruch, K., Meidtner, K., Boeing, H., Stefan, N. and Schulze, M. B. (2015). Characterization	
338	of metabolically unhealthy normal-weight individuals: Risk factors and their associations with type 2	
339	diabetes. Metabolism: Clinical and Experimental, 64(8), 862–871. doi: 10.1016/j.metabol.2015.03.009.	
340	Eisenmann, J. C., Laurson, K. R., Dubose, K. D., Smith, B. K. and Donnelly, J. E. (2010). Construct validity of	
341	a continuous metabolic syndrome score in children. Diabetology and Metabolic Syndrome, 2(1). doi:	
342	10.1186/1758-5996-2-8.	
343	Firouzi, S. A., Tucker, L. A., LeCheminant, J. D. and Bailey, B. W. (2018). Sagittal abdominal diameter, waist	
344	circumference, and BMI as predictors of multiple measures of glucose metabolism: An NHANES	
345	investigation of US adults. Journal of Diabetes Research, 2018, 1–14. doi: 10.1155/2018/3604108.	
346	Hadaegh, F., Bozorgmanesh, M., Safarkhani, M., Khalili, D. and Azizi, F. (2011). Predictability of body mass	
347	index for diabetes: Affected by the presence of metabolic syndrome?. BMC Public Health, 11(1), p. 383.	
348	doi: 10.1186/1471-2458-11-383.	
349	Heianza, Y., Kato, K., Kodama, S., Ohara, N., Suzuki, A., Tanaka, S., Hanyu, O., Sato, K. and Sone, H. (2015).	
350	Risk of the development of Type 2 diabetes in relation to overall obesity, abdominal obesity and the	
351	clustering of metabolic abnormalities in Japanese individuals: Does metabolically healthy overweight	
352	really exist? The Niigata Wellness Study. <i>Diabetic Medicine</i> , 32(5), 665–672. doi: 10.1111/dme.12646.	
353	Herningtyas, E. H. and Ng, T. S. (2019). Prevalence and distribution of metabolic syndrome and its	
354	components among provinces and ethnic groups in Indonesia. BMC Public Health, 19(1), p. 377. doi:	
355	10.1186/s12889-019-6711-7.	
356	Hinnouho, G. M., Czernichow, S., Dugravot, A., Nabi, H., Brunner, E. J., Kivimaki, M. and Singh-Manoux, A.	
357	(2015). Metabolically healthy obesity and the risk of cardiovascular disease and type 2 diabetes: The	
358	Whitehall II cohort study. European Heart Journal, 36(9), 551–559. doi: 10.1093/eurhearti/ehu123.	
359	Jung, H. S., Chang, Y., Eun, Y. K., Kim, C. W., Choi, E. S., Kwon, M. J., Cho, J., Zhang, Y., Rampal, S., Zhao, D.,	
360	Soo, K. H., Shin, H., Guallar, E. and Ryu, S. (2014). Impact of body mass index, metabolic health and	
361	weight change on incident diabetes in a Korean population. Obesity, 22(8), 1880–1887. doi:	
362	10.1002/oby.20751.	
363	Karimah, M. (2018). Rasio Lingkar Pinggal-panggul Memiliki Hubungan Paling Kuat dengan Kadar Glukosa	
364	Darah'. Jurnal Berkala Epidemiologi, 6(3), 219–226.	
365	Kim, M., Paik, J. K., Kang, R., Kim, S. Y., Lee, S. H. and Lee, J. H. (2013). Increased oxidative stress in normal-	
366	weight postmenopausal women with metabolic syndrome compared with metabolically healthy	
367	overweight/obese individuals. <i>Metabolism: Clinical and Experimental</i> , 62(4), 554–560. doi:	
368	10.1016/j.metabol.2012.10.006.	
369	Leone, A., Vizzuso, S., Brambilla, P., Mameli, C., Ravella, S., De Amicis, R., Battezzati,A., Zuccotti, G, Bertoli,	
370	S. and Verduci, E. (2020). Evaluation of different adiposity indices and association with metabolic	<b>Commented</b> [acer10]: please list all the authors
371	syndrome risk in obese children: Is there a winner?. <i>International Journal of Molecular Sciences</i> , 21(11),	 Commented [A11R10]: Revised
372	p. 4083. doi: 10.3390/ijms21114083.	
373	Li, Y., Zhao, L ., Yu, D., Wang, Z.and Ding, G. (2018). Metabolic syndrome prevalence and its risk factors	Commented [acer12]: list all authors
374	among adults in China: A nationally representative cross-sectional study. PLoS ONE, 13(6), p. e0199293.	 Commented [A13R12]: Revised
375	doi: 10.1371/journal.pone.0199293.	Commented [ATSK12]. Revised
376	Moore, L. M., Fals, A.M., Jannelle, P.J., Green, J.F., Pepe, J. and Richard, T. (2015). Analysis of Pediatric	Commented [acer14]: list all authors
377	Waist to Hip Ratio Relationship to Metabolic Syndrome Markers. Journal of Pediatric Health Care,	 Commented [A15R14]: Revised
378	29(4), 319–324. doi: 10.1016/j.pedhc.2014.12.003.	Commented [ATSK14]. Nevised
379	Ofer, K., Leiba, R., Avizohar, O. and Karban, A. (2019). Normal body mass index (BMI) can rule out	
380	metabolic syndrome: An Israeli cohort study. <i>Medicine</i> , 98(9), p. e14712. doi:	

Okosun, I. S., Boltri, J. M., Lyn, R. and Smith, M.D. (2010). Continuous metabolic syndrome risk score, body

mass index percentile, and leisure time physical activity in American children. Journal of Clinical

10.1097/MD.000000000014712.

381 382

384	Hypertension, 12(8), 636–644. doi: 10.1111/j.1751-7176.2010.00338.x.		
385	Okosun, I. S., Lyn, R., Smith, D.M., Eriksen, M. and Seale, P. (2010). Validity of a Continuous Metabolic Risk		Commented [A16]: Revised
386	Score as an Index for Modeling Metabolic Syndrome in Adolescents. Annals of Epidemiology, 20(11),		
387	843–851. doi: 10.1016/j.annepidem.2010.08.001.		
388	Okura, T., Nakamura, R., Fujioka, Y., Kitao, S.K., Ito, Y., Matsumoto, K., Shoji, K., Sumi, K., Matsuzawa, K.,		Commented [A17]: Revised
389	Izawa, S., Ueta, W., Kato, M., Imamura, T., Taniquchi, I. and Yamamoto, K. (2018). Body mass index ≥23		
390	is a risk factor for insulin resistance and diabetes in Japanese people: A brief report. <i>PLOS ONE</i> . Edited		
391	by P. Bjornstad, 13(7), p. e0201052. doi: 10.1371/journal.pone.0201052.		(
392 <mark>1.</mark>	Pajunen, P., Rissanen, H., Laaksonen, M.A., Heliövaara, M., Reunanen, A. and Knekt, P. (2013). Sagittal		Commented [A18]: Revised
393	abdominal diameter as a new predictor for incident diabetes. <i>Diabetes Care</i> , 36(2), 283–288. doi:		
394	10 <mark>.2337/dc11-2451.</mark>		Commented [acer19]: list all authors
395	Pratiwi, Z. A., Hasanbasri, M. and Huriyati, E. (2017). Penentuan titik potong skor sindroma metabolik		Commented [A20R19]: Revised
396	remaja dan penilaian validitas diagnostik parameter antropometri: analisis Riskesdas 2013. <i>Jurnal Gizi</i>		(
397	Klinik Indonesia, 14(2), p. 80. doi: 10.22146/ijcn.25590.		
398	Prybyla, O. (2020). Metabolic phenotyping: is it so important?. Journal of Cognitive Neuropsychology.		
399	<mark>iMedPub., 4(1), 1-3.</mark>		
400	Rodea-Montero, E. R., Evia-Viscarra, M. L. and Apolinar-Jiménez, E. (2014). Waist-to-height ratio is a better		
401	anthropometric index than waist circumference and BMI in predicting metabolic syndrome among		
402	obese mexican adolescents. <i>International Journal of Endocrinology</i> , 2014, 195407. doi:		
403	<b>10.1155/2014/195407</b> .		
404	Rokhmah, F. D., Handayani, D. and Al-Rasyid, H. (2015). Korelasi lingkar pinggang dan rasio lingkar		
405	pinggang-panggul terhadap kadar glukosa plasma menggunakan tes toleransi glukosa oral. <i>Jurnal Gizi</i>		
406	Klinik Indonesia, 12(1), 28–35. doi: 10.22146/ijcn.22425.		
407	Rose, S., Dieny, F. F., Nuryanto, N. and Tsani, A. F. A. (2020). The correlation between waist-to-height ratio		Commented [acer21]: replace with 'and'
408	(wHtR) and second to fourth digit ratio (2D:4D) with an increase in metabolic syndrome scores in obese		a lot of the 'and' are missing from the authors list.
409	adolescent girls. Electronic Journal of General Medicine, 17(3), p. em211. doi: 10.29333/ejgm/7872.	$\langle \rangle$	Please include to the references below
410	Samocha-Bonet, D., Dixit, V. D., Kahn, C. R., Leibel, R. L., Lin, X., Nieuwdorp, M., Pietiläinen, K. H., Rabasa-		Commented [A22R21]: revised
411	Lhoret, R., Roden, M., Scherer, P. E., Klein, S. and Ravussin, E. (2014). Metabolically healthy and		(
412	unhealthy obese - The 2013 stock conference report. Obesity Reviews, 15(9), 697–708. doi:		
413	10.1111/obr.12199.		
414	Soewondo, P., Purnamasari, D., Oemardi, M., Waspadji, S. and Soegondo, S. (2010). Prevalence of		
415	Metabolic Syndrome Using NCEP/ATP III Criteria in Jakarta, Indonesia: The Jakarta Primary Non-		
416	communicable Disease Risk Factors Surveillance 2006. Acta Medica Indonesiana - The International		
417	Journal of Medicin <mark>e, 42(4), 199–203.</mark>	_	Commented [A23]: revised
418	Si Rahayu, M. and Maulina, M. (2017). Hubungan Rasio Lingkar Pinggang dan Lingkar Pinggul dengan		Commented [A25]. Tevised
419	Penyakit Jantung Koroner. <i>Jurnal Aceh Medika</i> , 1(1), 1–10. Available at:		
420	www.jurnal.abulyatama.ac.id/acehmedika (Accessed: 8 April 2021).		
421	Srikanthan, K., Feyh, A., Visweshwar, H., Shapiro, J. I. and Sodhi, K.(2016). Systematic review of metabolic		
422	syndrome biomarkers: A panel for early detection, management, and risk stratification in the West		
423	Virginian population. International Journal of Medical Sciences, 13(1), 25–38. doi: 10.7150/ijms.13800.		
	Suliga, E., Kozieł, D., Cieśla, E. and Głuszek, S. (2015). Association between dietary patterns and metabolic		
424 425	syndrome in individuals with normal weight: A cross-sectional study. Nutrition Journal, 14(1), p. 55.		
425 426	doi: 10.1186/s12937-015-0045-9.		
427	Sumardiyono, S., Pamungkasari, E. P., Mahendra, A. G., Utomo, O. S., Mahajana, D., Cahyadi, W. R. and		
428	Ulfia, M. (2018). Hubungan Lingkar Pinggang dan Lingkar Panggul dengan Tekanan Darah pada Pasien		
429	Program Pengelolaan Penyakit Kronis (Prolanis). Smart Medical Journal, 1(1), p. 26. doi:		
430	10.13057/smj.v1i1.24504.		
431	Susetyowati, S. (2016). Gizi Remaja, in <i>Ilmu Gizi: Teori dan Aplikasi</i> . Jakarta, Indonesia: EGC, 160–164.		

432	Zhang, Y. X., Wang, Z. X., Chu, Z. H. and Zhao, J. S. (2016). Profiles of body mass index and the nutritional
433	status among children and adolescents categorized by waist-to-height ratio cut-offs. International
434	Journal of Cardiology, 223, 529–533. doi: 10.1016/j.ijcard.2016.07.303.

Zhou, D., Yang, M., Yuan, Z. P., Zhang, D. D., Liang, L., Wang, C. L., Zhang, S., Zhu, H. H., Lai, M. D. and Zhu, 

- Y. M. (2014) . Waist-to-Height Ratio: A simple, effective and practical screening tool for childhood obesity and metabolic syndrome. *Preventive Medicine*, 67, 35–40. doi: 10.1016/j.ypmed.2014.06.025.

# Tables and Figures – 1 PAGE 1 TABLE/FIGURE. PLACE ALL TABLES AND FIGURES AT THE END OF THE MANUSCRIPT BODY AFTER THE REFERENCES

Variabel	Minimum	Maximum	Mean	SD
Anthropometric Indicators				
WHtR (ratio)	0.37	0.71	0.51	0.07
WHR (ratio)	0.67	0.96	0.80	0.06
BMI (kg/m²)	15.81	39.30	24.04	4.72
Sagital Abdominal Diameter (cm)	11.35	25.50	16.79	2.42
Hip Circumference (cm)	80.60	138.45	98.96	9.30
Waist Circumference (cm)	58.00	112.10	79.44	10.78
Metabolic Profiles				
Blood Glucose Levels (mg/dL)	66.00	110.00	92.00	7.59
Trygliceride Levels (mg/dL)	29.00	309.00	88.35	44.68
Cholesterol HDL Levels (mg/dL)	36.00	109.00	61.73	26.43
Sistolic Blood Pressure (mmHg)	84.00	144.00	114.63	11.13
Diastolic Blood Pressure (mmHg)	55.00	178.00	82.40	55.52
cMetS (Score of Metabolic Syndrome)	-7.10	11.93	0.01	2.90

445	Table 2. Anthropometric Overview and Components of	Metabo	olic Syndror
446			
447	Characteristics	n	%
448	Anthropometric		
449	Body Mass Index (BMI)		
450	Underweight (< 18.5 kg/m²)	6	3.7
451	Normal (18.5 – 22.9 kg/m <sup>2</sup> )	71	43.6
452	Overweight (23-24.9 kg/m <sup>2</sup> )	28	17.2
453	Obese (≥25.0 kg/m <sup>2</sup> )	58	35.6
	Waist Height Ratio (WHtR)		
454	Normal (<0.50)	45	27.6
455	At Risk (≥0.50)	118	72.4
456	Waist Hip Ratio		
457	Normal (<0.85)	127	77.9
458	Central Obesity (≥0.85)	36	22.1
459		30	22.1
460	Sagital Abdominal Diameter (SAD)	140	07 7
461	Normal (<19.3 cm)	143	87.7
462	At Risk (>19.3 cm)	20	12.3
	Wait Circumference		
	Normal (<80 cm)	73	44.8
	Obese (≤80 cm)	90	55.2
	Metabolic Profiles		
	Blood Glucose Levels		
	Normal (<110 mg/dL)	136	83.4
	High (≥110 mg/dL)	27	16.6
	Triglycerides		
	Normal (<150 mg/dL)	149	914
	High (≥150 mg/dL)	14	8.6
	Cholesterol HDL		0.0
	Normal (≥150 mg/dL)	135	82.8
	Low (<150 mg/dL)	28	17.2
	Sistolic Blood Pressure	20	17.2
	Normal (<130 mg/dL)	136	83.4
	High (≥130 mg/dL)	27	16.6
	Diastolic Blood Pressure	400	70 5
	Normal (<85 mg/dL)	128	78.5
	High (≥85 mg/dL)	35	21.5
	cMetS (Score of Metabolic Syndrome)		
	Normal (<2.21)	109	66.9
	At Risk (≥2.21)	54	33.1
	Metabolic Types		
	Metabolic Unhealthy Normal Weight (MUNW)	17	10.4
	Metabolic Healthy Normal Weight (MHNW)	88	54
	Metabolic Unhealthy Obese Weight (MUOW)	38	23.3
	Metabolic Healthy Obese Weight (MHOW)	20	12.3

404	ingrycenices, Blood Sugar, HDL and metabolic syndrome scores)													
Variable	Sistolic BP		Distolic	Distolic BP TG		Blood Glucose HDL		Blood Glucose		Blood Glucose HI			cMetS	
	r	р	r	р	r	р	r	р	r	р	r	р		
WHtR	0.358	<0.001	0.306	<0.001	0.289	<0.001	0.210	0.007	-0.266	0.001	0.599	<0.001		
BMI	0.370	<0.001	0.313	<0.001	0.315	<0.001	0.221	0.005	-0.292	<0.001	0.600	<0.001		
SAD	0.352	<0.001	0.284	<0.001	0.278	<0.001	0.191	0.015	-0.264	0.001	0.575	<0.001		
WC	0.377	<0.001	0.284	<0.001	0.295	<0.001	0.212	0.005	-0.243	0.002	0.616	<0.001		
HC	0.369	<0.001	0.332	<0.001	0.302	<0.001	0.179	0.002	-0.273	<0.001	0.581	<0.001		
WHR	0.244	0.002	0.128	0.104	0.194	0.013	0.172	0.028	-0.149	0.048	0.415	<0.001		
465														

Table 3. The Relationship between Anthropometric Indicators and Metabolic Profiles (Blood Pressure,
 Triglycerides, Blood Sugar, HDL and metabolic syndrome scores)

		syndrome	scores		
Variable	Sistolic BP				
	Constant	USC <sup>a</sup>	<i>р1<sup>ь</sup></i>	p2 <sup>c</sup>	<sup>d</sup> Adjusted R <sup>2</sup>
BMI	91.759	0.951	<0.001	<0.001	0.158
	Blood Gluco	ose Levels			
	Constant	USC <sup>a</sup>	<i>р1<sup>ь</sup></i>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>
BMI	83.454	0.355	0.005	<0.001	0.043
	HDL				
	Constant	USC <sup>a</sup>	<i>р1<sup>ь</sup></i>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>
BMI	81.429	-0.819	<0.001	<0.001	0.080
	Triglyceride	s			
	Constant	USC <sup>a</sup>	<b>р1</b> <sup>ь</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>
WC	-6.614	1.195	<0.001	<0.001	0.078
	Score of Me	tabolic Syndi	rome		
	Constant	USC <sup>a</sup>	<i>р1<sup>ь</sup></i>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>
WC	-13.163	0.166	<0.001	<0.001	0.375

# Table 4. Anthropometric indicators most associated with metabolic components and metabolic syndrome scores

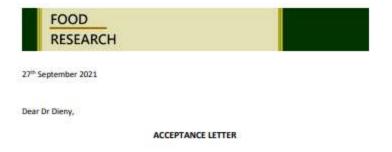
ACCEPTED					
FR- <mark>2021-250</mark> - Decision	on your manuscript 🍃 Kotak Masuk 🗴		*	₿	ß
Food Research <foodresearch.my@outlo kepada saya ↓</foodresearch.my@outlo 	k.com>	@ Min, 26 Sep 2021, 14.25	☆	¢	:
🛪 Inggris 🔹 🗲 Indonesia 👻	erjemahkan pesan	Nonaktifkan u	intuk: I	nggris	×
Dear Dr Dieny,					

nor the Mit Mit Program (March 1994)

It is a pleasure to accept your manuscript for publication in Food Research journal. Please refer to the attachment for your acceptance letter. I will contact you again once the galley proof is ready for viewing and approval.

Thank you for your fine contribution. We look forward to your continued contributions to the Journal.

Sincerely, Dr Vivian New Editor Food Research



Food Research is pleased to inform you that the following manuscript has been accepted for publication in Food Research journal.

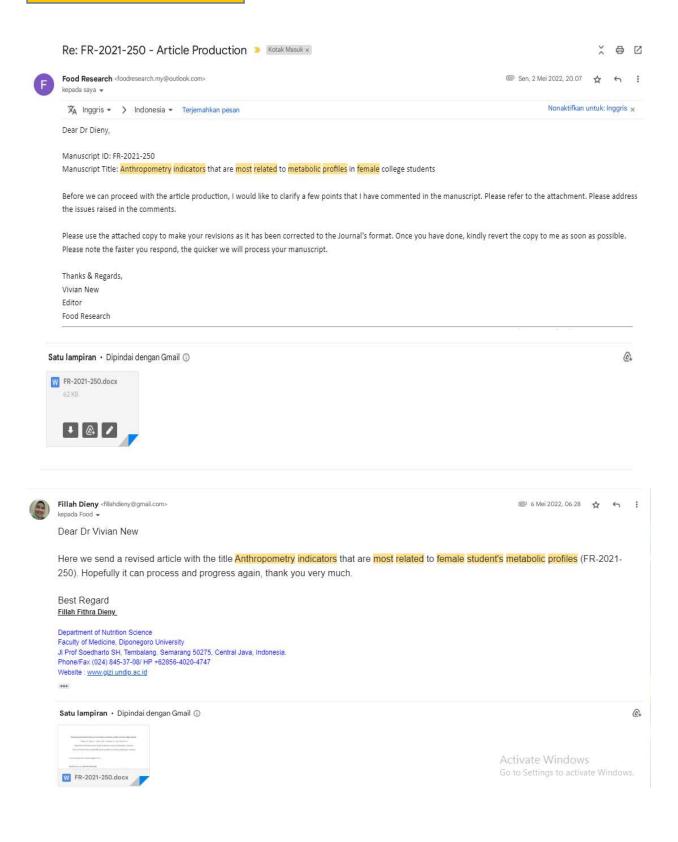
Manuscript Title	5	Anthropometry indicators that are most related to metabolic profiles in female college students
Authors		Dieny, F.F., Rose S., Tsani, A.F.A., Jauharany, F.F. and Fitranti, D.Y.

We thank you for your fine contribution to the Food Research journal and encourage you to submit other articles to the Journal.

Yours sincerely,

SonQe

Professor Dr. Son Radu Chief Editor Food Research



F	Food Research <foodresearch.my@outlook.com> kepada saya →</foodresearch.my@outlook.com>	6 Mei 2022, 08.10 👌 🕤 🚦
	🕱 Inggris 🔹 🗲 Indonesia 👻 Terjemahkan pesan	Nonaktifkan untuk: Inggris 🗙
	Dear Dr Dieny,	
	Received with thanks.	
	Thanks & Regards Vivian New	
	Editor Food Research	
F	Food Research ⊲foodresearch.my@outlook.com> kepada saya  ❤	@ 6 Mei 2022, 09.34 😭 ← 🚦
	🛪 Inggris 🔹 > Indonesia 👻 Terjemahkan pesan	Nonaktifkan untuk: Inggris 🗙
	Dear Dr Dieny,	
	Please address the comment raised in the manuscript.	
	Thanks & Regards Vivian New Editor	
	Food Research	
	From: Fillah Dieny < <u>fillahdieny@gmail.com</u> > Sent: Friday, 6 May, 2022 7:28 AM To: Food Research < <u>foodresearch.my@outlook.com</u> > Subject: Re: FR-2021-250 - Article Production	
	in the second	
	Satu lampiran • Dipindai dengan Gmail ()	<i>©</i> +
		Activate Windows
	W FR-2021-250.docx	Go to Settings to activate Windows.
0	Fillah Dieny <fillahdieny@gmail.com> kepada Food ↓ Dear Dr Vivian New</fillahdieny@gmail.com>	@ 10 Mei 2022, 06.15 🔄 ← 🕴
	Here we send a revised article with the title Anthropometry indicators that are most related to female s 250). Hopefully it can process and progress again, thank you very much.	student's metabolic profiles (FR-2021-
	Fillah Fithra Dieny	
	Department of Nutrition Science Faculty of Medicine, Diponegoro University JI Prof Soedharto SH, Tembalang, Semarang 50275, Central Java, Indonesia. Phone/Fax (024) 845-37-08/ HP +62856-4020-4747	
	Website : <u>www.gizi.undip.ac.id</u>	
	Satu lampiran • Dipindai dengan Gmail 🛈	æ
	Amount and a more stand of the left and a dist Theory Taylor Multiple Amount and the left Theory Taylor Amount and the left and the l	
		Activate Windows
	W FR-2021-250 (2).d	Go to Settings to activate Windows.

Food Research <foodresearch.my@outlook.com> kepada saya 👻</foodresearch.my@outlook.com>	10 Mei 2022, 08.46	н	
🕅 Inggris 🕶 🗲 Indonesia 🕶 Terjemahkan pesan	Nonaktifkan u	untuk: Ingg	gri
Dear Dr Dieny,			
Received with thanks			
Thanks & Regards Vivian New Editor			
Food Research			
Food Research ⊲foodresearch.my@outlook.com> kepada saya  ❤	@ 13 Mei 2022, 15.24	☆ ↔	h
🛪 Inggris 🗸 🖒 Indonesia 🗸 Terjemahkan pesan	Nonaktifkan u	untuk: Ingg	gri
Dear Dr Dieny, Please refer to the attachment for the galley proof of your manuscript FR-2021-250 entitled college students' . Please check the content of the galley proof. If there are any mistakes, ple	Anthropometry indicators that are most related to metabolic profile se comment and highlight in the PDF itself and revert to us within	es in fema	ali
Dear Dr Dieny, Please refer to the attachment for the galley proof of your manuscript FR-2021-250 entitled	Anthropometry indicators that are most related to metabolic profile se comment and highlight in the PDF itself and revert to us within	es in fema	al
Dear Dr Dieny, Please refer to the attachment for the galley proof of your manuscript FR-2021-250 entitled college students' . Please check the content of the galley proof. If there are any mistakes, ple	Anthropometry indicators that are most related to metabolic profile se comment and highlight in the PDF itself and revert to us within early viewing.	<mark>es</mark> in fema two (2) da	ali lay
Dear Dr Dieny, Please refer to the attachment for the galley proof of your manuscript FR-2021-250 entitled college students' . Please check the content of the galley proof. If there are any mistakes, ple receipt. Once we have finalized the PDF version, your manuscript will be published online for	Anthropometry indicators that are most related to metabolic profile se comment and highlight in the PDF itself and revert to us within early viewing. t as soon as possible before 3 June 2022 for us to complete the pu	<mark>es</mark> in fema two (2) da	ali lay
Dear Dr Dieny, Please refer to the attachment for the galley proof of your manuscript FR-2021-250 entitled college students' . Please check the content of the galley proof. If there are any mistakes, ple receipt. Once we have finalized the PDF version, your manuscript will be published online fo Please see the attachment for the invoice INV22125. We hope that you can make the payme	Anthropometry indicators that are most related to metabolic profile se comment and highlight in the PDF itself and revert to us within early viewing. t as soon as possible before 3 June 2022 for us to complete the pu	<mark>es</mark> in fema two (2) da	alı lay
Dear Dr Dieny, Please refer to the attachment for the galley proof of your manuscript FR-2021-250 entitled college students' . Please check the content of the galley proof. If there are any mistakes, ple receipt. Once we have finalized the PDF version, your manuscript will be published online fo Please see the attachment for the invoice INV22125. We hope that you can make the payme manuscript. The manuscript information e.g. volume, issue, page numbers and DOI, will be p Thanks & Regards, Vivian New	Anthropometry indicators that are most related to metabolic profile se comment and highlight in the PDF itself and revert to us within early viewing. t as soon as possible before 3 June 2022 for us to complete the pu	<mark>es</mark> in fema two (2) da	alı lay
Dear Dr Dieny, Please refer to the attachment for the galley proof of your manuscript FR-2021-250 entitled college students' . Please check the content of the galley proof. If there are any mistakes, ple receipt. Once we have finalized the PDF version, your manuscript will be published online fo Please see the attachment for the invoice INV22125. We hope that you can make the payme manuscript. The manuscript information e.g. volume, issue, page numbers and DOI, will be p Thanks & Regards, Vivian New Editor	Anthropometry indicators that are most related to metabolic profile se comment and highlight in the PDF itself and revert to us within early viewing. t as soon as possible before 3 June 2022 for us to complete the pu	<mark>es</mark> in fema two (2) da	ali lay
Dear Dr Dieny, Please refer to the attachment for the galley proof of your manuscript FR-2021-250 entitled college students' . Please check the content of the galley proof. If there are any mistakes, ple receipt. Once we have finalized the PDF version, your manuscript will be published online fo Please see the attachment for the invoice INV22125. We hope that you can make the payme manuscript. The manuscript information e.g. volume, issue, page numbers and DOI, will be p Thanks & Regards, Vivian New	Anthropometry indicators that are most related to metabolic profile se comment and highlight in the PDF itself and revert to us within early viewing. t as soon as possible before 3 June 2022 for us to complete the pu	<mark>es</mark> in fema two (2) da	al lay
Dear Dr Dieny, Please refer to the attachment for the galley proof of your manuscript FR-2021-250 entitled college students' . Please check the content of the galley proof. If there are any mistakes, ple receipt. Once we have finalized the PDF version, your manuscript will be published online fo Please see the attachment for the invoice INV22125. We hope that you can make the payme manuscript. The manuscript information e.g. volume, issue, page numbers and DOI, will be p Thanks & Regards, Vivian New Editor Food Research	Anthropometry indicators that are most related to metabolic profile se comment and highlight in the PDF itself and revert to us within early viewing. t as soon as possible before 3 June 2022 for us to complete the pu	<mark>es</mark> in fema two (2) da	allay
Dear Dr Dieny, Please refer to the attachment for the galley proof of your manuscript FR-2021-250 entitled college students' . Please check the content of the galley proof. If there are any mistakes, ple receipt. Once we have finalized the PDF version, your manuscript will be published online fo Please see the attachment for the invoice INV22125. We hope that you can make the payme manuscript. The manuscript information e.g. volume, issue, page numbers and DOI, will be p Thanks & Regards, Vivian New Editor	Anthropometry indicators that are most related to metabolic profile se comment and highlight in the PDF itself and revert to us within early viewing. t as soon as possible before 3 June 2022 for us to complete the pu	es in fema two (2) da blication (	ali lay of
Dear Dr Dieny, Please refer to the attachment for the galley proof of your manuscript FR-2021-250 entitled college students' . Please check the content of the galley proof. If there are any mistakes, ple receipt. Once we have finalized the PDF version, your manuscript will be published online fo Please see the attachment for the invoice INV22125. We hope that you can make the payme manuscript. The manuscript information e.g. volume, issue, page numbers and DOI, will be p Thanks & Regards, Vivian New Editor Food Research	Anthropometry indicators that are most related to metabolic profile se comment and highlight in the PDF itself and revert to us within early viewing. t as soon as possible before 3 June 2022 for us to complete the pu	es in fema two (2) da blication (	ale lay
Dear Dr Dieny, Please refer to the attachment for the galley proof of your manuscript FR-2021-250 entitled college students' . Please check the content of the galley proof. If there are any mistakes, ple receipt. Once we have finalized the PDF version, your manuscript will be published online fo Please see the attachment for the invoice INV22125. We hope that you can make the payme manuscript. The manuscript information e.g. volume, issue, page numbers and DOI, will be p Thanks & Regards, Vivian New Editor Food Research Lampiran • Dipindai dengan Gmail ③	Anthropometry indicators that are most related to metabolic profile se comment and highlight in the PDF itself and revert to us within early viewing. t as soon as possible before 3 June 2022 for us to complete the pu	es in fema two (2) da blication (	ali lay of



📼 18 Mei 2022, 13.18 🟠 🕤 🚦 Here we send proof of payment for article and revision of the article in the acknowledgment section. I hope this can be proceed to the next one,

best regards	
Fillah Fithra Dieny	

Dear Dr Vivian

thank you



2 Lampiran • Dipindai dengan Gmail 🛈



± @.

	Food Research kepada saya 👻	<food< th=""><th>lresearch.my@ou</th><th>.com&gt;</th><th></th><th>@ 18 Mei 2022, 14.56</th><th></th><th><i>←</i></th></food<>	lresearch.my@ou	.com>		@ 18 Mei 2022, 14.56		<i>←</i>
	🛪 Inggris 🕶	>	Indonesia 🕶	rjemahkan pesan		Nonaktifkan	untuk	Ing
	Dear Dr Dieny,							
	Thank you very Please refer to t			evised galley proof. If the galley proof is fine, please	e approve the galley proof.			
	Thanks & Rega	rds						
	Vivian New							
	Editor							
	Food Research							
1020	Satu lampiran •		indai dengan G	0				
	Adaption of the second state adaption of the second state <sup>1</sup> Heat IT, heat I, "heat at the <sup>1</sup> Heat IT, heat I, "heat at the <sup>1</sup> Heat IT, heat I, "heat at the <sup>1</sup> Heat II," heat I, "heat I, heat II <sup>1</sup> Heat II," heat I, "heat I, heat II <sup>1</sup> Heat II," heat I, "heat II <sup>1</sup> Heat II," heat I, "heat II <sup>1</sup> Heat III <sup>1</sup> Heat IIII <sup>1</sup> Heat III <sup>1</sup> Heat III <sup>1</sup> Heat IIIII	n nainh pai na 11 na 19m Thair Mar						
	FR-2021-250	.pdf						
k	Fillah Dieny <fila kepada Food ★ Approved, please p</fila 					18 Mei 2022, 17.14	☆	÷
1	Thank you							
1								
	Food Research kepada saya -	I <foot< td=""><td>dresearch.my@ou</td><td>.cam&gt;</td><td></td><td>18 Mei 2022, 19.47</td><td>☆</td><td>÷</td></foot<>	dresearch.my@ou	.cam>		18 Mei 2022, 19.47	☆	÷
	🗙 Inggris -	>	Indonesia 🕶	rjemahkan pesan		Nonaktifkan	untuk:	Ing
	Dear Dr Dieny,							
	Noted with tha	nks. I	'll notify you o	article's publication soon.				
	Thanks & Rega	rds						
	Vivian New							
	Editor							
	Food Research							

# Anthropometry indicators that are most related to metabolic profiles in female college students

<sup>1,2,</sup>\*Dieny, F.F., <sup>1</sup>Rose S., <sup>1,2</sup>Tsani, A.F.A., <sup>1</sup>Jauharany, F.F. and <sup>1,2</sup>Fitranti, D.Y. <sup>1</sup>Department of Nutrition Science, Faculty of Medicine, Universitas Diponegoro, Indonesia <sup>2</sup>Center of Nutrition Research (CENURE), Faculty of Medicine, Universitas Diponegoro, Indonesia

\*Corresponding author: fillahdieny@gmail.com

ORCID ID Author 1: 0000-0001-6071-8901 ORCID ID Author 2: 0000-0002-1898-1842 ORCID ID Author 3: 0000-0002-3407-5188 ORCID ID Author 4: 0000-0001-9471-9419 ORCID ID Author 5: 0000-0002-1656-9563

#### Article history:

Received: 2 June 2021 Received in revised form: 8 July 2021 Accepted: 27 September 2021

# Abstract

Metabolic syndrome is not a disease but is a set of several disorders and causes an increased risk of cardiovascular disease and diabetes mellitus complications. Several studies have shown that non-invasive approaches such as anthropometric measurements can be used for the early detection of metabolic syndrome. This study aimed to analyse the anthropometric indicators related to metabolic syndrome in female college students. This cross-sectional study with a total of 163 female college students, aged

between 19 and 24 years old. Purposive sampling was used in this study. The independent variables in this study were the Waist-to-Height Ratio (WHR), Waist-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference. The dependent variable in this study is the metabolic syndrome component that has been converted into a metabolic syndrome score (cMetS). The analysis results showed that all anthropometric indicators, namely WHtR, BMI, SAD, waist circumference, hip circumference and WHR have a strong positive relationship with the metabolic syndrome score (p<0.001). BMI was the anthropometric indicator that is most associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood sugar (p<0.05), and HDL (p<0.001). Waist circumference was the anthropometric indicator that is most associated with triglycerides and metabolic syndrome score (p<0.001). Metabolic syndrome in female college students can be identified using anthropometric measurements, one of which is BMI and WHR which are very easy to measure and efficient. BMI and WHR have the strongest relationship and can be used to detect early risk of metabolic syndrome in female college students.

Keywords: Adolescent, Anthropometric indicator, Female, Metabolic profile, Metabolic syndrome

#### 1. Introduction

Metabolic syndrome is a set of body metabolic disorders such as dyslipidemia, hyperglycemia, hypertension, and central obesity (Srikanthan *et al.*, 2016; Devi *et al.*, 2017; Christijani, 2019). Metabolic syndrome is not a disease, but is a set of several disorders that causes an increased risk of cardiovascular disease and diabetes mellitus complications. Some epidemiological studies have shown that metabolic syndrome doubles the risk of cardiovascular diseases (Sri Rahayu and Maulina, 2017).

Indonesia as a developing country cannot be separated from the existing nutritional problems in the world, including the incidence of obesity and metabolic syndrome. Several studies found that the prevalence of metabolic syndrome keeps increasing every year. A study in China showed the prevalence of metabolic syndrome in adults was 24.2% (Li *et al.*, 2018). Another study indicated that the prevalence of metabolic syndrome in Indonesia was 21.66% (Herningtyas and Ng, 2019). In recent studies, metabolic syndrome can be assessed using the continuous value of metabolic syndrome (cMets) or the metabolic syndrome score recommended by the American Diabetic Association of Diabetes. The metabolic syndrome score is a z-score resulting from the assessment of all components

Commented [VN1]: The sentence is left hanging. Please edit

of the metabolic syndrome (Pratiwi, *et al.*, 2017). The advantages of using cMetS are (1) reducing dichotomization factors because cardiovascular disease is a progression of several components of the metabolic syndrome, (2) cMetS is more sensitive and less error-prone than categoric metabolic syndrome assessments, (3) increasing the statistical power (Okosun *et al.*, 2010b).

Central obesity is one of the components of metabolic syndrome parameters. Central obesity is associated with increased blood pressure, serum triglycerides, decreased HDL, and glucose intolerance. Based on the National Basic Health Research (Riskesdas) in 2018, the prevalence of obesity in adults was 21.8%, and the prevalence of central obesity at age of more than 15 years increased from 26.6% in 2013 to 31% in 2018 (Badan Penelitian dan Pengembangan Kesehatan, 2018). Obesity is closely related to degenerative diseases. Riskesdas (2018) showed that the prevalence of stroke, diabetes mellitus, heart disease, and hypertension is higher in women than men.

Several studies have shown that non-invasive approaches such as anthropometric measurements can be used for the early detection of metabolic syndrome (Pratiwi, *et al.*, 2017). Anthropometric measurements are described as the measurements of body dimensions and body composition to assess nutritional status. The advantages of anthropometric measurements are relatively fast and easy, as they can be performed using portable and calibrated instruments with standardized methods (Rokhmah, *et al.*, 2015). Some anthropometric measurements that can be used for early detection of metabolic syndrome are Waist-to-Height Ratio (WHR), waist-to-hip ratio (WHR), hip circumference, Body Mass Index (BMI), Sagital Abdominal Diameter (SAD).

One of the anthropometric measurements which can be a parameter for central obesity is the ratio of waist circumference to height (WHtR). The instruments used in the measurement are microtoise and measuring tape, which take a longer time. Studies on waist circumference have been shown to have a strong correlation with abdominal fat deposits (Zhou *et al.*, 2014). The distribution of abdominal adipose tissue (central obesity) in adults is associated with a component of the metabolic syndrome (Rodea-Montero, *et al.*, 2014). A study on adult subjects has shown that people who have the same waist circumference but are shorter in height have a greater risk of developing metabolic syndrome than taller people (Zhou *et al.*, 2014). Therefore, WHtR can be used as a simple and effective anthropometric index to identify the metabolic risk associated with obesity (Rodea-Montero, *et al.*, 2014).

The Waist-To-Hip Ratio (WHR) is a measurement that may indicate central obesity (Karimah, 2018). The higher the WHR value, the higher the risk level for several metabolic diseases. The Waist-To-Hip Ratio is calculated by dividing the measurement of the waist circumference by the circumference of the hip. The cut-off points for WHR are  $\geq$ 1.0 for men and  $\geq$ 0.85 for women (Rokhmah *et al.*, 2015). Individuals with a high waist and hip circumference will also have a higher distribution of fat in their abdominal area. Irregular fats distribution in the abdominal area indirectly causes higher triglyceride levels circulating in the blood, which will affect blood pressure (Sumardiyono *et al.*, 2018). WHR measurement is more sensitive in assessing the distribution of fat in the abdomen. This measurement of waist circumference is performed by determining the lower part of arcus costae and crista iliaca (Sri Rahayu and Maulina, 2017).

Body Mass Index (BMI) is a practical and easy measurement to perform, but it cannot distinguish between fat mass, bone mass and muscle mass. BMI is calculated as body weight (kg) / height squared (m<sup>2</sup>) (Okura *et al.*, 2018). BMI can be used as the first measurement before any other anthropometric measurements.

Sagittal Abdominal Diameter (SAD) or the height of the abdomen while the subjects are in a lying position. This anthropometric measurement has not been widely used to measure fat tissue in the abdominal area. SAD measurements using computed tomography or magnetic resonance imaging, and are associated with components of metabolic syndrome. The measurements of SAD are taken when the subject is lying down on the examination table with a naked upper body. SAD is related to central obesity in individuals with obesity and normal nutritional status. Furthermore, SAD is associated with diabetes mellitus and a predictor of cardiovascular disease incidence, even when SAD is measured in a standing position (Pajunen *et al.*, 2013). Based on the above-mentioned problems, our study aimed to analyze the anthropometric indicators related to metabolic syndrome in female college students.

#### 2. Materials and methods

2.1 Design, location, and time

A cross-sectional study design and this research was conducted from March to July 2020. Anthropometric and biochemical data were collected at the Cito Laboratory, Banyumanik Semarang with health protocols applied. This study was approved by the Medical/Health Research Bioethics Commission, Faculty of Medicine, Sultan Agung Islamic University Semarang with Number No.296 /IX /2020 /Bioethical Commission.

# 2.2 Samplings

This study was conducted during the SARS-CoV-2 outbreak, which later was named COVID-19 by the WHO, hence the registration for study participants was done online. Purposive sampling was used in this study and the total number of subjects required was 163. Samples are selected based on inclusion criteria, such as voluntary to be research subjects, female college students in Semarang City, aged 19-24 years in Semarang, not consuming alcohol, not smoking, and voluntary to follow a series of study instructions. Exclusion criteria are subjects who withdraw and those who are ill during the research study. Based on the exclusion criteria mentioned, no subjects are included in the exclusion criteria. Subjects were asked to fill in personal data using a Google Form, and eligible subjects will be contacted by the researchers to plan a direct meeting.

The health protocol applied during the anthropometric and biochemical data collection process, consisted of the subject filling out a COVID-19 sign/symptom screening questionnaire, the subject was checked for temperature, the subject washed hands before entering the room, the distance between subjects was at least 1 meter, the subject and researcher used a mask and face shield. Researchers used gloves and protective clothing. During the study, hand sanitisers were provided, and anthropometric tools that were on the subject's skin were wiped with alcohol.

## 2.3 Data collected

The independent variables in this study were the Waist-to-Height Ratio (WHR), Waist-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference. Weight and height data were obtained through direct measurements using a digital stamp scale GEA brand with an accuracy of 0.1 kg and microtoise with an accuracy of 0.1 cm. Waist circumference and hip circumference were measured using a measuring tape (Medline) to the nearest 1 mm and abdominal height was measured using the Abawerk Schaffenburg abdominal calliper to the nearest 1 mm. SAD measurements were performed with the subject in a supine position on a flat surface with both knees forming an angle of 90° (Firouzi *et al.*, 2018). Anthropometric data were collected by trained enumerators.

The cut-off point used in this study refers to previous studies because it had been adjusted for the Asian race (Rose *et al.*, 2020). Each anthropometric measurement is stated as "at-risk" if the individuals have  $\geq 0.50$  for WHtR (Zhang *et al.*, 2016),  $\geq 0.85$  for WHR (Rokhmah *et al.*, 2015), > 19.3 cm for Sagital Abdominal Diameter (SAD) (Dieny *et al.*, 2020), and have the normal to overweight BMI (18.5 - 25 kg/m<sup>2</sup>) or obese BMI ( $\geq 25.0$  kg/m<sup>2</sup>) (Susetyowati, 2016).

The dependent variable in this study is the metabolic syndrome component that has been converted into a metabolic syndrome score (cMetS) with the cut-off point of cMetS> 2.21 (Rose et al., 2020). The guidelines for metabolic syndrome in this study are taken from the National Cholesterol Education Program-Adult Treatment Panel (NCEP-ATP III) 2005 which has been frequently used in Indonesia. There are 5 parameters to assess metabolic syndrome: (1) fasting blood glucose levels ≥110 mg/dL, (2) triglyceride levels ≥150 mg/dL (3) HDL cholesterol levels <50 mg/dL, (4) central obesity in women with waist circumference ≥80 cm, and (5) systolic and diastolic blood pressures ≥130 mmHg and ≥85 mmHg, respectively (Soewondo et al., 2010). The calculation of the metabolic syndrome score (cMetS) was done in the following steps: (1) after measuring all parameters of the metabolic syndrome, standardisation was carried out to obtain a Z-score; (2) the blood pressure must be converted into Mean Arterial Blood (MAP) by dividing the difference between systolic and diastolic blood pressure by three and summed with the diastolic blood pressure; (3) the HDL cholesterol standardization results were multiplied by (-1) because the parameter was inversely related to the risk of metabolic syndrome; (4) All Z-scores were added to obtain the cMetS values; (5) The final step was to compare the cMetS values with the cut-off point of ≥2,21 (Eisenmann et al., 2010; Okosun et al., 2010a; Rose et al., 2020). The subjects were instructed to do fasting for at least 8 hrs, only drinking water was permitted.

Other than the cMetS score, metabolic syndrome risk can also be assessed from the classification of metabolic types. This classification combines the internal and external signs of the body such as biochemical parameters, the ratio of subcutaneous fat to abdominal fat, and blood pressure (Prybyla O, 2020). The main phenotypes that reflect the possible combination of metabolic profile and the degree of obesity are metabolic healthy obese weight, metabolic healthy normal weight, metabolic unhealthy normal weight, and metabolic unhealthy normal weight.

#### 2.4 Data analysis

All data were analyzed using computer programs and statistical analyses were performed using SPSS statistical software version 22. Univariate analysis was used to describe subjects characteristics.

The distribution of data for normality was assessed using the Kolmogorov Smirnov test before statistics. The relationship of anthropometric indicators with metabolic profile (Blood Pressure, Triglycerides, Blood Sugar, HDL and metabolic syndrome scores) was determined using the Person correlation test. Furthermore, Anthropometric indicators that are most related to the metabolic component and metabolic syndrome score were analyzed using the Multiple Linear Regression test.

#### 3. Results and discussion

The subject characteristics measured in female students aged 19-24 years include age, anthropometric indicators, and metabolic syndromes. Table 1 shows the characteristics of the study subjects. The mean WHR value in this study was 0.51. Meanwhile, the mean WHR was 0.80; the mean BMI was 24.04 kg/m<sup>2</sup>; the mean SAD was 16.79 cm, and the mean waist circumference was 79.44 cm.

Table 2 shows the various nutritional status of the subjects based on BMI. It was found that 43.6% of the subjects had normal BMI, 17.2% were overweight and 35.6% were obese. Based on the WHtR anthropometric indicator, 72.4% of subjects were at risk of having obesity, based on WHR, 22.1% had central obesity, based on BMI, 35.6% were obese, based on SAD 12.3% of the subjects were at risk, and based on waist circumference 55.2% had central obesity. According to the metabolic profile that was assessed, 16.6% had high Fasting Blood Glucose levels, 8.6% had hypertriglycerides, 17.2% had low HDL, and 16.6% had high systolic blood pressure, and 21.5% had high diastolic blood pressure. In addition, we found that 33.1% of the subjects had high metabolic syndrome (cMetS) scores. This proportion was similar to the assessment based on the metabolic type of unhealthy subjects (subjects who had  $\geq$  3 risk factors of the metabolic profile), which was 33.7%. Moreover, two subjects had five risk factors: abdominal obesity, hypertension, hyperglycemia, hypertriglycerides, and low HDL.

The objective of this study was to determine the anthropometric indicators associated with metabolic syndromes in female students. The study included 163 female students aged 19-24 years. The students are in their late adolescents who begin to have an independent life. Inappropriate and unhealthy eating behaviour will have an impact on the student's nutritional status. Excessive nutritional status and obesity will affect student's body metabolism. Based on the study results, 33.1% of the subjects had a high metabolic syndrome (cMetS) score. In line with the previous study conducted in 2019 on 18-to-21-year-old students at Universitas Diponegoro, 20% of the subjects had high cMetS (Rose *et al.*, 2020). Meanwhile, a study conducted by Pratiwi et al in 2017 using secondary data from the National Basic Health Research 2013 found that 19.98% of adolescents aged 15-24 years

**Commented [VN2]:** Please rephrase the sentence. The sentence is confusing.

had high cMetS (Pratiwi, *et al.*, 2017). To conclude, there is a trend of Metabolic Syndrome Score (cMetS) among young women in Semarang.

The assessment of metabolic syndrome using a continuous type (scoring) rather than using a dichotomy or binary ("yes" and "no") is recommended (Christijani, 2019). An adolescent can be diagnosed with metabolic syndrome if their Metabolic Syndrome Score (cMetS) >2.21 (Pratiwi, *et al.*, 2017). Anthropometric indicators used in this study are Waist and Height Ratio (WHR), Waist-to-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and Waist Circumference. Based on the correlation analyses, all anthropometric indicators have a significant positive relationship with the Metabolic Syndrome Score (cMetS). Furthermore, the multivariate analyses show that the anthropometric indicators of BMI and WHR are strongly associated with cMetS.

If the metabolic type is considered based on nutritional status (subjects with non-obese BMI (<25kg/m<sup>2</sup>) with metabolic healthy and metabolic unhealthy and subjects with obese BMI (>25kg/m<sup>2</sup>) with metabolic healthy and metabolic unhealthy), subjects are categorized as metabolic unhealthy (experiencing metabolic syndrome) if they fulfil  $\geq$  3 risk factors including high waist circumference, blood pressure, fasting blood glucose and triglyceride levels, and low HDL levels. Based on these criteria, it was found that 10.4% of the subjects had a metabolic unhealthy normal weight (MUNW) and 23.3% of the subjects had metabolic unhealthy obesity weight (MUOW). Of non-obese subjects, 54% of them were metabolic healthy. Our study also shows that 10.4% of the subjects were classified as metabolic unhealthy normal weight (MUNW). The subjects' BMI in this category is in the normal range but has a high percentage of body fat that makes them at high risk of developing metabolic disorders (Eckel et al., 2015; Suliga et al., 2015). Several recent cohort studies have shown a greater risk of type II diabetes mellitus in individuals with MUNW compared to individuals with MHNW (Ärnlöv et al., 2011; Hadaegh et al., 2011; Aung et al., 2014; Jung et al., 2014; Hinnouho et al., 2015). Other studies have shown that women with the MUNW type have a long-term impact of an increased risk of cardiovascular diseases such as higher blood pressure, triglyceride and glucose levels as well as lower levels of adiponectin, HDL, and LDL compared to women with the MHNW type (Kim et al., 2013).

In this study, 23.3% of the subjects belonged to the Metabolic Unhealthy Obese Weight (MUOW) type. Subjects with this metabolic type have an obese BMI and have a high risk of developing metabolic disorders. A study conducted in Japan on 29,564 subjects showed that individuals with MUOW had a greater risk of developing type II diabetes mellitus compared to individuals with MHOW (Heianza *et al.*, 2015).

It was also found that 12.3% of the subjects were categorized as metabolic healthy obese weight (MHOW). Individuals in this metabolic type have an obese BMI but do not show any metabolic risks. Given the impact of obesity in relation to the risk of metabolic diseases, various studies have been conducted to examine the long-term effects of MHOW. Individuals with MHOW had a different fat distribution pattern (less ectopic and visceral fat), and lower inflammatory markers (Samocha-Bonet *et al.*, 2014). Other studies also have shown that women with MHOW had lower blood pressure, triglyceride levels, and glucose levels, but higher levels of HDL, adiponectin, and LDL compared to women with MUNW (Kim *et al.*, 2013). This condition was associated with good diet quality in individuals with MHOW. Based on National Health and Nutrition Examination Surveys (NHANES) data, Camhi *et al.* (2015) examined the quality of diet in obese subjects and found that adolescents and adult women with the MHOW metabolic type had higher diet quality scores due to high intake of fruit, whole grains, meat, and nuts.

Table 3 and Table 4 show the results of statistical analyses on anthropometric indicators related to metabolic syndromes. Table 3 shows the bivariate statistical analysis using the Pearson correlation test. The analysis results showed that all anthropometric indicators, namely WHtR, BMI, SAD, waist circumference, hip circumference and WHR have a strong positive relationship with the metabolic syndrome score (p<0.001), which means that the higher the anthropometric value, the higher the metabolic syndrome score. In addition, the analysis of the relationship between anthropometric indicators and each metabolic profile revealed that almost all of the independent variables (WHtR, waist and hip circumference, WHR, BMI, and SAD) were associated with each metabolic profile, such as baseline systolic pressure, diastolic blood pressure, triglyceride levels, blood sugar levels, and HDL. Only WHR was not associated with diastolic blood pressure (p>0.005).

Table 4 shows the results of the analysis using multiple linear regression to determine anthropometric indicators that are most associated with each metabolic profile and metabolic syndrome score. The results showed that BMI was the anthropometric indicator that is most associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood sugar (p<0.05), and HDL (p <0.001). In addition, waist circumference was the anthropometric indicator that is most associated with triglycerides and metabolic syndrome score (p<0.001). Based on the Adjusted R<sup>2</sup> value on the metabolic syndrome score, we found that 37.5% of the metabolic syndrome score was related to anthropometric indicators, such as WHtR, waist and hip circumference, WHR, BMI, and SAD. The rest may be influenced by other variables that are not included in this study. The correlation test results indicated that all anthropometric indicators had a positive relationship with the metabolic syndrome scores with p <0.001. Meanwhile, the regression analyses show that BMI and WHR were inversely related to cMetS. This is in line with research that reported an increase in the WHR value could be associated with the risk of metabolic syndrome in children and adolescents in Florida (Moore *et al.*, 2015). Another study revealed that there was a strong relationship between overweight and obese adolescents with metabolic syndrome (Al-Bachir and Bakir, 2017). Furthermore, a study on adolescents in South Africa found that central obesity as measured by the hip circumference could lead to an increased risk of cardiovascular diseases and death. Therefore, hip circumference and waist circumference can be used to predict the risk of cardiovascular diseases and death in the future (Cameron *et al.*, 2012).

Body Mass Index (BMI) is the most widely used indicator of measurement in epidemiological studies and is used as a substitute for evaluating body composition. However, BMI cannot distinguish fat from fat mass and lean mass, and it fails to show the presence of adipose and body fat distribution (Ofer *et al.*, 2019; Leone *et al.*, 2020). However, the BMI cut-offs for metabolic syndrome have not yet been determined (Ofer *et al.*, 2019). Obesity in adolescents is generally assessed using a BMI of  $\geq$ 25.0 kg/m<sup>2</sup>. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m<sup>2</sup>) and obesity ( $\geq$ 25.0 kg/m<sup>2</sup>), and we found that 35.6% of the subjects were obese. The finding is in line with the research on the subject of students at Universitas Diponegoro aged 18-21 years. They found that 40% of their study population had obesity level I and 36.3% had obesity level II (Rose *et al.*, 2020).

Abdominal obesity is often assessed to determine a metabolic syndrome in people. One of the indicators used to measure abdominal obesity is the Waist-to-Hip Ratio (WHR) which is calculated by dividing the waist circumference and the hip circumference. Measurement of waist circumference is more sensitive in assessing the distribution of body fat in the abdominal wall, which is also a component of metabolic syndrome. The limit of the WHR value for a female is  $\geq$  0.85 (Rokhmah, *et al.*, 2015). This study shows that every 1% increase in the WHR value will increase the cMetS value by 10.411. Hip circumference is also an indicator that has a strong correlation with cMetS, but many studies have used it as a ratio along with waist circumference for assessing a person's central obesity status.

# 4. Conclusion

Metabolic syndrome in female students can be identified using anthropometric measurements, one of which is BMI and WHR which are very easy to measure and efficient. BMI and WHR have the strongest relationship and can be used to detect early risk of metabolic syndrome in female college students.

# **Conflict of interest**

The authors declare no conflict of interest.

# Acknowledgements

The authors would like to thank all the subjects who participated in this study. We would also like to express our gratitude to The Ministry of Research, Technology and Higher Education, Indonesia" which was funded by the "Hibah Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) 2019.

# References

- Al-Bachir, M. and Bakir, M.A. (2017). Predictive value of body mass index to metabolic syndrome risk factors in Syrian adolescents. *Journal of Medical Case Reports*, 11(1), 170. https://doi.org/10.1186/s13256-017-1315-2
- Ärnlöv, J., Sundström, J., Ingelsson, E. and Lind, L. (2011). Impact of BMI and the metabolic syndrome on the risk of diabetes in middle-aged men. *Diabetes Care*, 34(1), 61–65. https://doi.org/10.2337/dc10-0955
- Aung, K.K., Lorenzo, C., Hinojosa, M.A. and Haffner, S.M. (2014). Risk of developing diabetes and cardiovascular disease in metabolically unhealthy normal-weight and metabolically healthy obese individuals. *Journal of Clinical Endocrinology and Metabolism*, 99(2), 462–468. https://doi.org/10.1210/jc.2013-2832
- Badan Penelitian dan Pengembangan Kesehatan. (2018). *Riset Kesehatan Dasar (RISKESDAS) 2018*. Jakarta, Indonesia.
- Cameron, A.J., Magliano, D.J., Shaw, J.E., Zimmet, P.Z., Carstensen, B., Alberti, K.G.M.M., Tuomilehto, J., Barr, E.L.M., Pauvaday, V.K., Kowlessur, S. and Söderberg, S. (2012). The influence of hip circumference on the relationship between abdominal obesity and mortality. *International Journal of Epidemiology*, 41(2), 484–494. https://doi.org/10.1093/ije/dyr198
- Camhi, S.M., Whitney Evans, E., Hayman, L.L., Lichtenstein, A.H. and Must, A. (2015). Healthy eating index and metabolically healthy obesity in U.S. adolescents and adults. *Preventive Medicine*, 77, 23–27. https://doi.org/10.1016/j.ypmed.2015.04.023
- Christijani, R. (2019). Determination of Diagnosis of Metabolic Syndrome based on Assessment of Metabolic Syndrome and NCEP ATP-III Score in Adolescent. *The Journal of Nutrition and Food Research*, 42(1), 21–28. https://doi.org/10.22435/pgm.v42i1.2418
- Devi, R., Manhas, S., Prasad, S., Sharma, S., Bhaskar, N. and Mahajan, S. (2017). Short Review of Metabolic Syndrome. *International Journal of Research and Review*, 4(2), 29.
- Dieny, F.F., Setyaningsih, R.F., Fitranti, D.Y., Jauharany, F.F., Putra, Y.D. and Tsani, A.F.A. (2020). Abdominal diameter profiles have relationship with insulin resistance in obese female adolescents. *Electronic Journal of General Medicine*, 17(5), em219. https://doi.org/10.29333/ejgm/7882
- Eckel, N., Mühlenbruch, K., Meidtner, K., Boeing, H., Stefan, N. and Schulze, M. B. (2015). Characterization of metabolically unhealthy normal-weight individuals: Risk factors and their associations with type 2 diabetes. *Metabolism: Clinical and Experimental*, 64(8), 862–871. https://doi.org/10.1016/j.metabol.2015.03.009

- Eisenmann, J.C., Laurson, K.R., Dubose, K.D., Smith, B.K. and Donnelly, J.E. (2010). Construct validity of a continuous metabolic syndrome score in children. *Diabetology and Metabolic Syndrome*, 2(1). https://doi.org/10.1186/1758-5996-2-8
- Firouzi, S.A., Tucker, L.A., LeCheminant, J.D. and Bailey, B.W. (2018). Sagittal abdominal diameter, waist circumference, and BMI as predictors of multiple measures of glucose metabolism: An NHANES investigation of US adults. *Journal of Diabetes Research*, 2018(9-10), 1–14. https://doi.org/10.1155/2018/3604108
- Hadaegh, F., Bozorgmanesh, M., Safarkhani, M., Khalili, D. and Azizi, F. (2011). Predictability of body mass index for diabetes: Affected by the presence of metabolic syndrome? *BMC Public Health*, 11(1), 383. https://doi.org/10.1186/1471-2458-11-383
- Heianza, Y., Kato, K., Kodama, S., Ohara, N., Suzuki, A., Tanaka, S., Hanyu, O., Sato, K. and Sone, H. (2015).
  Risk of the development of Type 2 diabetes in relation to overall obesity, abdominal obesity and the clustering of metabolic abnormalities in Japanese individuals: Does metabolically healthy overweight really exist? The Niigata Wellness Study. *Diabetic Medicine*, 32(5), 665–672. https://doi.org/10.1111/dme.12646
- Herningtyas, E.H. and Ng, T.S. (2019). Prevalence and distribution of metabolic syndrome and its components among provinces and ethnic groups in Indonesia. *BMC Public Health*, 19(1), 377. https://doi.org/10.1186/s12889-019-6711-7
- Hinnouho, G.M., Czernichow, S., Dugravot, A., Nabi, H., Brunner, E.J., Kivimaki, M. and Singh-Manoux, A. (2015). Metabolically healthy obesity and the risk of cardiovascular disease and type 2 diabetes: The Whitehall II cohort study. *European Heart Journal*, 36(9), 551–559. https://doi.org/10.1093/eurheartj/ehu123
- Jung, H.S., Chang, Y., Eun, Y.K., Kim, C.W., Choi, E.S., Kwon, M.J., Cho, J., Zhang, Y., Rampal, S., Zhao, D., Soo, K.H., Shin, H., Guallar, E. and Ryu, S. (2014). Impact of body mass index, metabolic health and weight change on incident diabetes in a Korean population. *Obesity*, 22(8), 1880–1887. https://doi.org/10.1002/oby.20751
- Karimah, M. (2018). Rasio Lingkar Pinggal-panggul Memiliki Hubungan Paling Kuat dengan Kadar Glukosa Darah'. Jurnal Berkala Epidemiologi, 6(3), 219–226. https://doi.org/10.20473/jbe.V6I32018.219-226
- Kim, M., Paik, J.K., Kang, R., Kim, S.Y., Lee, S.H. and Lee, J.H. (2013). Increased oxidative stress in normalweight postmenopausal women with metabolic syndrome compared with metabolically healthy overweight/obese individuals. *Metabolism: Clinical and Experimental*, 62(4), 554–560. https://doi.org/10.1016/j.metabol.2012.10.006

- Leone, A., Vizzuso, S., Brambilla, P., Mameli, C., Ravella, S., De Amicis, R., Battezzati, A., Zuccotti, G., Bertoli, S. and Verduci, E. (2020). Evaluation of different adiposity indices and association with metabolic syndrome risk in obese children: Is there a winner? *International Journal of Molecular Sciences*, 21(11), 4083. https://doi.org/10.3390/ijms21114083
- Li, Y., Zhao, L., Yu, D., Wang, Z. and Ding, G. (2018). Metabolic syndrome prevalence and its risk factors among adults in China: A nationally representative cross-sectional study. *PLoS ONE*, 13(6), e0199293. https://doi.org/10.1371/journal.pone.0199293
- Moore, L.M., Fals, A.M., Jannelle, P.J., Green, J.F., Pepe, J. and Richard, T. (2015). Analysis of Pediatric Waist to Hip Ratio Relationship to Metabolic Syndrome Markers. *Journal of Pediatric Health Care*, 29(4), 319–324. https://doi.org/10.1016/j.pedhc.2014.12.003
- Ofer, K., Leiba, R., Avizohar, O. and Karban, A. (2019). Normal body mass index (BMI) can rule out metabolic syndrome: An Israeli cohort study. *Medicine*, 98(9), e14712. https://doi.org/10.1097/MD.000000000014712
- Okosun, I.S., Boltri, J.M., Lyn, R. and Smith, M.D. (2010a). Continuous metabolic syndrome risk score, body mass index percentile, and leisure time physical activity in American children. *Journal of Clinical Hypertension*, 12(8), 636–644. https://doi.org/10.1111/j.1751-7176.2010.00338.x
- Okosun, I.S., Lyn, R., Smith, D.M., Eriksen, M. and Seale, P. (2010b). Validity of a Continuous Metabolic Risk Score as an Index for Modeling Metabolic Syndrome in Adolescents. *Annals of Epidemiology*, 20(11), 843–851. https://doi.org/10.1016/j.annepidem.2010.08.001
- Okura, T., Nakamura, R., Fujioka, Y., Kitao, S.K., Ito, Y., Matsumoto, K., Shoji, K., Sumi, K., Matsuzawa, K., Izawa, S., Ueta, W., Kato, M., Imamura, T., Taniquchi, I. and Yamamoto, K. (2018). Body mass index ≥23 is a risk factor for insulin resistance and diabetes in Japanese people: A brief report. *PLOS ONE*, 13(7), e0201052. https://doi.org/10.1371/journal.pone.0201052
- Pajunen, P., Rissanen, H., Laaksonen, M.A., Heliövaara, M., Reunanen, A. and Knekt, P. (2013). Sagittal abdominal diameter as a new predictor for incident diabetes. *Diabetes Care*, 36(2), 283–288. https://doi.org/10.2337/dc11-2451
- Pratiwi, Z.A., Hasanbasri, M. and Huriyati, E. (2017). Penentuan titik potong skor sindroma metabolik remaja dan penilaian validitas diagnostik parameter antropometri: analisis Riskesdas 2013. Jurnal Gizi Klinik Indonesia, 14(2), 80. https://doi.org/10.22146/ijcn.25590
- Prybyla, O. (2020). *Metabolic phenotyping: is it so important? Journal of Cognitive Neuropsychology*, 4(1), 1-3.

Rodea-Montero, E.R., Evia-Viscarra, M.L. and Apolinar-Jiménez, E. (2014). Waist-to-height ratio is a better

anthropometric index than waist circumference and BMI in predicting metabolic syndrome among obese mexican adolescents. *International Journal of Endocrinology*, 2014, 195407. https://doi.org/10.1155/2014/195407

- Rokhmah, F.D., Handayani, D. and Al-Rasyid, H. (2015). Korelasi lingkar pinggang dan rasio lingkar pinggang-panggul terhadap kadar glukosa plasma menggunakan tes toleransi glukosa oral. Jurnal Gizi Klinik Indonesia, 12(1), 28–35. https://doi.org/10.22146/ijcn.22425
- Rose, S., Dieny, F.F., Nuryanto, N. and Tsani, A.F.A. (2020). The correlation between waist-to-height ratio (wHtR) and second to fourth digit ratio (2D:4D) with an increase in metabolic syndrome scores in obese adolescent girls. *Electronic Journal of General Medicine*, 17(3), em211. https://doi.org/10.29333/ejgm/7872
- Samocha-Bonet, D., Dixit, V.D., Kahn, C.R., Leibel, R.L., Lin, X., Nieuwdorp, M., Pietiläinen, K.H., Rabasa-Lhoret, R., Roden, M., Scherer, P.E., Klein, S. and Ravussin, E. (2014). Metabolically healthy and unhealthy obese - The 2013 stock conference report. *Obesity Reviews*, 15(9), 697–708. https://doi.org/10.1111/obr.12199
- Soewondo, P., Purnamasari, D., Oemardi, M., Waspadji, S. and Soegondo, S. (2010). Prevalence of Metabolic Syndrome Using NCEP/ATP III Criteria in Jakarta, Indonesia: The Jakarta Primary Noncommunicable Disease Risk Factors Surveillance 2006. Acta Medica Indonesiana - The International Journal of Medicine, 42(4), 199–203.
- Sri Rahayu, M. and Maulina, M. (2017). Hubungan Rasio Lingkar Pinggang dan Lingkar Pinggul dengan Penyakit Jantung Koroner. *Jurnal Aceh Medika*, 1(1), 1–10. Retrieved April 8, 2021 from www.jurnal.abulyatama.ac.id/acehmedika (Accessed: 8 April 2021).
- Srikanthan, K., Feyh, A., Visweshwar, H., Shapiro, J.I. and Sodhi, K. (2016). Systematic review of metabolic syndrome biomarkers: A panel for early detection, management, and risk stratification in the West Virginian population. *International Journal of Medical Sciences*, 13(1), 25–38. https://doi.org/10.7150/ijms.13800
- Suliga, E., Kozieł, D., Cieśla, E. and Głuszek, S. (2015). Association between dietary patterns and metabolic syndrome in individuals with normal weight: A cross-sectional study. *Nutrition Journal*, 14(1), 55. https://doi.org/10.1186/s12937-015-0045-9
- Sumardiyono, S., Pamungkasari, E.P., Mahendra, A.G., Utomo, O.S., Mahajana, D., Cahyadi, W.R. and Ulfia, M. (2018). Hubungan Lingkar Pinggang dan Lingkar Panggul dengan Tekanan Darah pada Pasien Program Pengelolaan Penyakit Kronis (Prolanis). *Smart Medical Journal*, 1(1), 26. https://doi.org/10.13057/smj.v1i1.24504

Susetyowati, S. (2016). Gizi Remaja, in Ilmu Gizi: Teori dan Aplikasi. Jakarta, Indonesia: EGC, 160–164.

- Zhang, Y.X., Wang, Z.X., Chu, Z.H. and Zhao, J.S. (2016). Profiles of body mass index and the nutritional status among children and adolescents categorized by waist-to-height ratio cut-offs. *International Journal of Cardiology*, 223, 529–533. https://doi.org/10.1016/j.ijcard.2016.07.303
- Zhou, D., Yang, M., Yuan, Z. P., Zhang, D.D., Liang, L., Wang, C.L., Zhang, S., Zhu, H.H., Lai, M.D. and Zhu,
  Y.M. (2014). Waist-to-Height Ratio: A simple, effective and practical screening tool for childhood obesity and metabolic syndrome. *Preventive Medicine*, 67, 35–40. https://doi.org/10.1016/j.ypmed.2014.06.025

Variable	Minimum	Maximum	Mean	SD
Anthropometric Indicators				
WHtR (ratio)	0.37	0.71	0.51	0.07
WHR (ratio)	0.67	0.96	0.80	0.06
BMI (kg/m²)	15.81	39.30	24.04	4.72
Sagital Abdominal Diameter (cm)	11.35	25.50	16.79	2.42
Hip Circumference (cm)	80.60	138.45	98.96	9.30
Waist Circumference (cm)	58.00	112.10	79.44	10.78
Metabolic Profiles				
Blood Glucose Levels (mg/dL)	66.00	110.00	92.00	7.59
Trygliceride Levels (mg/dL)	29.00	309.00	88.35	44.68
Cholesterol HDL Levels (mg/dL)	36.00	109.00	61.73	26.43
Systolic Blood Pressure (mmHg)	84.00	144.00	114.63	11.13
Diastolic Blood Pressure (mmHg)	55.00	178.00	82.40	55.52
cMetS (Score of Metabolic Syndrome)	-7.10	11.93	0.01	2.90

Table 1. Minimum, maximum, average and standard deviation

Characteristics	n	%
Anthropometric		
Body Mass Index (BMI)		
Underweight (< 18.5 kg/m²)	6	3.7
Normal (18.5 – 22.9 kg/m²)	71	43.6
Overweight (23-24.9 kg/m²)	28	17.2
Obese (≥25.0 kg/m²)	58	35.6
Waist Height Ratio (WHtR)		
Normal (<0.50)	45	27.6
At Risk (≥0.50)	118	72.4
Waist Hip Ratio		
Normal (<0.85)	127	77.9
Central Obesity (≥0.85)	36	22.1
Sagital Abdominal Diameter (SAD)		
Normal (≤19.3 cm)	143	87.7
At Risk (>19.3 cm)	20	12.3
Wait Circumference		
Normal (<80 cm)	73	44.8
Obese (≤80 cm)	90	55.2
Metabolic Profiles		
Blood Glucose Levels		
Normal (<110 mg/dL)	136	83.4
High (≥110 mg/dL)	27	16.6
Triglycerides		
Normal (<150 mg/dL)	149	914
High (≥150 mg/dL)	14	8.6
Cholesterol HDL		
Normal (≥150 mg/dL)	135	82.8
Low (<150 mg/dL)	28	17.2
Sistolic Blood Pressure		

Table 2. Anthropometric overview and components of metabolic syndrome

Normal (<130 mg/dL)	136	83.4
High (≥130 mg/dL)	27	16.6
Diastolic Blood Pressure		
Normal (<85 mg/dL)	128	78.5
High (≥85 mg/dL)	35	21.5
cMetS (Score of Metabolic Syndrome)		
Normal (<2.21)	109	66.9
At Risk (≥2.21)	54	33.1
Metabolic Types		
Metabolic Unhealthy Normal Weight (MUNW)	17	10.4
Metabolic Healthy Normal Weight (MHNW)	88	54
Metabolic Unhealthy Obese Weight (MUOW)	38	23.3
Metabolic Healthy Obese Weight (MHOW)	20	12.3

	triglycerides, blood sugar, HDL and metabolic syndrome scores)									Commented [VN3]: Rather than bold the			
Variable	Systolic BP		Diastolic BP		TG		Blood Glucose		HDL		cMetS	U	<ul> <li>showed significant difference, you should i table note, p-value&lt;0.05/0.01 indicates sig</li> </ul>
	r	p	r	p	r	p	r	p	r	p	r	<i>p</i> difference.	
WHtR	0.358	<0.001	0.306	<0.001	0.289	<0.001	0.210	0.007	-0.266	0.001	0.599	<0.001	
BMI	0.370	<0.001	0.313	<0.001	0.315	<0.001	0.221	0.005	-0.292	<0.001	0.600	<0.001	
SAD	0.352	<0.001	0.284	<0.001	0.278	<0.001	0.191	0.015	-0.264	0.001	0.575	<0.001	
WC	0.377	<0.001	0.284	<0.001	0.295	<0.001	0.212	0.005	-0.243	0.002	0.616	<0.001	
нс	0.369	<0.001	0.332	<0.001	0.302	<0.001	0.179	0.002	-0.273	<0.001	0.581	<0.001	
WHR	0.244	0.002	0.128	0.104	0.194	0.013	0.172	0.028	-0.149	0.048	0.415	<0.001	

# Table 3. The relationship between anthropometric indicators and metabolic profiles (blood pressure,

		syndrome scores								
Variable	Systolic BP									
	Constant	USCª	p1 <sup>b</sup>	p2 <sup>c</sup>	<sup>d</sup> Adjusted R <sup>2</sup>					
BMI	91.759	0.951	<0.001	<0.001	0.158					
	Blood Gluc	ose Levels								
	Constant	USC <sup>a</sup>	p1 <sup>b</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>					
BMI	83.454	0.355	0.005	<0.001	0.043					
	HDL									
	Constant	USC <sup>a</sup>	p1 <sup>b</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>					
BMI	81.429	-0.819	<0.001	<0.001	0.080					
	Triglyceride	es								
	Constant	USC <sup>a</sup>	p1 <sup>b</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>					
WC	-6.614	1.195	<0.001	<0.001	0.078					
	Score of Metabolic Syndrome									
	Constant	USC <sup>a</sup>	p1 <sup>b</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>					
WC	-13.163	0.166	<0.001	<0.001	0.375					

Table 4. Anthropometric indicators most associated with metabolic components and metabolic

<sup>a</sup>Unstandardized Coefficient, <sup>b</sup> p-value, <sup>c</sup> p F-Test (ANOVA), <sup>d</sup> coefficient of determination

# Anthropometry indicators that are most related to metabolic profiles in female college students

<sup>1,2,</sup>\*Dieny, F.F., <sup>1</sup>Rose S., <sup>1,2</sup>Tsani, A.F.A., <sup>1</sup>Jauharany, F.F. and <sup>1,2</sup>Fitranti, D.Y. <sup>1</sup>Department of Nutrition Science, Faculty of Medicine, Universitas Diponegoro, Indonesia <sup>2</sup>Center of Nutrition Research (CENURE), Faculty of Medicine, Universitas Diponegoro, Indonesia

\*Corresponding author: fillahdieny@gmail.com

ORCID ID Author 1: 0000-0001-6071-8901 ORCID ID Author 2: 0000-0002-1898-1842 ORCID ID Author 3: 0000-0002-3407-5188 ORCID ID Author 4: 0000-0001-9471-9419 ORCID ID Author 5: 0000-0002-1656-9563

#### Article history:

Received: 2 June 2021 Received in revised form: 8 July 2021 Accepted: 27 September 2021

# Abstract

Metabolic syndrome is not a disease but is a set of several disorders and causes an increased risk of cardiovascular disease and diabetes mellitus complications. Several studies have shown that non-invasive approaches such as anthropometric measurements can be used for the early detection of metabolic syndrome. This study aimed to analyse the anthropometric indicators related to metabolic syndrome in female college students. The design of this research is cross sectional, with the number of subjects

involved as many as 163 female college students aged 19 to 24 years old. Purposive sampling was used in the sampling of this research. The independent variables in this study were the Waist-to-Height Ratio (WHtR), Waist-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference. The dependent variable in this study is the metabolic syndrome component that has been converted into a metabolic syndrome score (cMetS). The analysis results showed that all anthropometric indicators, namely WHtR, BMI, SAD, waist circumference, hip circumference and WHR have a strong positive relationship with the metabolic syndrome score (p<0.001). BMI was the anthropometric indicator that is most associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood sugar (p<0.05), and HDL (p<0.001). Waist circumference was the anthropometric indicator that is most associated with triglycerides and metabolic syndrome score (p<0.001). Metabolic syndrome in female college students can be identified using anthropometric measurements, one of which is BMI and WHR which are very easy to measure and efficient. BMI and WHR have the strongest relationship and can be used to detect early risk of metabolic syndrome in female college students.

Keywords: Adolescent, Anthropometric indicator, Female, Metabolic profile, Metabolic syndrome

#### 1. Introduction

Metabolic syndrome is a set of body metabolic disorders such as dyslipidemia, hyperglycemia, hypertension, and central obesity (Srikanthan *et al.*, 2016; Devi *et al.*, 2017; Christijani, 2019). Metabolic syndrome is not a disease, but is a set of several disorders that causes an increased risk of cardiovascular disease and diabetes mellitus complications. Some epidemiological studies have shown that metabolic syndrome doubles the risk of cardiovascular diseases (Sri Rahayu and Maulina, 2017).

Indonesia as a developing country cannot be separated from the existing nutritional problems in the world, including the incidence of obesity and metabolic syndrome. Several studies found that the prevalence of metabolic syndrome keeps increasing every year. A study in China showed the prevalence of metabolic syndrome in adults was 24.2% (Li *et al.*, 2018). Another study indicated that the prevalence of metabolic syndrome in Indonesia was 21.66% (Herningtyas and Ng, 2019). In recent studies, metabolic syndrome can be assessed using the continuous value of metabolic syndrome (cMets) or the metabolic syndrome score recommended by the American Diabetic Association of Diabetes. The metabolic syndrome score is a z-score resulting from the assessment of all components

of the metabolic syndrome (Pratiwi, *et al.*, 2017). The advantages of using cMetS are (1) reducing dichotomization factors because cardiovascular disease is a progression of several components of the metabolic syndrome, (2) cMetS is more sensitive and less error-prone than categoric metabolic syndrome assessments, (3) increasing the statistical power (Okosun *et al.*, 2010b).

Central obesity is one of the components of metabolic syndrome parameters. Central obesity is associated with increased blood pressure, serum triglycerides, decreased HDL, and glucose intolerance. Based on the National Basic Health Research (Riskesdas) in 2018, the prevalence of obesity in adults was 21.8%, and the prevalence of central obesity at age of more than 15 years increased from 26.6% in 2013 to 31% in 2018 (Badan Penelitian dan Pengembangan Kesehatan, 2018). Obesity is closely related to degenerative diseases. Riskesdas (2018) showed that the prevalence of stroke, diabetes mellitus, heart disease, and hypertension is higher in women than men.

Several studies have shown that non-invasive approaches such as anthropometric measurements can be used for the early detection of metabolic syndrome (Pratiwi, *et al.*, 2017). Anthropometric measurements are described as the measurements of body dimensions and body composition to assess nutritional status. The advantages of anthropometric measurements are relatively fast and easy, as they can be performed using portable and calibrated instruments with standardized methods (Rokhmah, *et al.*, 2015). Some anthropometric measurements that can be used for early detection of metabolic syndrome are Waist-to-Height Ratio (WHR), waist-to-hip ratio (WHR), hip circumference, Body Mass Index (BMI), Sagital Abdominal Diameter (SAD).

One of the anthropometric measurements which can be a parameter for central obesity is the ratio of waist circumference to height (WHtR). The instruments used in the measurement are microtoise and measuring tape, which take a longer time. Studies on waist circumference have been shown to have a strong correlation with abdominal fat deposits (Zhou *et al.*, 2014). The distribution of abdominal adipose tissue (central obesity) in adults is associated with a component of the metabolic syndrome (Rodea-Montero, *et al.*, 2014). A study on adult subjects has shown that people who have the same waist circumference but are shorter in height have a greater risk of developing metabolic syndrome than taller people (Zhou *et al.*, 2014). Therefore, WHtR can be used as a simple and effective anthropometric index to identify the metabolic risk associated with obesity (Rodea-Montero, *et al.*, 2014).

The Waist-To-Hip Ratio (WHR) is a measurement that may indicate central obesity (Karimah, 2018). The higher the WHR value, the higher the risk level for several metabolic diseases. The Waist-To-Hip Ratio is calculated by dividing the measurement of the waist circumference by the circumference of the hip. The cut-off points for WHR are  $\geq$ 1.0 for men and  $\geq$ 0.85 for women (Rokhmah *et al.*, 2015). Individuals with a high waist and hip circumference will also have a higher distribution of fat in their abdominal area. Irregular fats distribution in the abdominal area indirectly causes higher triglyceride levels circulating in the blood, which will affect blood pressure (Sumardiyono *et al.*, 2018). WHR measurement is more sensitive in assessing the distribution of fat in the abdomen. This measurement of waist circumference is performed by determining the lower part of arcus costae and crista iliaca (Sri Rahayu and Maulina, 2017).

Body Mass Index (BMI) is a practical and easy measurement to perform, but it cannot distinguish between fat mass, bone mass and muscle mass. BMI is calculated as body weight (kg) / height squared (m<sup>2</sup>) (Okura *et al.*, 2018). BMI can be used as the first measurement before any other anthropometric measurements.

Sagittal Abdominal Diameter (SAD) or the height of the abdomen while the subjects are in a lying position. This anthropometric measurement has not been widely used to measure fat tissue in the abdominal area. SAD measurements using computed tomography or magnetic resonance imaging, and are associated with components of metabolic syndrome. The measurements of SAD are taken when the subject is lying down on the examination table with a naked upper body. SAD is related to central obesity in individuals with obesity and normal nutritional status. Furthermore, SAD is associated with diabetes mellitus and a predictor of cardiovascular disease incidence, even when SAD is measured in a standing position (Pajunen *et al.*, 2013). Based on the above-mentioned problems, our study aimed to analyze the anthropometric indicators related to metabolic syndrome in female college students.

#### 2. Materials and methods

2.1 Design, location, and time

A cross-sectional study design and this research was conducted from March to July 2020. Anthropometric and biochemical data were collected at the Cito Laboratory, Banyumanik Semarang with health protocols applied. This study was approved by the Medical/Health Research Bioethics Commission, Faculty of Medicine, Sultan Agung Islamic University Semarang with Number No.296 /IX /2020 /Bioethical Commission.

# 2.2 Samplings

This study was conducted during the SARS-CoV-2 outbreak, which later was named COVID-19 by the WHO, hence the registration for study participants was done online. Purposive sampling was used in this study and the total number of subjects required was 163. Samples are selected based on inclusion criteria, such as voluntary to be research subjects, female college students in Semarang City, aged 19-24 years in Semarang, not consuming alcohol, not smoking, and voluntary to follow a series of study instructions. Exclusion criteria are subjects who withdraw and those who are ill during the research study. Based on the exclusion criteria mentioned, no subjects are included in the exclusion criteria. Subjects were asked to fill in personal data using a Google Form, and eligible subjects will be contacted by the researchers to plan a direct meeting.

The health protocol applied during the anthropometric and biochemical data collection process, consisted of the subject filling out a COVID-19 sign/symptom screening questionnaire, the subject was checked for temperature, the subject washed hands before entering the room, the distance between subjects was at least 1 meter, the subject and researcher used a mask and face shield. Researchers used gloves and protective clothing. During the study, hand sanitisers were provided, and anthropometric tools that were on the subject's skin were wiped with alcohol.

## 2.3 Data collected

The independent variables in this study were the Waist-to-Height Ratio (WHR), Waist-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference. Weight and height data were obtained through direct measurements using a digital stamp scale GEA brand with an accuracy of 0.1 kg and microtoise with an accuracy of 0.1 cm. Waist circumference and hip circumference were measured using a measuring tape (Medline) to the nearest 1 mm and abdominal height was measured using the Abawerk Schaffenburg abdominal calliper to the nearest 1 mm. SAD measurements were performed with the subject in a supine position on a flat surface with both knees forming an angle of 90° (Firouzi *et al.*, 2018). Anthropometric data were collected by trained enumerators.

The cut-off point used in this study refers to previous studies because it had been adjusted for the Asian race (Rose *et al.*, 2020). Each anthropometric measurement is stated as "at-risk" if the individuals have  $\geq 0.50$  for WHtR (Zhang *et al.*, 2016),  $\geq 0.85$  for WHR (Rokhmah *et al.*, 2015), > 19.3 cm for Sagital Abdominal Diameter (SAD) (Dieny *et al.*, 2020), and have the normal to overweight BMI (18.5 - 25 kg/m<sup>2</sup>) or obese BMI ( $\geq 25.0$  kg/m<sup>2</sup>) (Susetyowati, 2016).

The dependent variable in this study is the metabolic syndrome component that has been converted into a metabolic syndrome score (cMetS) with the cut-off point of cMetS> 2.21 (Rose et al., 2020). The guidelines for metabolic syndrome in this study are taken from the National Cholesterol Education Program-Adult Treatment Panel (NCEP-ATP III) 2005 which has been frequently used in Indonesia. There are 5 parameters to assess metabolic syndrome: (1) fasting blood glucose levels ≥110 mg/dL, (2) triglyceride levels ≥150 mg/dL (3) HDL cholesterol levels <50 mg/dL, (4) central obesity in women with waist circumference ≥80 cm, and (5) systolic and diastolic blood pressures ≥130 mmHg and ≥85 mmHg, respectively (Soewondo et al., 2010). The calculation of the metabolic syndrome score (cMetS) was done in the following steps: (1) after measuring all parameters of the metabolic syndrome, standardisation was carried out to obtain a Z-score; (2) the blood pressure must be converted into Mean Arterial Blood (MAP) by dividing the difference between systolic and diastolic blood pressure by three and summed with the diastolic blood pressure; (3) the HDL cholesterol standardization results were multiplied by (-1) because the parameter was inversely related to the risk of metabolic syndrome; (4) All Z-scores were added to obtain the cMetS values; (5) The final step was to compare the cMetS values with the cut-off point of ≥2,21 (Eisenmann et al., 2010; Okosun et al., 2010a; Rose et al., 2020). The subjects were instructed to do fasting for at least 8 hrs, only drinking water was permitted.

Other than the cMetS score, metabolic syndrome risk can also be assessed from the classification of metabolic types. This classification combines the internal and external signs of the body such as biochemical parameters, the ratio of subcutaneous fat to abdominal fat, and blood pressure (Prybyla O, 2020). The main phenotypes that reflect the possible combination of metabolic profile and the degree of obesity are metabolic healthy obese weight, metabolic healthy normal weight, metabolic unhealthy normal weight, and metabolic unhealthy normal weight.

#### 2.4 Data analysis

All data were analyzed using computer programs and statistical analyses were performed using SPSS statistical software version 22. Univariate analysis was used to describe subjects characteristics.

The normality test of the data using the Kolmogorov-Smirnov test was carried out before testing the hypothesis. The relationship of anthropometric indicators with metabolic profile (Blood Pressure, Triglycerides, Blood Sugar, HDL and metabolic syndrome scores) was determined using the Person correlation test. Furthermore, Anthropometric indicators that are most related to the metabolic component and metabolic syndrome score were analyzed using the Multiple Linear Regression test.

#### 3. Results and discussion

The subject characteristics measured in female students aged 19-24 years include age, anthropometric indicators, and metabolic syndromes. Table 1 shows the characteristics of the study subjects. The mean WHR value in this study was 0.51. Meanwhile, the mean WHR was 0.80; the mean BMI was 24.04 kg/m<sup>2</sup>; the mean SAD was 16.79 cm, and the mean waist circumference was 79.44 cm.

Table 2 shows the various nutritional status of the subjects based on BMI. It was found that 43.6% of the subjects had normal BMI, 17.2% were overweight and 35.6% were obese. Based on the WHtR anthropometric indicator, 72.4% of subjects were at risk of having obesity, based on WHR, 22.1% had central obesity, based on BMI, 35.6% were obese, based on SAD 12.3% of the subjects were at risk, and based on waist circumference 55.2% had central obesity. According to the metabolic profile that was assessed, 16.6% had high Fasting Blood Glucose levels, 8.6% had hypertriglycerides, 17.2% had low HDL, and 16.6% had high systolic blood pressure, and 21.5% had high diastolic blood pressure. In addition, we found that 33.1% of the subjects had high metabolic syndrome (cMetS) scores. This proportion was similar to the assessment based on the metabolic type of unhealthy subjects (subjects who had  $\geq$  3 risk factors of the metabolic profile), which was 33.7%. Moreover, two subjects had five risk factors: abdominal obesity, hypertension, hyperglycemia, hypertriglycerides, and low HDL.

The objective of this study was to determine the anthropometric indicators associated with metabolic syndromes in female students. The study included 163 female students aged 19-24 years. The students are in their late adolescents who begin to have an independent life. Inappropriate and unhealthy eating behaviour will have an impact on the student's nutritional status. Excessive nutritional status and obesity will affect student's body metabolism. Based on the study results, 33.1% of the subjects had a high metabolic syndrome (cMetS) score. In line with the previous study conducted in 2019 on 18-to-21-year-old students at Universitas Diponegoro, 20% of the subjects had high cMetS (Rose *et al.*, 2020). Meanwhile, a study conducted by Pratiwi et al in 2017 using secondary data from the National Basic Health Research 2013 found that 19.98% of adolescents aged 15-24 years

had high cMetS (Pratiwi, *et al.*, 2017). To conclude, there is a trend of Metabolic Syndrome Score (cMetS) among young women in Semarang.

The assessment of metabolic syndrome using a continuous type (scoring) rather than using a dichotomy or binary ("yes" and "no") is recommended (Christijani, 2019). An adolescent can be diagnosed with metabolic syndrome if their Metabolic Syndrome Score (cMetS) >2.21 (Pratiwi, *et al.*, 2017). Anthropometric indicators used in this study are Waist and Height Ratio (WHR), Waist-to-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and Waist Circumference. Based on the correlation analyses, all anthropometric indicators have a significant positive relationship with the Metabolic Syndrome Score (cMetS). Furthermore, the multivariate analyses show that the anthropometric indicators of BMI and WHR are strongly associated with cMetS.

If the metabolic type is considered based on nutritional status (subjects with non-obese BMI (<25kg/m<sup>2</sup>) with metabolic healthy and metabolic unhealthy and subjects with obese BMI (>25kg/m<sup>2</sup>) with metabolic healthy and metabolic unhealthy), subjects are categorized as metabolic unhealthy (experiencing metabolic syndrome) if they fulfil  $\geq$  3 risk factors including high waist circumference, blood pressure, fasting blood glucose and triglyceride levels, and low HDL levels. Based on these criteria, it was found that 10.4% of the subjects had a metabolic unhealthy normal weight (MUNW) and 23.3% of the subjects had metabolic unhealthy obesity weight (MUOW). Of non-obese subjects, 54% of them were metabolic healthy. Our study also shows that 10.4% of the subjects were classified as metabolic unhealthy normal weight (MUNW). The subjects' BMI in this category is in the normal range but has a high percentage of body fat that makes them at high risk of developing metabolic disorders (Eckel et al., 2015; Suliga et al., 2015). Several recent cohort studies have shown a greater risk of type II diabetes mellitus in individuals with MUNW compared to individuals with MHNW (Ärnlöv et al., 2011; Hadaegh et al., 2011; Aung et al., 2014; Jung et al., 2014; Hinnouho et al., 2015). Other studies have shown that women with the MUNW type have a long-term impact of an increased risk of cardiovascular diseases such as higher blood pressure, triglyceride and glucose levels as well as lower levels of adiponectin, HDL, and LDL compared to women with the MHNW type (Kim et al., 2013).

In this study, 23.3% of the subjects belonged to the Metabolic Unhealthy Obese Weight (MUOW) type. Subjects with this metabolic type have an obese BMI and have a high risk of developing metabolic disorders. A study conducted in Japan on 29,564 subjects showed that individuals with MUOW had a greater risk of developing type II diabetes mellitus compared to individuals with MHOW (Heianza *et al.*, 2015).

It was also found that 12.3% of the subjects were categorized as metabolic healthy obese weight (MHOW). Individuals in this metabolic type have an obese BMI but do not show any metabolic risks. Given the impact of obesity in relation to the risk of metabolic diseases, various studies have been conducted to examine the long-term effects of MHOW. Individuals with MHOW had a different fat distribution pattern (less ectopic and visceral fat), and lower inflammatory markers (Samocha-Bonet *et al.*, 2014). Other studies also have shown that women with MHOW had lower blood pressure, triglyceride levels, and glucose levels, but higher levels of HDL, adiponectin, and LDL compared to women with MUNW (Kim *et al.*, 2013). This condition was associated with good diet quality in individuals with MHOW. Based on National Health and Nutrition Examination Surveys (NHANES) data, Camhi *et al.* (2015) examined the quality of diet in obese subjects and found that adolescents and adult women with the MHOW metabolic type had higher diet quality scores due to high intake of fruit, whole grains, meat, and nuts.

Table 3 and Table 4 show the results of statistical analyses on anthropometric indicators related to metabolic syndromes. Table 3 shows the bivariate statistical analysis using the Pearson correlation test. The analysis results showed that all anthropometric indicators, namely WHtR, BMI, SAD, waist circumference, hip circumference and WHR have a strong positive relationship with the metabolic syndrome score (p<0.001), which means that the higher the anthropometric value, the higher the metabolic syndrome score. In addition, the analysis of the relationship between anthropometric indicators and each metabolic profile revealed that almost all of the independent variables (WHtR, waist and hip circumference, WHR, BMI, and SAD) were associated with each metabolic profile, such as baseline systolic pressure, diastolic blood pressure, triglyceride levels, blood sugar levels, and HDL. Only WHR was not associated with diastolic blood pressure (p>0.005).

Table 4 shows the results of the analysis using multiple linear regression to determine anthropometric indicators that are most associated with each metabolic profile and metabolic syndrome score. The results showed that BMI was the anthropometric indicator that is most associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood sugar (p<0.05), and HDL (p <0.001). In addition, waist circumference was the anthropometric indicator that is most associated with triglycerides and metabolic syndrome score (p<0.001). Based on the Adjusted R<sup>2</sup> value on the metabolic syndrome score, we found that 37.5% of the metabolic syndrome score was related to anthropometric indicators, such as WHtR, waist and hip circumference, WHR, BMI, and SAD. The rest may be influenced by other variables that are not included in this study. The correlation test results indicated that all anthropometric indicators had a positive relationship with the metabolic syndrome scores with p <0.001. Meanwhile, the regression analyses show that BMI and WHR were inversely related to cMetS. This is in line with research that reported an increase in the WHR value could be associated with the risk of metabolic syndrome in children and adolescents in Florida (Moore *et al.*, 2015). Another study revealed that there was a strong relationship between overweight and obese adolescents with metabolic syndrome (Al-Bachir and Bakir, 2017). Furthermore, a study on adolescents in South Africa found that central obesity as measured by the hip circumference could lead to an increased risk of cardiovascular diseases and death. Therefore, hip circumference and waist circumference can be used to predict the risk of cardiovascular diseases and death in the future (Cameron *et al.*, 2012).

Body Mass Index (BMI) is the most widely used indicator of measurement in epidemiological studies and is used as a substitute for evaluating body composition. However, BMI cannot distinguish fat from fat mass and lean mass, and it fails to show the presence of adipose and body fat distribution (Ofer *et al.*, 2019; Leone *et al.*, 2020). However, the BMI cut-offs for metabolic syndrome have not yet been determined (Ofer *et al.*, 2019). Obesity in adolescents is generally assessed using a BMI of  $\geq$ 25.0 kg/m<sup>2</sup>. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m<sup>2</sup>) and obesity ( $\geq$ 25.0 kg/m<sup>2</sup>), and we found that 35.6% of the subjects were obese. The finding is in line with the research on the subject of students at Universitas Diponegoro aged 18-21 years. They found that 40% of their study population had obesity level I and 36.3% had obesity level II (Rose *et al.*, 2020).

Abdominal obesity is often assessed to determine a metabolic syndrome in people. One of the indicators used to measure abdominal obesity is the Waist-to-Hip Ratio (WHR) which is calculated by dividing the waist circumference and the hip circumference. Measurement of waist circumference is more sensitive in assessing the distribution of body fat in the abdominal wall, which is also a component of metabolic syndrome. The limit of the WHR value for a female is  $\geq$  0.85 (Rokhmah, *et al.*, 2015). This study shows that every 1% increase in the WHR value will increase the cMetS value by 10.411. Hip circumference is also an indicator that has a strong correlation with cMetS, but many studies have used it as a ratio along with waist circumference for assessing a person's central obesity status.

### 4. Conclusion

Metabolic syndrome in female students can be identified using anthropometric measurements, one of which is BMI and WHR which are very easy to measure and efficient. BMI and WHR have the strongest relationship and can be used to detect early risk of metabolic syndrome in female college students.

## **Conflict of interest**

The authors declare no conflict of interest.

## Acknowledgements

The authors would like to thank all the subjects who participated in this study. We would also like to express our gratitude to The Ministry of Research, Technology and Higher Education, Indonesia" which was funded by the "Hibah Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) 2019.

### References

- Al-Bachir, M. and Bakir, M.A. (2017). Predictive value of body mass index to metabolic syndrome risk factors in Syrian adolescents. *Journal of Medical Case Reports*, 11(1), 170. https://doi.org/10.1186/s13256-017-1315-2
- Ärnlöv, J., Sundström, J., Ingelsson, E. and Lind, L. (2011). Impact of BMI and the metabolic syndrome on the risk of diabetes in middle-aged men. *Diabetes Care*, 34(1), 61–65. https://doi.org/10.2337/dc10-0955
- Aung, K.K., Lorenzo, C., Hinojosa, M.A. and Haffner, S.M. (2014). Risk of developing diabetes and cardiovascular disease in metabolically unhealthy normal-weight and metabolically healthy obese individuals. *Journal of Clinical Endocrinology and Metabolism*, 99(2), 462–468. https://doi.org/10.1210/jc.2013-2832
- Badan Penelitian dan Pengembangan Kesehatan. (2018). *Riset Kesehatan Dasar (RISKESDAS) 2018*. Jakarta, Indonesia.
- Cameron, A.J., Magliano, D.J., Shaw, J.E., Zimmet, P.Z., Carstensen, B., Alberti, K.G.M.M., Tuomilehto, J., Barr, E.L.M., Pauvaday, V.K., Kowlessur, S. and Söderberg, S. (2012). The influence of hip circumference on the relationship between abdominal obesity and mortality. *International Journal of Epidemiology*, 41(2), 484–494. https://doi.org/10.1093/ije/dyr198
- Camhi, S.M., Whitney Evans, E., Hayman, L.L., Lichtenstein, A.H. and Must, A. (2015). Healthy eating index and metabolically healthy obesity in U.S. adolescents and adults. *Preventive Medicine*, 77, 23–27. https://doi.org/10.1016/j.ypmed.2015.04.023
- Christijani, R. (2019). Determination of Diagnosis of Metabolic Syndrome based on Assessment of Metabolic Syndrome and NCEP ATP-III Score in Adolescent. *The Journal of Nutrition and Food Research*, 42(1), 21–28. https://doi.org/10.22435/pgm.v42i1.2418
- Devi, R., Manhas, S., Prasad, S., Sharma, S., Bhaskar, N. and Mahajan, S. (2017). Short Review of Metabolic Syndrome. *International Journal of Research and Review*, 4(2), 29.
- Dieny, F.F., Setyaningsih, R.F., Fitranti, D.Y., Jauharany, F.F., Putra, Y.D. and Tsani, A.F.A. (2020). Abdominal diameter profiles have relationship with insulin resistance in obese female adolescents. *Electronic Journal of General Medicine*, 17(5), em219. https://doi.org/10.29333/ejgm/7882
- Eckel, N., Mühlenbruch, K., Meidtner, K., Boeing, H., Stefan, N. and Schulze, M. B. (2015). Characterization of metabolically unhealthy normal-weight individuals: Risk factors and their associations with type 2 diabetes. *Metabolism: Clinical and Experimental*, 64(8), 862–871. https://doi.org/10.1016/j.metabol.2015.03.009

- Eisenmann, J.C., Laurson, K.R., Dubose, K.D., Smith, B.K. and Donnelly, J.E. (2010). Construct validity of a continuous metabolic syndrome score in children. *Diabetology and Metabolic Syndrome*, 2(1). https://doi.org/10.1186/1758-5996-2-8
- Firouzi, S.A., Tucker, L.A., LeCheminant, J.D. and Bailey, B.W. (2018). Sagittal abdominal diameter, waist circumference, and BMI as predictors of multiple measures of glucose metabolism: An NHANES investigation of US adults. *Journal of Diabetes Research*, 2018(9-10), 1–14. https://doi.org/10.1155/2018/3604108
- Hadaegh, F., Bozorgmanesh, M., Safarkhani, M., Khalili, D. and Azizi, F. (2011). Predictability of body mass index for diabetes: Affected by the presence of metabolic syndrome? *BMC Public Health*, 11(1), 383. https://doi.org/10.1186/1471-2458-11-383
- Heianza, Y., Kato, K., Kodama, S., Ohara, N., Suzuki, A., Tanaka, S., Hanyu, O., Sato, K. and Sone, H. (2015).
  Risk of the development of Type 2 diabetes in relation to overall obesity, abdominal obesity and the clustering of metabolic abnormalities in Japanese individuals: Does metabolically healthy overweight really exist? The Niigata Wellness Study. *Diabetic Medicine*, 32(5), 665–672. https://doi.org/10.1111/dme.12646
- Herningtyas, E.H. and Ng, T.S. (2019). Prevalence and distribution of metabolic syndrome and its components among provinces and ethnic groups in Indonesia. *BMC Public Health*, 19(1), 377. https://doi.org/10.1186/s12889-019-6711-7
- Hinnouho, G.M., Czernichow, S., Dugravot, A., Nabi, H., Brunner, E.J., Kivimaki, M. and Singh-Manoux, A. (2015). Metabolically healthy obesity and the risk of cardiovascular disease and type 2 diabetes: The Whitehall II cohort study. *European Heart Journal*, 36(9), 551–559. https://doi.org/10.1093/eurheartj/ehu123
- Jung, H.S., Chang, Y., Eun, Y.K., Kim, C.W., Choi, E.S., Kwon, M.J., Cho, J., Zhang, Y., Rampal, S., Zhao, D., Soo, K.H., Shin, H., Guallar, E. and Ryu, S. (2014). Impact of body mass index, metabolic health and weight change on incident diabetes in a Korean population. *Obesity*, 22(8), 1880–1887. https://doi.org/10.1002/oby.20751
- Karimah, M. (2018). Waist-Hip Circumference Ratio as Strongest Factor Correlation with Blood Glucose Level. Jurnal Berkala Epidemiologi, 6(3), 219–226. https://doi.org/10.20473/jbe.V6l32018.219-226
- Kim, M., Paik, J.K., Kang, R., Kim, S.Y., Lee, S.H. and Lee, J.H. (2013). Increased oxidative stress in normalweight postmenopausal women with metabolic syndrome compared with metabolically healthy overweight/obese individuals. *Metabolism: Clinical and Experimental*, 62(4), 554–560. https://doi.org/10.1016/j.metabol.2012.10.006

- Leone, A., Vizzuso, S., Brambilla, P., Mameli, C., Ravella, S., De Amicis, R., Battezzati, A., Zuccotti, G., Bertoli, S. and Verduci, E. (2020). Evaluation of different adiposity indices and association with metabolic syndrome risk in obese children: Is there a winner? *International Journal of Molecular Sciences*, 21(11), 4083. https://doi.org/10.3390/ijms21114083
- Li, Y., Zhao, L., Yu, D., Wang, Z. and Ding, G. (2018). Metabolic syndrome prevalence and its risk factors among adults in China: A nationally representative cross-sectional study. *PLoS ONE*, 13(6), e0199293. https://doi.org/10.1371/journal.pone.0199293
- Moore, L.M., Fals, A.M., Jannelle, P.J., Green, J.F., Pepe, J. and Richard, T. (2015). Analysis of Pediatric Waist to Hip Ratio Relationship to Metabolic Syndrome Markers. *Journal of Pediatric Health Care*, 29(4), 319–324. https://doi.org/10.1016/j.pedhc.2014.12.003
- Ofer, K., Leiba, R., Avizohar, O. and Karban, A. (2019). Normal body mass index (BMI) can rule out metabolic syndrome: An Israeli cohort study. *Medicine*, 98(9), e14712. https://doi.org/10.1097/MD.000000000014712
- Okosun, I.S., Boltri, J.M., Lyn, R. and Smith, M.D. (2010a). Continuous metabolic syndrome risk score, body mass index percentile, and leisure time physical activity in American children. *Journal of Clinical Hypertension*, 12(8), 636–644. https://doi.org/10.1111/j.1751-7176.2010.00338.x
- Okosun, I.S., Lyn, R., Smith, D.M., Eriksen, M. and Seale, P. (2010b). Validity of a Continuous Metabolic Risk Score as an Index for Modeling Metabolic Syndrome in Adolescents. *Annals of Epidemiology*, 20(11), 843–851. https://doi.org/10.1016/j.annepidem.2010.08.001
- Okura, T., Nakamura, R., Fujioka, Y., Kitao, S.K., Ito, Y., Matsumoto, K., Shoji, K., Sumi, K., Matsuzawa, K., Izawa, S., Ueta, W., Kato, M., Imamura, T., Taniquchi, I. and Yamamoto, K. (2018). Body mass index ≥23 is a risk factor for insulin resistance and diabetes in Japanese people: A brief report. *PLOS ONE*, 13(7), e0201052. https://doi.org/10.1371/journal.pone.0201052
- Pajunen, P., Rissanen, H., Laaksonen, M.A., Heliövaara, M., Reunanen, A. and Knekt, P. (2013). Sagittal abdominal diameter as a new predictor for incident diabetes. *Diabetes Care*, 36(2), 283–288. https://doi.org/10.2337/dc11-2451
- Pratiwi, Z.A., Hasanbasri, M. and Huriyati, E. (2017). Determination of cutoff points for metabolic syndrome scores in Indonesian adolescents and assessment of the diagnostic validity of anthropometric parameters. Jurnal Gizi *Klinik Indonesia*, 14(2), 80. https://doi.org/10.22146/ijcn.25590
- Prybyla, O. (2020). Metabolic phenotyping: is it so important? Journal of Cognitive Neuropsychology, 4(1), 1-3.

- Rodea-Montero, E.R., Evia-Viscarra, M.L. and Apolinar-Jiménez, E. (2014). Waist-to-height ratio is a better anthropometric index than waist circumference and BMI in predicting metabolic syndrome among obese mexican adolescents. *International Journal of Endocrinology*, 2014, 195407. https://doi.org/10.1155/2014/195407
- Rokhmah, F.D., Handayani, D. and Al-Rasyid, H. (2015). Correlation between waist circumference (WC) and waist-hip ratio (WHR) with plasma glucose levels using oral glucose tolerance test method. Jurnal Gizi Klinik Indonesia, 12(1), 28–35. https://doi.org/10.22146/ijcn.22425
- Rose, S., Dieny, F.F., Nuryanto, N. and Tsani, A.F.A. (2020). The correlation between waist-to-height ratio (wHtR) and second to fourth digit ratio (2D:4D) with an increase in metabolic syndrome scores in obese adolescent girls. *Electronic Journal of General Medicine*, 17(3), em211. https://doi.org/10.29333/ejgm/7872
- Samocha-Bonet, D., Dixit, V.D., Kahn, C.R., Leibel, R.L., Lin, X., Nieuwdorp, M., Pietiläinen, K.H., Rabasa-Lhoret, R., Roden, M., Scherer, P.E., Klein, S. and Ravussin, E. (2014). Metabolically healthy and unhealthy obese - The 2013 stock conference report. *Obesity Reviews*, 15(9), 697–708. https://doi.org/10.1111/obr.12199
- Soewondo, P., Purnamasari, D., Oemardi, M., Waspadji, S. and Soegondo, S. (2010). Prevalence of Metabolic Syndrome Using NCEP/ATP III Criteria in Jakarta, Indonesia: The Jakarta Primary Noncommunicable Disease Risk Factors Surveillance 2006. Acta Medica Indonesiana - The International Journal of Medicine, 42(4), 199–203.
- Sri Rahayu, M. and Maulina, M. (2017). The relationship between hip and waist circumference ratio with the incidence of coronary heart disease. Jurnal Aceh Medika, 1(1), 1–10. Retrieved April 8, 2021 from www.jurnal.abulyatama.ac.id/acehmedika (Accessed: 8 April 2021).
- Srikanthan, K., Feyh, A., Visweshwar, H., Shapiro, J.I. and Sodhi, K. (2016). Systematic review of metabolic syndrome biomarkers: A panel for early detection, management, and risk stratification in the West Virginian population. *International Journal of Medical Sciences*, 13(1), 25–38. https://doi.org/10.7150/ijms.13800
- Suliga, E., Kozieł, D., Cieśla, E. and Głuszek, S. (2015). Association between dietary patterns and metabolic syndrome in individuals with normal weight: A cross-sectional study. *Nutrition Journal*, 14(1), 55. https://doi.org/10.1186/s12937-015-0045-9
- Sumardiyono, S., Pamungkasari, E.P., Mahendra, A.G., Utomo, O.S., Mahajana, D., Cahyadi, W.R. and Ulfia,
   M. (2018). Hubungan Lingkar Pinggang dan Lingkar Panggul dengan Tekanan Darah pada Pasien
   Program Pengelolaan Penyakit Kronis (Prolanis). *Smart Medical Journal*, 1(1), 26.

# https://doi.org/10.13057/smj.v1i1.24504

Susetyowati, S. (2016). Gizi Remaja, in *Ilmu Gizi: Teori dan Aplikasi*. Jakarta, Indonesia: EGC, 160–164.

- Zhang, Y.X., Wang, Z.X., Chu, Z.H. and Zhao, J.S. (2016). Profiles of body mass index and the nutritional status among children and adolescents categorized by waist-to-height ratio cut-offs. *International Journal of Cardiology*, 223, 529–533. https://doi.org/10.1016/j.ijcard.2016.07.303
- Zhou, D., Yang, M., Yuan, Z. P., Zhang, D.D., Liang, L., Wang, C.L., Zhang, S., Zhu, H.H., Lai, M.D. and Zhu,
  Y.M. (2014). Waist-to-Height Ratio: A simple, effective and practical screening tool for childhood obesity and metabolic syndrome. *Preventive Medicine*, 67, 35–40. https://doi.org/10.1016/j.ypmed.2014.06.025

Variable	Minimum	Maximum	Mean	SD
Anthropometric Indicators				
WHtR (ratio)	0.37	0.71	0.51	0.07
WHR (ratio)	0.67	0.96	0.80	0.06
BMI (kg/m²)	15.81	39.30	24.04	4.72
Sagital Abdominal Diameter (cm)	11.35	25.50	16.79	2.42
Hip Circumference (cm)	80.60	138.45	98.96	9.30
Waist Circumference (cm)	58.00	112.10	79.44	10.78
Metabolic Profiles				
Blood Glucose Levels (mg/dL)	66.00	110.00	92.00	7.59
Trygliceride Levels (mg/dL)	29.00	309.00	88.35	44.68
Cholesterol HDL Levels (mg/dL)	36.00	109.00	61.73	26.43
Systolic Blood Pressure (mmHg)	84.00	144.00	114.63	11.13
Diastolic Blood Pressure (mmHg)	55.00	178.00	82.40	55.52
cMetS (Score of Metabolic Syndrome)	-7.10	11.93	0.01	2.90

Table 1. Minimum, maximum, average and standard deviation

Characteristics	n	%
Anthropometric		
Body Mass Index (BMI)		
Underweight (< 18.5 kg/m²)	6	3.7
Normal (18.5 – 22.9 kg/m²)	71	43.6
Overweight (23-24.9 kg/m²)	28	17.2
Obese (≥25.0 kg/m²)	58	35.6
Waist Height Ratio (WHtR)		
Normal (<0.50)	45	27.6
At Risk (≥0.50)	118	72.4
Waist Hip Ratio		
Normal (<0.85)	127	77.9
Central Obesity (≥0.85)	36	22.1
Sagital Abdominal Diameter (SAD)		
Normal (≤19.3 cm)	143	87.7
At Risk (>19.3 cm)	20	12.3
Wait Circumference		
Normal (<80 cm)	73	44.8
Obese (≤80 cm)	90	55.2
Metabolic Profiles		
Blood Glucose Levels		
Normal (<110 mg/dL)	136	83.4
High (≥110 mg/dL)	27	16.6
Triglycerides		
Normal (<150 mg/dL)	149	914
High (≥150 mg/dL)	14	8.6
Cholesterol HDL		
Normal (≥150 mg/dL)	135	82.8
Low (<150 mg/dL)	28	17.2
Sistolic Blood Pressure		

Table 2. Anthropometric overview and components of metabolic syndrome

Normal (<130 mg/dL)	136	83.4
High (≥130 mg/dL)	27	16.6
Diastolic Blood Pressure		
Normal (<85 mg/dL)	128	78.5
High (≥85 mg/dL)	35	21.5
cMetS (Score of Metabolic Syndrome)		
Normal (<2.21)	109	66.9
At Risk (≥2.21)	54	33.1
Metabolic Types		
Metabolic Unhealthy Normal Weight (MUNW)	17	10.4
Metabolic Healthy Normal Weight (MHNW)	88	54
Metabolic Unhealthy Obese Weight (MUOW)	38	23.3
Metabolic Healthy Obese Weight (MHOW)	20	12.3

			triglycerides, blood sugar, HDL and metabolic syndrome scores)								-	Commented [VN1]: Rather than bold the p-val	
Variable Systolic BP		stolic BP Diastolic BP		TG Blood Gl		lucose HDL		HDL		0	difference, you should indic <0.05/0.01 indicates signific		
	r	p	r	p	r	p	r	p	r	р	r	<i>p</i> difference.	
WHtR	0.358	<0.001	0.306	<0.001	0.289	<0.001	0.210	0.007	-0.266	0.001	0.599	<0.001	
BMI	0.370	<0.001	0.313	<0.001	0.315	<0.001	0.221	0.005	-0.292	<0.001	0.600	<0.001	
SAD	0.352	<0.001	0.284	<0.001	0.278	<0.001	0.191	0.015	-0.264	0.001	0.575	<0.001	
WC	0.377	<0.001	0.284	<0.001	0.295	<0.001	0.212	0.005	-0.243	0.002	0.616	<0.001	
нс	0.369	<0.001	0.332	<0.001	0.302	<0.001	0.179	0.002	-0.273	<0.001	0.581	<0.001	
WHR	0.244	0.002	0.128	0.104	0.194	0.013	0.172	0.028	-0.149	0.048	0.415	<0.001	

Table 3. The relationship between anthropometric indicators and metabolic profiles (blood pressure,

		syndrome	scores								
Variable	Systolic BP										
	Constant	USCª	p1 <sup>b</sup>	p2 <sup>c</sup>	<sup>d</sup> Adjusted R <sup>2</sup>						
BMI	91.759	0.951	<0.001	<0.001	0.158						
	Blood Gluc	ose Levels									
	Constant	USC <sup>a</sup>	p1 <sup>b</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>						
BMI	83.454	0.355	0.005	<0.001	0.043						
	HDL										
	Constant	USC <sup>a</sup>	p1 <sup>b</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>						
BMI	81.429	-0.819	<0.001	<0.001	0.080						
	Triglyceride	Triglycerides									
	Constant	USC <sup>a</sup>	p1 <sup>b</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>						
WC	-6.614	1.195	<0.001	<0.001	0.078						
	Score of M	Score of Metabolic Syndrome									
	Constant	USC <sup>a</sup>	p1 <sup>b</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>						
WC	-13.163	0.166	<0.001	<0.001	0.375						
-											

Table 4. Anthropometric indicators most associated with metabolic components and metabolic

<sup>a</sup>Unstandardized Coefficient, <sup>b</sup> p-value, <sup>c</sup> p F-Test (ANOVA), <sup>d</sup> coefficient of determination

## Anthropometry indicators that are most related to metabolic profiles in female college students

<sup>1,2,</sup>\*Dieny, F.F., <sup>1</sup>Rose S., <sup>1,2</sup>Tsani, A.F.A., <sup>1</sup>Jauharany, F.F. and <sup>1,2</sup>Fitranti, D.Y. <sup>1</sup>Department of Nutrition Science, Faculty of Medicine, Universitas Diponegoro, Indonesia <sup>2</sup>Center of Nutrition Research (CENURE), Faculty of Medicine, Universitas Diponegoro, Indonesia

\*Corresponding author: fillahdieny@gmail.com

ORCID ID Author 1: 0000-0001-6071-8901 ORCID ID Author 2: 0000-0002-1898-1842 ORCID ID Author 3: 0000-0002-3407-5188 ORCID ID Author 4: 0000-0001-9471-9419 ORCID ID Author 5: 0000-0002-1656-9563

#### Article history:

Received: 2 June 2021 Received in revised form: 8 July 2021 Accepted: 27 September 2021

### Abstract

Metabolic syndrome is not a disease but is a set of several disorders and causes an increased risk of cardiovascular disease and diabetes mellitus complications. Several studies have shown that non-invasive approaches such as anthropometric measurements can be used for the early detection of metabolic syndrome. This study aimed to analyse the anthropometric indicators related to metabolic syndrome in female college students. The design of this research was cross sectional, with the number of subjects

involved were as many as 163 female college students aged 19 to 24 years old. Purposive sampling was used in the sampling of this research. The independent variables in this study were the Waist-to-Height Ratio (WHR), Waist-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference. The dependent variable in this study is the metabolic syndrome component that has been converted into a metabolic syndrome score (cMetS). The analysis results showed that all anthropometric indicators, namely WHtR, BMI, SAD, waist circumference, hip circumference and WHR have a strong positive relationship with the metabolic syndrome score (p<0.001). BMI was the anthropometric indicator that is most associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood sugar (p<0.05), and HDL (p<0.001). Waist circumference was the anthropometric indicator that is most associated with triglycerides and metabolic syndrome score (p<0.001). Metabolic syndrome in female college students can be identified using anthropometric measurements, one of which is BMI and WHR which are very easy to measure and efficient. BMI and WHR have the strongest relationship and can be used to detect early risk of metabolic syndrome in female college students.

Keywords: Adolescent, Anthropometric indicator, Female, Metabolic profile, Metabolic syndrome

#### 1. Introduction

Metabolic syndrome is a set of body metabolic disorders such as dyslipidemia, hyperglycemia, hypertension, and central obesity (Srikanthan *et al.*, 2016; Devi *et al.*, 2017; Christijani, 2019). Metabolic syndrome is not a disease but is a set of several disorders that causes an increased risk of cardiovascular disease and diabetes mellitus complications. Some epidemiological studies have shown that metabolic syndrome doubles the risk of cardiovascular diseases (Sri Rahayu and Maulina, 2017).

Indonesia as a developing country cannot be separated from the existing nutritional problems in the world, including the incidence of obesity and metabolic syndrome. Several studies found that the prevalence of metabolic syndrome keeps increasing every year. A study in China showed the prevalence of metabolic syndrome in adults was 24.2% (Li *et al.*, 2018). Another study indicated that the prevalence of metabolic syndrome in Indonesia was 21.66% (Herningtyas and Ng, 2019). In recent studies, metabolic syndrome can be assessed using the continuous value of metabolic syndrome (cMets) or the metabolic syndrome score recommended by the American Diabetic Association of Diabetes. The metabolic syndrome score is a z-score resulting from the assessment of all components

of the metabolic syndrome (Pratiwi, *et al.*, 2017). The advantages of using cMetS are (1) reducing dichotomization factors because cardiovascular disease is a progression of several components of the metabolic syndrome, (2) cMetS is more sensitive and less error-prone than categoric metabolic syndrome assessments, (3) increasing the statistical power (Okosun *et al.*, 2010b).

Central obesity is one of the components of metabolic syndrome parameters. Central obesity is associated with increased blood pressure, serum triglycerides, decreased HDL, and glucose intolerance. Based on the National Basic Health Research (Riskesdas) in 2018, the prevalence of obesity in adults was 21.8%, and the prevalence of central obesity at age of more than 15 years increased from 26.6% in 2013 to 31% in 2018 (Badan Penelitian dan Pengembangan Kesehatan, 2018). Obesity is closely related to degenerative diseases. Riskesdas (2018) showed that the prevalence of stroke, diabetes mellitus, heart disease, and hypertension is higher in women than men.

Several studies have shown that non-invasive approaches such as anthropometric measurements can be used for the early detection of metabolic syndrome (Pratiwi, *et al.*, 2017). Anthropometric measurements are described as the measurements of body dimensions and body composition to assess nutritional status. The advantages of anthropometric measurements are relatively fast and easy, as they can be performed using portable and calibrated instruments with standardized methods (Rokhmah, *et al.*, 2015). Some anthropometric measurements that can be used for early detection of metabolic syndrome are Waist-to-Height Ratio (WHR), waist-to-hip ratio (WHR), hip circumference, Body Mass Index (BMI), Sagital Abdominal Diameter (SAD).

One of the anthropometric measurements which can be a parameter for central obesity is the ratio of waist circumference to height (WHtR). The instruments used in the measurement are microtoise and measuring tape, which take a longer time. Studies on waist circumference have been shown to have a strong correlation with abdominal fat deposits (Zhou *et al.*, 2014). The distribution of abdominal adipose tissue (central obesity) in adults is associated with a component of the metabolic syndrome (Rodea-Montero, *et al.*, 2014). A study on adult subjects has shown that people who have the same waist circumference but are shorter in height have a greater risk of developing metabolic syndrome than taller people (Zhou *et al.*, 2014). Therefore, WHtR can be used as a simple and effective anthropometric index to identify the metabolic risk associated with obesity (Rodea-Montero, *et al.*, 2014).

The Waist-To-Hip Ratio (WHR) is a measurement that may indicate central obesity (Karimah, 2018). The higher the WHR value, the higher the risk level for several metabolic diseases. The Waist-To-Hip Ratio is calculated by dividing the measurement of the waist circumference by the circumference of the hip. The cut-off points for WHR are  $\geq$ 1.0 for men and  $\geq$ 0.85 for women (Rokhmah *et al.*, 2015). Individuals with a high waist and hip circumference will also have a higher distribution of fat in their abdominal area. Irregular fats distribution in the abdominal area indirectly causes higher triglyceride levels circulating in the blood, which will affect blood pressure (Sumardiyono *et al.*, 2018). WHR measurement is more sensitive in assessing the distribution of fat in the abdomen. This measurement of waist circumference is performed by determining the lower part of arcus costae and crista iliaca (Sri Rahayu and Maulina, 2017).

Body Mass Index (BMI) is a practical and easy measurement to perform, but it cannot distinguish between fat mass, bone mass and muscle mass. BMI is calculated as body weight (kg) / height squared (m<sup>2</sup>) (Okura *et al.*, 2018). BMI can be used as the first measurement before any other anthropometric measurements.

Sagittal Abdominal Diameter (SAD) or the height of the abdomen while the subjects are in a lying position. This anthropometric measurement has not been widely used to measure fat tissue in the abdominal area. SAD measurements using computed tomography or magnetic resonance imaging, and are associated with components of metabolic syndrome. The measurements of SAD are taken when the subject is lying down on the examination table with a naked upper body. SAD is related to central obesity in individuals with obesity and normal nutritional status. Furthermore, SAD is associated with diabetes mellitus and a predictor of cardiovascular disease incidence, even when SAD is measured in a standing position (Pajunen *et al.*, 2013). Based on the above-mentioned problems, our study aimed to analyze the anthropometric indicators related to metabolic syndrome in female college students.

#### 2. Materials and methods

2.1 Design, location, and time

A cross-sectional study design and this research was conducted from March to July 2020. Anthropometric and biochemical data were collected at the Cito Laboratory, Banyumanik Semarang with health protocols applied. This study was approved by the Medical/Health Research Bioethics Commission, Faculty of Medicine, Sultan Agung Islamic University Semarang with Number No.296 /IX /2020 /Bioethical Commission.

## 2.2 Samplings

This study was conducted during the SARS-CoV-2 outbreak, which later was named COVID-19 by the WHO, hence the registration for study participants was done online. Purposive sampling was used in this study and the total number of subjects required was 163. Samples are selected based on inclusion criteria, such as voluntary to be research subjects, female college students in Semarang City, aged 19-24 years in Semarang, not consuming alcohol, not smoking, and voluntary to follow a series of study instructions. Exclusion criteria are subjects who withdraw and those who are ill during the research study. Based on the exclusion criteria mentioned, no subjects are included in the exclusion criteria. Subjects were asked to fill in personal data using a Google Form, and eligible subjects will be contacted by the researchers to plan a direct meeting.

The health protocol applied during the anthropometric and biochemical data collection process, consisted of the subject filling out a COVID-19 sign/symptom screening questionnaire, the subject was checked for temperature, the subject washed hands before entering the room, the distance between subjects was at least 1 meter, the subject and researcher used a mask and face shield. Researchers used gloves and protective clothing. During the study, hand sanitisers were provided, and anthropometric tools that were on the subject's skin were wiped with alcohol.

### 2.3 Data collected

The independent variables in this study were the Waist-to-Height Ratio (WHR), Waist-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference. Weight and height data were obtained through direct measurements using a digital stamp scale GEA brand with an accuracy of 0.1 kg and microtoise with an accuracy of 0.1 cm. Waist circumference and hip circumference were measured using a measuring tape (Medline) to the nearest 1 mm and abdominal height was measured using the Abawerk Schaffenburg abdominal calliper to the nearest 1 mm. SAD measurements were performed with the subject in a supine position on a flat surface with both knees forming an angle of 90° (Firouzi *et al.*, 2018). Anthropometric data were collected by trained enumerators.

The cut-off point used in this study refers to previous studies because it had been adjusted for the Asian race (Rose *et al.*, 2020). Each anthropometric measurement is stated as "at-risk" if the individuals have  $\geq 0.50$  for WHtR (Zhang *et al.*, 2016),  $\geq 0.85$  for WHR (Rokhmah *et al.*, 2015), > 19.3 cm for Sagital Abdominal Diameter (SAD) (Dieny *et al.*, 2020), and have the normal to overweight BMI (18.5 - 25 kg/m<sup>2</sup>) or obese BMI ( $\geq 25.0$  kg/m<sup>2</sup>) (Susetyowati, 2016).

The dependent variable in this study is the metabolic syndrome component that has been converted into a metabolic syndrome score (cMetS) with the cut-off point of cMetS> 2.21 (Rose et al., 2020). The guidelines for metabolic syndrome in this study are taken from the National Cholesterol Education Program-Adult Treatment Panel (NCEP-ATP III) 2005 which has been frequently used in Indonesia. There are 5 parameters to assess metabolic syndrome: (1) fasting blood glucose levels ≥110 mg/dL, (2) triglyceride levels ≥150 mg/dL (3) HDL cholesterol levels <50 mg/dL, (4) central obesity in women with waist circumference ≥80 cm, and (5) systolic and diastolic blood pressures ≥130 mmHg and ≥85 mmHg, respectively (Soewondo et al., 2010). The calculation of the metabolic syndrome score (cMetS) was done in the following steps: (1) after measuring all parameters of the metabolic syndrome, standardisation was carried out to obtain a Z-score; (2) the blood pressure must be converted into Mean Arterial Blood (MAP) by dividing the difference between systolic and diastolic blood pressure by three and summed with the diastolic blood pressure; (3) the HDL cholesterol standardization results were multiplied by (-1) because the parameter was inversely related to the risk of metabolic syndrome; (4) All Z-scores were added to obtain the cMetS values; (5) The final step was to compare the cMetS values with the cut-off point of ≥2,21 (Eisenmann et al., 2010; Okosun et al., 2010a; Rose et al., 2020). The subjects were instructed to do fasting for at least 8 hrs, only drinking water was permitted.

Other than the cMetS score, metabolic syndrome risk can also be assessed from the classification of metabolic types. This classification combines the internal and external signs of the body such as biochemical parameters, the ratio of subcutaneous fat to abdominal fat, and blood pressure (Prybyla O, 2020). The main phenotypes that reflect the possible combination of metabolic profile and the degree of obesity are metabolic healthy obese weight, metabolic healthy normal weight, metabolic unhealthy normal weight, and metabolic unhealthy normal weight.

#### 2.4 Data analysis

All data were analyzed using computer programs and statistical analyses were performed using SPSS statistical software version 22. Univariate analysis was used to describe subjects characteristics.

The normality test of the data using the Kolmogorov-Smirnov test was carried out before testing the hypothesis. The relationship of anthropometric indicators with metabolic profile (Blood Pressure, Triglycerides, Blood Sugar, HDL and metabolic syndrome scores) was determined using the Person correlation test. Furthermore, Anthropometric indicators that are most related to the metabolic component and metabolic syndrome score were analyzed using the Multiple Linear Regression test.

#### 3. Results and discussion

The subject characteristics measured in female students aged 19-24 years include age, anthropometric indicators, and metabolic syndromes. Table 1 shows the characteristics of the study subjects. The mean WHR value in this study was 0.51. Meanwhile, the mean WHR was 0.80; the mean BMI was 24.04 kg/m<sup>2</sup>; the mean SAD was 16.79 cm, and the mean waist circumference was 79.44 cm.

Table 2 shows the various nutritional status of the subjects based on BMI. It was found that 43.6% of the subjects had normal BMI, 17.2% were overweight and 35.6% were obese. Based on the WHtR anthropometric indicator, 72.4% of subjects were at risk of having obesity, based on WHR, 22.1% had central obesity, based on BMI, 35.6% were obese, based on SAD 12.3% of the subjects were at risk, and based on waist circumference 55.2% had central obesity. According to the metabolic profile that was assessed, 16.6% had high Fasting Blood Glucose levels, 8.6% had hypertriglycerides, 17.2% had low HDL, and 16.6% had high systolic blood pressure, and 21.5% had high diastolic blood pressure. In addition, we found that 33.1% of the subjects had high metabolic syndrome (cMetS) scores. This proportion was similar to the assessment based on the metabolic type of unhealthy subjects (subjects who had  $\geq$  3 risk factors of the metabolic profile), which was 33.7%. Moreover, two subjects had five risk factors: abdominal obesity, hypertension, hyperglycemia, hypertriglycerides, and low HDL.

The objective of this study was to determine the anthropometric indicators associated with metabolic syndromes in female students. The study included 163 female students aged 19-24 years. The students are in their late adolescents who begin to have an independent life. Inappropriate and unhealthy eating behaviour will have an impact on the student's nutritional status. Excessive nutritional status and obesity will affect student's body metabolism. Based on the study results, 33.1% of the subjects had a high metabolic syndrome (cMetS) score. In line with the previous study conducted in 2019 on 18-to-21-year-old students at Universitas Diponegoro, 20% of the subjects had high cMetS (Rose *et al.*, 2020). Meanwhile, a study conducted by Pratiwi et al in 2017 using secondary data from the National Basic Health Research 2013 found that 19.98% of adolescents aged 15-24 years

had high cMetS (Pratiwi, *et al.*, 2017). To conclude, there is a trend of Metabolic Syndrome Score (cMetS) among young women in Semarang.

The assessment of metabolic syndrome using a continuous type (scoring) rather than using a dichotomy or binary ("yes" and "no") is recommended (Christijani, 2019). An adolescent can be diagnosed with metabolic syndrome if their Metabolic Syndrome Score (cMetS) >2.21 (Pratiwi, *et al.*, 2017). Anthropometric indicators used in this study are Waist and Height Ratio (WHR), Waist-to-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and Waist Circumference. Based on the correlation analyses, all anthropometric indicators have a significant positive relationship with the Metabolic Syndrome Score (cMetS). Furthermore, the multivariate analyses show that the anthropometric indicators of BMI and WHR are strongly associated with cMetS.

If the metabolic type is considered based on nutritional status (subjects with non-obese BMI (<25kg/m<sup>2</sup>) with metabolic healthy and metabolic unhealthy and subjects with obese BMI (>25kg/m<sup>2</sup>) with metabolic healthy and metabolic unhealthy), subjects are categorized as metabolic unhealthy (experiencing metabolic syndrome) if they fulfil  $\geq$  3 risk factors including high waist circumference, blood pressure, fasting blood glucose and triglyceride levels, and low HDL levels. Based on these criteria, it was found that 10.4% of the subjects had a metabolic unhealthy normal weight (MUNW) and 23.3% of the subjects had metabolic unhealthy obesity weight (MUOW). Of non-obese subjects, 54% of them were metabolic healthy. Our study also shows that 10.4% of the subjects were classified as metabolic unhealthy normal weight (MUNW). The subjects' BMI in this category is in the normal range but has a high percentage of body fat that makes them at high risk of developing metabolic disorders (Eckel et al., 2015; Suliga et al., 2015). Several recent cohort studies have shown a greater risk of type II diabetes mellitus in individuals with MUNW compared to individuals with MHNW (Ärnlöv et al., 2011; Hadaegh et al., 2011; Aung et al., 2014; Jung et al., 2014; Hinnouho et al., 2015). Other studies have shown that women with the MUNW type have a long-term impact of an increased risk of cardiovascular diseases such as higher blood pressure, triglyceride and glucose levels as well as lower levels of adiponectin, HDL, and LDL compared to women with the MHNW type (Kim et al., 2013).

In this study, 23.3% of the subjects belonged to the Metabolic Unhealthy Obese Weight (MUOW) type. Subjects with this metabolic type have an obese BMI and have a high risk of developing metabolic disorders. A study conducted in Japan on 29,564 subjects showed that individuals with MUOW had a greater risk of developing type II diabetes mellitus compared to individuals with MHOW (Heianza *et al.*, 2015).

It was also found that 12.3% of the subjects were categorized as metabolic healthy obese weight (MHOW). Individuals in this metabolic type have an obese BMI but do not show any metabolic risks. Given the impact of obesity in relation to the risk of metabolic diseases, various studies have been conducted to examine the long-term effects of MHOW. Individuals with MHOW had a different fat distribution pattern (less ectopic and visceral fat), and lower inflammatory markers (Samocha-Bonet *et al.*, 2014). Other studies also have shown that women with MHOW had lower blood pressure, triglyceride levels, and glucose levels, but higher levels of HDL, adiponectin, and LDL compared to women with MUNW (Kim *et al.*, 2013). This condition was associated with good diet quality in individuals with MHOW. Based on National Health and Nutrition Examination Surveys (NHANES) data, Camhi *et al.* (2015) examined the quality of diet in obese subjects and found that adolescents and adult women with the MHOW metabolic type had higher diet quality scores due to high intake of fruit, whole grains, meat, and nuts.

Table 3 and Table 4 show the results of statistical analyses on anthropometric indicators related to metabolic syndromes. Table 3 shows the bivariate statistical analysis using the Pearson correlation test. The analysis results showed that all anthropometric indicators, namely WHtR, BMI, SAD, waist circumference, hip circumference and WHR have a strong positive relationship with the metabolic syndrome score (p<0.001), which means that the higher the anthropometric value, the higher the metabolic syndrome score. In addition, the analysis of the relationship between anthropometric indicators and each metabolic profile revealed that almost all of the independent variables (WHtR, waist and hip circumference, WHR, BMI, and SAD) were associated with each metabolic profile, such as baseline systolic pressure, diastolic blood pressure, triglyceride levels, blood sugar levels, and HDL. Only WHR was not associated with diastolic blood pressure (p>0.005).

Table 4 shows the results of the analysis using multiple linear regression to determine anthropometric indicators that are most associated with each metabolic profile and metabolic syndrome score. The results showed that BMI was the anthropometric indicator that is most associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood sugar (p<0.05), and HDL (p <0.001). In addition, waist circumference was the anthropometric indicator that is most associated with triglycerides and metabolic syndrome score (p<0.001). Based on the Adjusted R<sup>2</sup> value on the metabolic syndrome score, we found that 37.5% of the metabolic syndrome score was related to anthropometric indicators, such as WHtR, waist and hip circumference, WHR, BMI, and SAD. The rest may be influenced by other variables that are not included in this study. The correlation test results indicated that all anthropometric indicators had a positive relationship with the metabolic syndrome scores with p <0.001. Meanwhile, the regression analyses show that BMI and WHR were inversely related to cMetS. This is in line with research that reported an increase in the WHR value could be associated with the risk of metabolic syndrome in children and adolescents in Florida (Moore *et al.*, 2015). Another study revealed that there was a strong relationship between overweight and obese adolescents with metabolic syndrome (Al-Bachir and Bakir, 2017). Furthermore, a study on adolescents in South Africa found that central obesity as measured by the hip circumference could lead to an increased risk of cardiovascular diseases and death. Therefore, hip circumference and waist circumference can be used to predict the risk of cardiovascular diseases and death in the future (Cameron *et al.*, 2012).

Body Mass Index (BMI) is the most widely used indicator of measurement in epidemiological studies and is used as a substitute for evaluating body composition. However, BMI cannot distinguish fat from fat mass and lean mass, and it fails to show the presence of adipose and body fat distribution (Ofer *et al.*, 2019; Leone *et al.*, 2020). However, the BMI cut-offs for metabolic syndrome have not yet been determined (Ofer *et al.*, 2019). Obesity in adolescents is generally assessed using a BMI of  $\geq$ 25.0 kg/m<sup>2</sup>. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m<sup>2</sup>) and obesity ( $\geq$ 25.0 kg/m<sup>2</sup>), and we found that 35.6% of the subjects were obese. The finding is in line with the research on the subject of students at Universitas Diponegoro aged 18-21 years. They found that 40% of their study population had obesity level I and 36.3% had obesity level II (Rose *et al.*, 2020).

Abdominal obesity is often assessed to determine a metabolic syndrome in people. One of the indicators used to measure abdominal obesity is the Waist-to-Hip Ratio (WHR) which is calculated by dividing the waist circumference and the hip circumference. Measurement of waist circumference is more sensitive in assessing the distribution of body fat in the abdominal wall, which is also a component of metabolic syndrome. The limit of the WHR value for a female is  $\geq$  0.85 (Rokhmah, *et al.*, 2015). This study shows that every 1% increase in the WHR value will increase the cMetS value by 10.411. Hip circumference is also an indicator that has a strong correlation with cMetS, but many studies have used it as a ratio along with waist circumference for assessing a person's central obesity status.

### 4. Conclusion

Metabolic syndrome in female students can be identified using anthropometric measurements, one of which is BMI and WHR which are very easy to measure and efficient. BMI and WHR have the strongest relationship and can be used to detect early risk of metabolic syndrome in female college students.

## **Conflict of interest**

The authors declare no conflict of interest.

## Acknowledgements

The authors would like to thank all the subjects who participated in this study. We would also like to express our gratitude to The Ministry of Research, Technology and Higher Education, Indonesia" which was funded by the "Hibah Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) 2019.

### References

- Al-Bachir, M. and Bakir, M.A. (2017). Predictive value of body mass index to metabolic syndrome risk factors in Syrian adolescents. *Journal of Medical Case Reports*, 11(1), 170. https://doi.org/10.1186/s13256-017-1315-2
- Ärnlöv, J., Sundström, J., Ingelsson, E. and Lind, L. (2011). Impact of BMI and the metabolic syndrome on the risk of diabetes in middle-aged men. *Diabetes Care*, 34(1), 61–65. https://doi.org/10.2337/dc10-0955
- Aung, K.K., Lorenzo, C., Hinojosa, M.A. and Haffner, S.M. (2014). Risk of developing diabetes and cardiovascular disease in metabolically unhealthy normal-weight and metabolically healthy obese individuals. *Journal of Clinical Endocrinology and Metabolism*, 99(2), 462–468. https://doi.org/10.1210/jc.2013-2832
- Badan Penelitian dan Pengembangan Kesehatan. (2018). *Riset Kesehatan Dasar (RISKESDAS) 2018*. Jakarta, Indonesia.
- Cameron, A.J., Magliano, D.J., Shaw, J.E., Zimmet, P.Z., Carstensen, B., Alberti, K.G.M.M., Tuomilehto, J., Barr, E.L.M., Pauvaday, V.K., Kowlessur, S. and Söderberg, S. (2012). The influence of hip circumference on the relationship between abdominal obesity and mortality. *International Journal of Epidemiology*, 41(2), 484–494. https://doi.org/10.1093/ije/dyr198
- Camhi, S.M., Whitney Evans, E., Hayman, L.L., Lichtenstein, A.H. and Must, A. (2015). Healthy eating index and metabolically healthy obesity in U.S. adolescents and adults. *Preventive Medicine*, 77, 23–27. https://doi.org/10.1016/j.ypmed.2015.04.023
- Christijani, R. (2019). Determination of Diagnosis of Metabolic Syndrome based on Assessment of Metabolic Syndrome and NCEP ATP-III Score in Adolescent. *The Journal of Nutrition and Food Research*, 42(1), 21–28. https://doi.org/10.22435/pgm.v42i1.2418
- Devi, R., Manhas, S., Prasad, S., Sharma, S., Bhaskar, N. and Mahajan, S. (2017). Short Review of Metabolic Syndrome. *International Journal of Research and Review*, 4(2), 29.
- Dieny, F.F., Setyaningsih, R.F., Fitranti, D.Y., Jauharany, F.F., Putra, Y.D. and Tsani, A.F.A. (2020). Abdominal diameter profiles have relationship with insulin resistance in obese female adolescents. *Electronic Journal of General Medicine*, 17(5), em219. https://doi.org/10.29333/ejgm/7882
- Eckel, N., Mühlenbruch, K., Meidtner, K., Boeing, H., Stefan, N. and Schulze, M. B. (2015). Characterization of metabolically unhealthy normal-weight individuals: Risk factors and their associations with type 2 diabetes. *Metabolism: Clinical and Experimental*, 64(8), 862–871. https://doi.org/10.1016/j.metabol.2015.03.009

- Eisenmann, J.C., Laurson, K.R., Dubose, K.D., Smith, B.K. and Donnelly, J.E. (2010). Construct validity of a continuous metabolic syndrome score in children. *Diabetology and Metabolic Syndrome*, 2(1). https://doi.org/10.1186/1758-5996-2-8
- Firouzi, S.A., Tucker, L.A., LeCheminant, J.D. and Bailey, B.W. (2018). Sagittal abdominal diameter, waist circumference, and BMI as predictors of multiple measures of glucose metabolism: An NHANES investigation of US adults. *Journal of Diabetes Research*, 2018(9-10), 1–14. https://doi.org/10.1155/2018/3604108
- Hadaegh, F., Bozorgmanesh, M., Safarkhani, M., Khalili, D. and Azizi, F. (2011). Predictability of body mass index for diabetes: Affected by the presence of metabolic syndrome? *BMC Public Health*, 11(1), 383. https://doi.org/10.1186/1471-2458-11-383
- Heianza, Y., Kato, K., Kodama, S., Ohara, N., Suzuki, A., Tanaka, S., Hanyu, O., Sato, K. and Sone, H. (2015).
  Risk of the development of Type 2 diabetes in relation to overall obesity, abdominal obesity and the clustering of metabolic abnormalities in Japanese individuals: Does metabolically healthy overweight really exist? The Niigata Wellness Study. *Diabetic Medicine*, 32(5), 665–672. https://doi.org/10.1111/dme.12646
- Herningtyas, E.H. and Ng, T.S. (2019). Prevalence and distribution of metabolic syndrome and its components among provinces and ethnic groups in Indonesia. *BMC Public Health*, 19(1), 377. https://doi.org/10.1186/s12889-019-6711-7
- Hinnouho, G.M., Czernichow, S., Dugravot, A., Nabi, H., Brunner, E.J., Kivimaki, M. and Singh-Manoux, A. (2015). Metabolically healthy obesity and the risk of cardiovascular disease and type 2 diabetes: The Whitehall II cohort study. *European Heart Journal*, 36(9), 551–559. https://doi.org/10.1093/eurheartj/ehu123
- Jung, H.S., Chang, Y., Eun, Y.K., Kim, C.W., Choi, E.S., Kwon, M.J., Cho, J., Zhang, Y., Rampal, S., Zhao, D., Soo, K.H., Shin, H., Guallar, E. and Ryu, S. (2014). Impact of body mass index, metabolic health and weight change on incident diabetes in a Korean population. *Obesity*, 22(8), 1880–1887. https://doi.org/10.1002/oby.20751
- Karimah, M. (2018). Waist-Hip Circumference Ratio as Strongest Factor Correlation with Blood Glucose Level. Jurnal Berkala Epidemiologi, 6(3), 219–226. https://doi.org/10.20473/jbe.V6l32018.219-226
- Kim, M., Paik, J.K., Kang, R., Kim, S.Y., Lee, S.H. and Lee, J.H. (2013). Increased oxidative stress in normalweight postmenopausal women with metabolic syndrome compared with metabolically healthy overweight/obese individuals. *Metabolism: Clinical and Experimental*, 62(4), 554–560. https://doi.org/10.1016/j.metabol.2012.10.006

- Leone, A., Vizzuso, S., Brambilla, P., Mameli, C., Ravella, S., De Amicis, R., Battezzati, A., Zuccotti, G., Bertoli, S. and Verduci, E. (2020). Evaluation of different adiposity indices and association with metabolic syndrome risk in obese children: Is there a winner? *International Journal of Molecular Sciences*, 21(11), 4083. https://doi.org/10.3390/ijms21114083
- Li, Y., Zhao, L., Yu, D., Wang, Z. and Ding, G. (2018). Metabolic syndrome prevalence and its risk factors among adults in China: A nationally representative cross-sectional study. *PLoS ONE*, 13(6), e0199293. https://doi.org/10.1371/journal.pone.0199293
- Moore, L.M., Fals, A.M., Jannelle, P.J., Green, J.F., Pepe, J. and Richard, T. (2015). Analysis of Pediatric Waist to Hip Ratio Relationship to Metabolic Syndrome Markers. *Journal of Pediatric Health Care*, 29(4), 319–324. https://doi.org/10.1016/j.pedhc.2014.12.003
- Ofer, K., Leiba, R., Avizohar, O. and Karban, A. (2019). Normal body mass index (BMI) can rule out metabolic syndrome: An Israeli cohort study. *Medicine*, 98(9), e14712. https://doi.org/10.1097/MD.000000000014712
- Okosun, I.S., Boltri, J.M., Lyn, R. and Smith, M.D. (2010a). Continuous metabolic syndrome risk score, body mass index percentile, and leisure time physical activity in American children. *Journal of Clinical Hypertension*, 12(8), 636–644. https://doi.org/10.1111/j.1751-7176.2010.00338.x
- Okosun, I.S., Lyn, R., Smith, D.M., Eriksen, M. and Seale, P. (2010b). Validity of a Continuous Metabolic Risk Score as an Index for Modeling Metabolic Syndrome in Adolescents. *Annals of Epidemiology*, 20(11), 843–851. https://doi.org/10.1016/j.annepidem.2010.08.001
- Okura, T., Nakamura, R., Fujioka, Y., Kitao, S.K., Ito, Y., Matsumoto, K., Shoji, K., Sumi, K., Matsuzawa, K., Izawa, S., Ueta, W., Kato, M., Imamura, T., Taniquchi, I. and Yamamoto, K. (2018). Body mass index ≥23 is a risk factor for insulin resistance and diabetes in Japanese people: A brief report. *PLOS ONE*, 13(7), e0201052. https://doi.org/10.1371/journal.pone.0201052
- Pajunen, P., Rissanen, H., Laaksonen, M.A., Heliövaara, M., Reunanen, A. and Knekt, P. (2013). Sagittal abdominal diameter as a new predictor for incident diabetes. *Diabetes Care*, 36(2), 283–288. https://doi.org/10.2337/dc11-2451
- Pratiwi, Z.A., Hasanbasri, M. and Huriyati, E. (2017). Determination of cutoff points for metabolic syndrome scores in Indonesian adolescents and assessment of the diagnostic validity of anthropometric parameters. Jurnal Gizi *Klinik Indonesia*, 14(2), 80. https://doi.org/10.22146/ijcn.25590
- Prybyla, O. (2020). Metabolic phenotyping: is it so important? Journal of Cognitive Neuropsychology, 4(1), 1-3.

- Rodea-Montero, E.R., Evia-Viscarra, M.L. and Apolinar-Jiménez, E. (2014). Waist-to-height ratio is a better anthropometric index than waist circumference and BMI in predicting metabolic syndrome among obese mexican adolescents. *International Journal of Endocrinology*, 2014, 195407. https://doi.org/10.1155/2014/195407
- Rokhmah, F.D., Handayani, D. and Al-Rasyid, H. (2015). Correlation between waist circumference (WC) and waist-hip ratio (WHR) with plasma glucose levels using oral glucose tolerance test method. Jurnal Gizi Klinik Indonesia, 12(1), 28–35. https://doi.org/10.22146/ijcn.22425
- Rose, S., Dieny, F.F., Nuryanto, N. and Tsani, A.F.A. (2020). The correlation between waist-to-height ratio (wHtR) and second to fourth digit ratio (2D:4D) with an increase in metabolic syndrome scores in obese adolescent girls. *Electronic Journal of General Medicine*, 17(3), em211. https://doi.org/10.29333/ejgm/7872
- Samocha-Bonet, D., Dixit, V.D., Kahn, C.R., Leibel, R.L., Lin, X., Nieuwdorp, M., Pietiläinen, K.H., Rabasa-Lhoret, R., Roden, M., Scherer, P.E., Klein, S. and Ravussin, E. (2014). Metabolically healthy and unhealthy obese - The 2013 stock conference report. *Obesity Reviews*, 15(9), 697–708. https://doi.org/10.1111/obr.12199
- Soewondo, P., Purnamasari, D., Oemardi, M., Waspadji, S. and Soegondo, S. (2010). Prevalence of Metabolic Syndrome Using NCEP/ATP III Criteria in Jakarta, Indonesia: The Jakarta Primary Noncommunicable Disease Risk Factors Surveillance 2006. Acta Medica Indonesiana - The International Journal of Medicine, 42(4), 199–203.
- Sri Rahayu, M. and Maulina, M. (2017). The relationship between hip and waist circumference ratio with the incidence of coronary heart disease. Jurnal Aceh Medika, 1(1), 1–10. Retrieved April 8, 2021 from www.jurnal.abulyatama.ac.id/acehmedika (Accessed: 8 April 2021).
- Srikanthan, K., Feyh, A., Visweshwar, H., Shapiro, J.I. and Sodhi, K. (2016). Systematic review of metabolic syndrome biomarkers: A panel for early detection, management, and risk stratification in the West Virginian population. *International Journal of Medical Sciences*, 13(1), 25–38. https://doi.org/10.7150/ijms.13800
- Suliga, E., Kozieł, D., Cieśla, E. and Głuszek, S. (2015). Association between dietary patterns and metabolic syndrome in individuals with normal weight: A cross-sectional study. *Nutrition Journal*, 14(1), 55. https://doi.org/10.1186/s12937-015-0045-9
- Sumardiyono, S., Pamungkasari, E.P., Mahendra, A.G., Utomo, O.S., Mahajana, D., Cahyadi, W.R. and Ulfia,
   M. (2018). Hubungan Lingkar Pinggang dan Lingkar Panggul dengan Tekanan Darah pada Pasien
   Program Pengelolaan Penyakit Kronis (Prolanis). *Smart Medical Journal*, 1(1), 26.

# https://doi.org/10.13057/smj.v1i1.24504

Susetyowati, S. (2016). Gizi Remaja, in *Ilmu Gizi: Teori dan Aplikasi*. Jakarta, Indonesia: EGC, 160–164.

- Zhang, Y.X., Wang, Z.X., Chu, Z.H. and Zhao, J.S. (2016). Profiles of body mass index and the nutritional status among children and adolescents categorized by waist-to-height ratio cut-offs. *International Journal of Cardiology*, 223, 529–533. https://doi.org/10.1016/j.ijcard.2016.07.303
- Zhou, D., Yang, M., Yuan, Z. P., Zhang, D.D., Liang, L., Wang, C.L., Zhang, S., Zhu, H.H., Lai, M.D. and Zhu,
  Y.M. (2014). Waist-to-Height Ratio: A simple, effective and practical screening tool for childhood obesity and metabolic syndrome. *Preventive Medicine*, 67, 35–40. https://doi.org/10.1016/j.ypmed.2014.06.025

Variable	Minimum	Maximum	Mean	SD
Anthropometric Indicators				
WHtR (ratio)	0.37	0.71	0.51	0.07
WHR (ratio)	0.67	0.96	0.80	0.06
BMI (kg/m²)	15.81	39.30	24.04	4.72
Sagital Abdominal Diameter (cm)	11.35	25.50	16.79	2.42
Hip Circumference (cm)	80.60	138.45	98.96	9.30
Waist Circumference (cm)	58.00	112.10	79.44	10.78
Metabolic Profiles				
Blood Glucose Levels (mg/dL)	66.00	110.00	92.00	7.59
Trygliceride Levels (mg/dL)	29.00	309.00	88.35	44.68
Cholesterol HDL Levels (mg/dL)	36.00	109.00	61.73	26.43
Systolic Blood Pressure (mmHg)	84.00	144.00	114.63	11.13
Diastolic Blood Pressure (mmHg)	55.00	178.00	82.40	55.52
cMetS (Score of Metabolic Syndrome)	-7.10	11.93	0.01	2.90

Table 1. Minimum, maximum, average and standard deviation

Characteristics	n	%
Anthropometric		
Body Mass Index (BMI)		
Underweight (< 18.5 kg/m²)	6	3.7
Normal (18.5 – 22.9 kg/m²)	71	43.6
Overweight (23-24.9 kg/m²)	28	17.2
Obese (≥25.0 kg/m²)	58	35.6
Waist Height Ratio (WHtR)		
Normal (<0.50)	45	27.6
At Risk (≥0.50)	118	72.4
Waist Hip Ratio		
Normal (<0.85)	127	77.9
Central Obesity (≥0.85)	36	22.1
Sagital Abdominal Diameter (SAD)		
Normal (≤19.3 cm)	143	87.7
At Risk (>19.3 cm)	20	12.3
Wait Circumference		
Normal (<80 cm)	73	44.8
Obese (≤80 cm)	90	55.2
Metabolic Profiles		
Blood Glucose Levels		
Normal (<110 mg/dL)	136	83.4
High (≥110 mg/dL)	27	16.6
Triglycerides		
Normal (<150 mg/dL)	149	914
High (≥150 mg/dL)	14	8.6
Cholesterol HDL		
Normal (≥150 mg/dL)	135	82.8
Low (<150 mg/dL)	28	17.2
Sistolic Blood Pressure		

Table 2. Anthropometric overview and components of metabolic syndrome

Normal (<130 mg/dL)	136	83.4
High (≥130 mg/dL)	27	16.6
Diastolic Blood Pressure		
Normal (<85 mg/dL)	128	78.5
High (≥85 mg/dL)	35	21.5
cMetS (Score of Metabolic Syndrome)		
Normal (<2.21)	109	66.9
At Risk (≥2.21)	54	33.1
Metabolic Types		
Metabolic Unhealthy Normal Weight (MUNW)	17	10.4
Metabolic Healthy Normal Weight (MHNW)	88	54
Metabolic Unhealthy Obese Weight (MUOW)	38	23.3
Metabolic Healthy Obese Weight (MHOW)	20	12.3

r         p         diff           MI         0.358         <0.001         0.313         <0.001         0.315         <0.001         0.221         0.005         -0.292         <0.001         0.600         <0.001           AD         0.352         <0.001         0.284         <0.001         0.278         <0.001         0.191         0.015         -0.264         0.001         0.575         <0.001           VC         0.369         <0.001         0.284         <0.001         0.212         0.005         -0.243         0.002         0.616         <0.001           C         0.369 <td<< th=""><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th><th></th></td<<>													
Systolic BP         Diastolic BP         TG         Blood Glucose         HDL         cMets         tate difference           r         p         r         r         p         r         r         r         p         r         r         r         p         r         r         r				triglyce	triglycerides, blood sugar, HDL and metabolic syndrome scores)								
r         p         r	Variable Systolic BP		Diastolic BP		TG	ſG		Blood Glucose		HDL			
MI       0.370       <0.001       0.313       <0.001       0.315       <0.001       0.221       0.005       -0.292       <0.001       0.600       <0.001         AD       0.352       <0.001       0.284       <0.001       0.278       <0.001       0.191       0.015       -0.264       0.001       0.575       <0.001         VC       0.377       <0.001       0.284       <0.001       0.295       <0.001       0.212       0.005       -0.243       0.002       0.616       <0.001         C       0.369       <0.001       0.332       <0.001       0.302       <0.001       0.179       0.002       -0.273       <0.001       0.581       <0.001		r	р	r	р	r	р	r	p	r	р	r p difference.	
AD       0.352       <0.001       0.284       <0.001       0.278       <0.001       0.191       0.015       -0.264       0.001       0.575       <0.001         VC       0.377       <0.001	WHtR	0.358	<0.001	0.306	<0.001	0.289	<0.001	0.210	0.007	-0.266	0.001	0.599	<0.0
VC       0.377       <0.001       0.284       <0.001       0.295       <0.001       0.212       0.005       -0.243       0.002       0.616       <0.001         C       0.369       <0.001	BMI	0.370	<0.001	0.313	<0.001	0.315	<0.001	0.221	0.005	-0.292	<0.001	0.600	<0.0
C 0.369 <0.001 0.332 <0.001 0.302 <0.001 0.179 0.002 -0.273 <0.001 0.581 <0.001	SAD	0.352	<0.001	0.284	<0.001	0.278	<0.001	0.191	0.015	-0.264	0.001	0.575	<0.0
	WC	0.377	<0.001	0.284	<0.001	0.295	<0.001	0.212	0.005	-0.243	0.002	0.616	<0.0
VHR         0.244         0.002         0.128         0.104         0.013         0.172         0.028         -0.149         0.048         0.415         <0.001	HC	0.369	<0.001	0.332	<0.001	0.302	<0.001	0.179	0.002	-0.273	<0.001	0.581	<0.0
	WHR	0.244	0.002	0.128	0.104	0.194	0.013	0.172	0.028	-0.149	0.048	0.415	<0.0

Table 3. The relationship between anthropometric indicators and metabolic profiles (blood pressure,

		syndrome scores								
Variable	Systolic BP									
	Constant	USCª	p1 <sup>b</sup>	p2 <sup>c</sup>	<sup>d</sup> Adjusted R <sup>2</sup>					
BMI	91.759	0.951	<0.001	<0.001	0.158					
	Blood Gluc	ose Levels								
	Constant	USC <sup>a</sup>	p1 <sup>b</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>					
BMI	83.454	0.355	0.005	<0.001	0.043					
	HDL									
	Constant	USC <sup>a</sup>	p1 <sup>b</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>					
BMI	81.429	-0.819	<0.001	<0.001	0.080					
	Triglycerides									
	Constant	USC <sup>a</sup>	p1 <sup>b</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>					
WC	-6.614	1.195	<0.001	<0.001	0.078					
	Score of Metabolic Syndrome									
	Constant	USC <sup>a</sup>	p1 <sup>b</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>					
WC	-13.163	0.166	<0.001	<0.001	0.375					

Table 4. Anthropometric indicators most associated with metabolic components and metabolic

<sup>a</sup>Unstandardized Coefficient, <sup>b</sup> p-value, <sup>c</sup> p F-Test (ANOVA), <sup>d</sup> coefficient of determination

## Anthropometry indicators that are most related to metabolic profiles in female college students

<sup>1,2,</sup>\*Dieny, F.F., <sup>1</sup>Rose S., <sup>1,2</sup>Tsani, A.F.A., <sup>1</sup>Jauharany, F.F. and <sup>1,2</sup>Fitranti, D.Y. <sup>1</sup>Department of Nutrition Science, Faculty of Medicine, Universitas Diponegoro, Indonesia <sup>2</sup>Center of Nutrition Research (CENURE), Faculty of Medicine, Universitas Diponegoro, Indonesia

\*Corresponding author: fillahdieny@gmail.com

ORCID ID Author 1: 0000-0001-6071-8901 ORCID ID Author 2: 0000-0002-1898-1842 ORCID ID Author 3: 0000-0002-3407-5188 ORCID ID Author 4: 0000-0001-9471-9419 ORCID ID Author 5: 0000-0002-1656-9563

#### Article history:

Received: 2 June 2021 Received in revised form: 8 July 2021 Accepted: 27 September 2021

### Abstract

Metabolic syndrome is not a disease but is a set of several disorders and causes an increased risk of cardiovascular disease and diabetes mellitus complications. Several studies have shown that non-invasive approaches such as anthropometric measurements can be used for the early detection of metabolic syndrome. This study aimed to analyse the anthropometric indicators related to metabolic syndrome in female college students. The design of this research was cross sectional, with the number of subjects

involved were as many as 163 female college students aged 19 to 24 years old. Purposive sampling was used in the sampling of this research. The independent variables in this study were the Waist-to-Height Ratio (WHR), Waist-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference. The dependent variable in this study is the metabolic syndrome component that has been converted into a metabolic syndrome score (cMetS). The analysis results showed that all anthropometric indicators, namely WHtR, BMI, SAD, waist circumference, hip circumference and WHR have a strong positive relationship with the metabolic syndrome score (p<0.001). BMI was the anthropometric indicator that is most associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood sugar (p<0.05), and HDL (p<0.001). Waist circumference was the anthropometric indicator that is most associated with triglycerides and metabolic syndrome score (p<0.001). Metabolic syndrome in female college students can be identified using anthropometric measurements, one of which is BMI and WHR which are very easy to measure and efficient. BMI and WHR have the strongest relationship and can be used to detect early risk of metabolic syndrome in female college students.

Keywords: Adolescent, Anthropometric indicator, Female, Metabolic profile, Metabolic syndrome

#### 1. Introduction

Metabolic syndrome is a set of body metabolic disorders such as dyslipidemia, hyperglycemia, hypertension, and central obesity (Srikanthan *et al.*, 2016; Devi *et al.*, 2017; Christijani, 2019). Metabolic syndrome is not a disease but is a set of several disorders that causes an increased risk of cardiovascular disease and diabetes mellitus complications. Some epidemiological studies have shown that metabolic syndrome doubles the risk of cardiovascular diseases (Sri Rahayu and Maulina, 2017).

Indonesia as a developing country cannot be separated from the existing nutritional problems in the world, including the incidence of obesity and metabolic syndrome. Several studies found that the prevalence of metabolic syndrome keeps increasing every year. A study in China showed the prevalence of metabolic syndrome in adults was 24.2% (Li *et al.*, 2018). Another study indicated that the prevalence of metabolic syndrome in Indonesia was 21.66% (Herningtyas and Ng, 2019). In recent studies, metabolic syndrome can be assessed using the continuous value of metabolic syndrome (cMets) or the metabolic syndrome score recommended by the American Diabetic Association of Diabetes. The metabolic syndrome score is a z-score resulting from the assessment of all components

of the metabolic syndrome (Pratiwi, *et al.*, 2017). The advantages of using cMetS are (1) reducing dichotomization factors because cardiovascular disease is a progression of several components of the metabolic syndrome, (2) cMetS is more sensitive and less error-prone than categoric metabolic syndrome assessments, (3) increasing the statistical power (Okosun *et al.*, 2010b).

Central obesity is one of the components of metabolic syndrome parameters. Central obesity is associated with increased blood pressure, serum triglycerides, decreased HDL, and glucose intolerance. Based on the National Basic Health Research (Riskesdas) in 2018, the prevalence of obesity in adults was 21.8%, and the prevalence of central obesity at age of more than 15 years increased from 26.6% in 2013 to 31% in 2018 (Badan Penelitian dan Pengembangan Kesehatan, 2018). Obesity is closely related to degenerative diseases. Riskesdas (2018) showed that the prevalence of stroke, diabetes mellitus, heart disease, and hypertension is higher in women than men.

Several studies have shown that non-invasive approaches such as anthropometric measurements can be used for the early detection of metabolic syndrome (Pratiwi, *et al.*, 2017). Anthropometric measurements are described as the measurements of body dimensions and body composition to assess nutritional status. The advantages of anthropometric measurements are relatively fast and easy, as they can be performed using portable and calibrated instruments with standardized methods (Rokhmah, *et al.*, 2015). Some anthropometric measurements that can be used for early detection of metabolic syndrome are Waist-to-Height Ratio (WHR), waist-to-hip ratio (WHR), hip circumference, Body Mass Index (BMI), Sagital Abdominal Diameter (SAD).

One of the anthropometric measurements which can be a parameter for central obesity is the ratio of waist circumference to height (WHtR). The instruments used in the measurement are microtoise and measuring tape, which take a longer time. Studies on waist circumference have been shown to have a strong correlation with abdominal fat deposits (Zhou *et al.*, 2014). The distribution of abdominal adipose tissue (central obesity) in adults is associated with a component of the metabolic syndrome (Rodea-Montero, *et al.*, 2014). A study on adult subjects has shown that people who have the same waist circumference but are shorter in height have a greater risk of developing metabolic syndrome than taller people (Zhou *et al.*, 2014). Therefore, WHtR can be used as a simple and effective anthropometric index to identify the metabolic risk associated with obesity (Rodea-Montero, *et al.*, 2014).

The Waist-To-Hip Ratio (WHR) is a measurement that may indicate central obesity (Karimah, 2018). The higher the WHR value, the higher the risk level for several metabolic diseases. The Waist-To-Hip Ratio is calculated by dividing the measurement of the waist circumference by the circumference of the hip. The cut-off points for WHR are  $\geq$ 1.0 for men and  $\geq$ 0.85 for women (Rokhmah *et al.*, 2015). Individuals with a high waist and hip circumference will also have a higher distribution of fat in their abdominal area. Irregular fats distribution in the abdominal area indirectly causes higher triglyceride levels circulating in the blood, which will affect blood pressure (Sumardiyono *et al.*, 2018). WHR measurement is more sensitive in assessing the distribution of fat in the abdomen. This measurement of waist circumference is performed by determining the lower part of arcus costae and crista iliaca (Sri Rahayu and Maulina, 2017).

Body Mass Index (BMI) is a practical and easy measurement to perform, but it cannot distinguish between fat mass, bone mass and muscle mass. BMI is calculated as body weight (kg) / height squared (m<sup>2</sup>) (Okura *et al.*, 2018). BMI can be used as the first measurement before any other anthropometric measurements.

Sagittal Abdominal Diameter (SAD) or the height of the abdomen while the subjects are in a lying position. This anthropometric measurement has not been widely used to measure fat tissue in the abdominal area. SAD measurements using computed tomography or magnetic resonance imaging, and are associated with components of metabolic syndrome. The measurements of SAD are taken when the subject is lying down on the examination table with a naked upper body. SAD is related to central obesity in individuals with obesity and normal nutritional status. Furthermore, SAD is associated with diabetes mellitus and a predictor of cardiovascular disease incidence, even when SAD is measured in a standing position (Pajunen *et al.*, 2013). Based on the above-mentioned problems, our study aimed to analyze the anthropometric indicators related to metabolic syndrome in female college students.

#### 2. Materials and methods

#### 2.1 Design, location, and time

A cross-sectional study design and this research was conducted from March to July 2020. Anthropometric and biochemical data were collected at the Cito Laboratory, Banyumanik Semarang with health protocols applied. This study was approved by the Medical/Health Research Bioethics Commission, Faculty of Medicine, Sultan Agung Islamic University Semarang with Number No.296 /IX /2020 /Bioethical Commission.

#### 2.2 Samplings

This study was conducted during the SARS-CoV-2 outbreak, which later was named COVID-19 by the WHO, hence the registration for study participants was done online. Purposive sampling was used in this study and the total number of subjects required was 163. Samples are selected based on inclusion criteria, such as voluntary to be research subjects, female college students in Semarang City, aged 19-24 years in Semarang, not consuming alcohol, not smoking, and voluntary to follow a series of study instructions. Exclusion criteria are subjects who withdraw and those who are ill during the research study. Based on the exclusion criteria mentioned, no subjects are included in the exclusion criteria. Subjects were asked to fill in personal data using a Google Form, and eligible subjects will be contacted by the researchers to plan a direct meeting.

The health protocol applied during the anthropometric and biochemical data collection process, consisted of the subject filling out a COVID-19 sign/symptom screening questionnaire, the subject was checked for temperature, the subject washed hands before entering the room, the distance between subjects was at least 1 meter, the subject and researcher used a mask and face shield. Researchers used gloves and protective clothing. During the study, hand sanitisers were provided, and anthropometric tools that were on the subject's skin were wiped with alcohol.

#### 2.3 Data collected

The independent variables in this study were the Waist-to-Height Ratio (WHR), Waist-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference. Weight and height data were obtained through direct measurements using a digital stamp scale GEA brand with an accuracy of 0.1 kg and microtoise with an accuracy of 0.1 cm. Waist circumference and hip circumference were measured using a measuring tape (Medline) to the nearest 1 mm and abdominal height was measured using the Abawerk Schaffenburg abdominal calliper to the nearest 1 mm. SAD measurements were performed with the subject in a supine position on a flat surface with both knees forming an angle of 90° (Firouzi *et al.*, 2018). Anthropometric data were collected by trained enumerators.

The cut-off point used in this study refers to previous studies because it had been adjusted for the Asian race (Rose *et al.*, 2020). Each anthropometric measurement is stated as "at-risk" if the individuals have  $\geq 0.50$  for WHtR (Zhang *et al.*, 2016),  $\geq 0.85$  for WHR (Rokhmah *et al.*, 2015), > 19.3 cm for Sagital Abdominal Diameter (SAD) (Dieny *et al.*, 2020), and have the normal to overweight BMI (18.5 - 25 kg/m<sup>2</sup>) or obese BMI ( $\geq 25.0$  kg/m<sup>2</sup>) (Susetyowati, 2016).

The dependent variable in this study is the metabolic syndrome component that has been converted into a metabolic syndrome score (cMetS) with the cut-off point of cMetS> 2.21 (Rose et al., 2020). The guidelines for metabolic syndrome in this study are taken from the National Cholesterol Education Program-Adult Treatment Panel (NCEP-ATP III) 2005 which has been frequently used in Indonesia. There are 5 parameters to assess metabolic syndrome: (1) fasting blood glucose levels ≥110 mg/dL, (2) triglyceride levels ≥150 mg/dL (3) HDL cholesterol levels <50 mg/dL, (4) central obesity in women with waist circumference ≥80 cm, and (5) systolic and diastolic blood pressures ≥130 mmHg and ≥85 mmHg, respectively (Soewondo et al., 2010). The calculation of the metabolic syndrome score (cMetS) was done in the following steps: (1) after measuring all parameters of the metabolic syndrome, standardisation was carried out to obtain a Z-score; (2) the blood pressure must be converted into Mean Arterial Blood (MAP) by dividing the difference between systolic and diastolic blood pressure by three and summed with the diastolic blood pressure; (3) the HDL cholesterol standardization results were multiplied by (-1) because the parameter was inversely related to the risk of metabolic syndrome; (4) All Z-scores were added to obtain the cMetS values; (5) The final step was to compare the cMetS values with the cut-off point of ≥2,21 (Eisenmann et al., 2010; Okosun et al., 2010a; Rose et al., 2020). The subjects were instructed to do fasting for at least 8 hrs, only drinking water was permitted.

Other than the cMetS score, metabolic syndrome risk can also be assessed from the classification of metabolic types. This classification combines the internal and external signs of the body such as biochemical parameters, the ratio of subcutaneous fat to abdominal fat, and blood pressure (Prybyla O, 2020). The main phenotypes that reflect the possible combination of metabolic profile and the degree of obesity are metabolic healthy obese weight, metabolic healthy normal weight, metabolic unhealthy normal weight, and metabolic unhealthy normal weight.

#### 2.4 Data analysis

All data were analyzed using computer programs and statistical analyses were performed using SPSS statistical software version 22. Univariate analysis was used to describe subjects characteristics.

The normality test of the data using the Kolmogorov-Smirnov test was carried out before testing the hypothesis. The relationship of anthropometric indicators with metabolic profile (Blood Pressure, Triglycerides, Blood Sugar, HDL and metabolic syndrome scores) was determined using the Person correlation test. Furthermore, Anthropometric indicators that are most related to the metabolic component and metabolic syndrome score were analyzed using the Multiple Linear Regression test.

#### 3. Results and discussion

The subject characteristics measured in female students aged 19-24 years include age, anthropometric indicators, and metabolic syndromes. Table 1 shows the characteristics of the study subjects. The mean WHR value in this study was 0.51. Meanwhile, the mean WHR was 0.80; the mean BMI was 24.04 kg/m<sup>2</sup>; the mean SAD was 16.79 cm, and the mean waist circumference was 79.44 cm.

Table 2 shows the various nutritional status of the subjects based on BMI. It was found that 43.6% of the subjects had normal BMI, 17.2% were overweight and 35.6% were obese. Based on the WHtR anthropometric indicator, 72.4% of subjects were at risk of having obesity, based on WHR, 22.1% had central obesity, based on BMI, 35.6% were obese, based on SAD 12.3% of the subjects were at risk, and based on waist circumference 55.2% had central obesity. According to the metabolic profile that was assessed, 16.6% had high Fasting Blood Glucose levels, 8.6% had hypertriglycerides, 17.2% had low HDL, and 16.6% had high systolic blood pressure, and 21.5% had high diastolic blood pressure. In addition, we found that 33.1% of the subjects had high metabolic syndrome (cMetS) scores. This proportion was similar to the assessment based on the metabolic type of unhealthy subjects (subjects who had  $\geq$  3 risk factors of the metabolic profile), which was 33.7%. Moreover, two subjects had five risk factors: abdominal obesity, hypertension, hyperglycemia, hypertriglycerides, and low HDL.

The objective of this study was to determine the anthropometric indicators associated with metabolic syndromes in female students. The study included 163 female students aged 19-24 years. The students are in their late adolescents who begin to have an independent life. Inappropriate and unhealthy eating behaviour will have an impact on the student's nutritional status. Excessive nutritional status and obesity will affect student's body metabolism. Based on the study results, 33.1% of the subjects had a high metabolic syndrome (cMetS) score. In line with the previous study conducted in 2019 on 18-to-21-year-old students at Universitas Diponegoro, 20% of the subjects had high cMetS (Rose *et al.*, 2020). Meanwhile, a study conducted by Pratiwi et al in 2017 using secondary data from the National Basic Health Research 2013 found that 19.98% of adolescents aged 15-24 years

had high cMetS (Pratiwi, *et al.*, 2017). To conclude, there is a trend of Metabolic Syndrome Score (cMetS) among young women in Semarang.

The assessment of metabolic syndrome using a continuous type (scoring) rather than using a dichotomy or binary ("yes" and "no") is recommended (Christijani, 2019). An adolescent can be diagnosed with metabolic syndrome if their Metabolic Syndrome Score (cMetS) >2.21 (Pratiwi, *et al.*, 2017). Anthropometric indicators used in this study are Waist and Height Ratio (WHR), Waist-to-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and Waist Circumference. Based on the correlation analyses, all anthropometric indicators have a significant positive relationship with the Metabolic Syndrome Score (cMetS). Furthermore, the multivariate analyses show that the anthropometric indicators of BMI and WHR are strongly associated with cMetS.

If the metabolic type is considered based on nutritional status (subjects with non-obese BMI (<25kg/m<sup>2</sup>) with metabolic healthy and metabolic unhealthy and subjects with obese BMI (>25kg/m<sup>2</sup>) with metabolic healthy and metabolic unhealthy), subjects are categorized as metabolic unhealthy (experiencing metabolic syndrome) if they fulfil  $\geq$  3 risk factors including high waist circumference, blood pressure, fasting blood glucose and triglyceride levels, and low HDL levels. Based on these criteria, it was found that 10.4% of the subjects had a metabolic unhealthy normal weight (MUNW) and 23.3% of the subjects had metabolic unhealthy obesity weight (MUOW). Of non-obese subjects, 54% of them were metabolic healthy. Our study also shows that 10.4% of the subjects were classified as metabolic unhealthy normal weight (MUNW). The subjects' BMI in this category is in the normal range but has a high percentage of body fat that makes them at high risk of developing metabolic disorders (Eckel et al., 2015; Suliga et al., 2015). Several recent cohort studies have shown a greater risk of type II diabetes mellitus in individuals with MUNW compared to individuals with MHNW (Ärnlöv et al., 2011; Hadaegh et al., 2011; Aung et al., 2014; Jung et al., 2014; Hinnouho et al., 2015). Other studies have shown that women with the MUNW type have a long-term impact of an increased risk of cardiovascular diseases such as higher blood pressure, triglyceride and glucose levels as well as lower levels of adiponectin, HDL, and LDL compared to women with the MHNW type (Kim et al., 2013).

In this study, 23.3% of the subjects belonged to the Metabolic Unhealthy Obese Weight (MUOW) type. Subjects with this metabolic type have an obese BMI and have a high risk of developing metabolic disorders. A study conducted in Japan on 29,564 subjects showed that individuals with MUOW had a greater risk of developing type II diabetes mellitus compared to individuals with MHOW (Heianza *et al.*, 2015).

It was also found that 12.3% of the subjects were categorized as metabolic healthy obese weight (MHOW). Individuals in this metabolic type have an obese BMI but do not show any metabolic risks. Given the impact of obesity in relation to the risk of metabolic diseases, various studies have been conducted to examine the long-term effects of MHOW. Individuals with MHOW had a different fat distribution pattern (less ectopic and visceral fat), and lower inflammatory markers (Samocha-Bonet *et al.*, 2014). Other studies also have shown that women with MHOW had lower blood pressure, triglyceride levels, and glucose levels, but higher levels of HDL, adiponectin, and LDL compared to women with MUNW (Kim *et al.*, 2013). This condition was associated with good diet quality in individuals with MHOW. Based on National Health and Nutrition Examination Surveys (NHANES) data, Camhi *et al.* (2015) examined the quality of diet in obese subjects and found that adolescents and adult women with the MHOW metabolic type had higher diet quality scores due to high intake of fruit, whole grains, meat, and nuts.

Table 3 and Table 4 show the results of statistical analyses on anthropometric indicators related to metabolic syndromes. Table 3 shows the bivariate statistical analysis using the Pearson correlation test. The analysis results showed that all anthropometric indicators, namely WHtR, BMI, SAD, waist circumference, hip circumference and WHR have a strong positive relationship with the metabolic syndrome score (p<0.001), which means that the higher the anthropometric value, the higher the metabolic syndrome score. In addition, the analysis of the relationship between anthropometric indicators and each metabolic profile revealed that almost all of the independent variables (WHtR, waist and hip circumference, WHR, BMI, and SAD) were associated with each metabolic profile, such as baseline systolic pressure, diastolic blood pressure, triglyceride levels, blood sugar levels, and HDL. Only WHR was not associated with diastolic blood pressure (p>0.005).

Table 4 shows the results of the analysis using multiple linear regression to determine anthropometric indicators that are most associated with each metabolic profile and metabolic syndrome score. The results showed that BMI was the anthropometric indicator that is most associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood sugar (p<0.05), and HDL (p <0.001). In addition, waist circumference was the anthropometric indicator that is most associated with triglycerides and metabolic syndrome score (p<0.001). Based on the Adjusted R<sup>2</sup> value on the metabolic syndrome score, we found that 37.5% of the metabolic syndrome score was related to anthropometric indicators, such as WHtR, waist and hip circumference, WHR, BMI, and SAD. The rest may be influenced by other variables that are not included in this study. The correlation test results indicated that all anthropometric indicators had a positive relationship with the metabolic syndrome scores with p <0.001. Meanwhile, the regression analyses show that BMI and WHR were inversely related to cMetS. This is in line with research that reported an increase in the WHR value could be associated with the risk of metabolic syndrome in children and adolescents in Florida (Moore *et al.*, 2015). Another study revealed that there was a strong relationship between overweight and obese adolescents with metabolic syndrome (Al-Bachir and Bakir, 2017). Furthermore, a study on adolescents in South Africa found that central obesity as measured by the hip circumference could lead to an increased risk of cardiovascular diseases and death. Therefore, hip circumference and waist circumference can be used to predict the risk of cardiovascular diseases and death in the future (Cameron *et al.*, 2012).

Body Mass Index (BMI) is the most widely used indicator of measurement in epidemiological studies and is used as a substitute for evaluating body composition. However, BMI cannot distinguish fat from fat mass and lean mass, and it fails to show the presence of adipose and body fat distribution (Ofer *et al.*, 2019; Leone *et al.*, 2020). However, the BMI cut-offs for metabolic syndrome have not yet been determined (Ofer *et al.*, 2019). Obesity in adolescents is generally assessed using a BMI of  $\geq$ 25.0 kg/m<sup>2</sup>. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m<sup>2</sup>) and obesity ( $\geq$ 25.0 kg/m<sup>2</sup>), and we found that 35.6% of the subjects were obese. The finding is in line with the research on the subject of students at Universitas Diponegoro aged 18-21 years. They found that 40% of their study population had obesity level I and 36.3% had obesity level II (Rose *et al.*, 2020).

Abdominal obesity is often assessed to determine a metabolic syndrome in people. One of the indicators used to measure abdominal obesity is the Waist-to-Hip Ratio (WHR) which is calculated by dividing the waist circumference and the hip circumference. Measurement of waist circumference is more sensitive in assessing the distribution of body fat in the abdominal wall, which is also a component of metabolic syndrome. The limit of the WHR value for a female is  $\geq$  0.85 (Rokhmah, *et al.*, 2015). This study shows that every 1% increase in the WHR value will increase the cMetS value by 10.411. Hip circumference is also an indicator that has a strong correlation with cMetS, but many studies have used it as a ratio along with waist circumference for assessing a person's central obesity status.

#### 4. Conclusion

Metabolic syndrome in female students can be identified using anthropometric measurements, one of which is BMI and WHR which are very easy to measure and efficient. BMI and WHR have the strongest relationship and can be used to detect early risk of metabolic syndrome in female college students.

#### **Conflict of interest**

The authors declare no conflict of interest.

#### Acknowledgements

The authors would like to thank all the subjects who participated in this study. We would also like to express our gratitude to The Ministry of Research, Technology and Higher Education, Indonesia" which was funded by the "Hibah Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) 2019.

#### References

- Al-Bachir, M. and Bakir, M.A. (2017). Predictive value of body mass index to metabolic syndrome risk factors in Syrian adolescents. *Journal of Medical Case Reports*, 11(1), 170. https://doi.org/10.1186/s13256-017-1315-2
- Ärnlöv, J., Sundström, J., Ingelsson, E. and Lind, L. (2011). Impact of BMI and the metabolic syndrome on the risk of diabetes in middle-aged men. *Diabetes Care*, 34(1), 61–65. https://doi.org/10.2337/dc10-0955
- Aung, K.K., Lorenzo, C., Hinojosa, M.A. and Haffner, S.M. (2014). Risk of developing diabetes and cardiovascular disease in metabolically unhealthy normal-weight and metabolically healthy obese individuals. *Journal of Clinical Endocrinology and Metabolism*, 99(2), 462–468. https://doi.org/10.1210/jc.2013-2832
- Badan Penelitian dan Pengembangan Kesehatan. (2018). *Riset Kesehatan Dasar (RISKESDAS) 2018*. Jakarta, Indonesia.
- Cameron, A.J., Magliano, D.J., Shaw, J.E., Zimmet, P.Z., Carstensen, B., Alberti, K.G.M.M., Tuomilehto, J., Barr, E.L.M., Pauvaday, V.K., Kowlessur, S. and Söderberg, S. (2012). The influence of hip circumference on the relationship between abdominal obesity and mortality. *International Journal of Epidemiology*, 41(2), 484–494. https://doi.org/10.1093/ije/dyr198
- Camhi, S.M., Whitney Evans, E., Hayman, L.L., Lichtenstein, A.H. and Must, A. (2015). Healthy eating index and metabolically healthy obesity in U.S. adolescents and adults. *Preventive Medicine*, 77, 23–27. https://doi.org/10.1016/j.ypmed.2015.04.023
- Christijani, R. (2019). Determination of Diagnosis of Metabolic Syndrome based on Assessment of Metabolic Syndrome and NCEP ATP-III Score in Adolescent. *The Journal of Nutrition and Food Research*, 42(1), 21–28. https://doi.org/10.22435/pgm.v42i1.2418
- Devi, R., Manhas, S., Prasad, S., Sharma, S., Bhaskar, N. and Mahajan, S. (2017). Short Review of Metabolic Syndrome. *International Journal of Research and Review*, 4(2), 29.
- Dieny, F.F., Setyaningsih, R.F., Fitranti, D.Y., Jauharany, F.F., Putra, Y.D. and Tsani, A.F.A. (2020). Abdominal diameter profiles have relationship with insulin resistance in obese female adolescents. *Electronic Journal of General Medicine*, 17(5), em219. https://doi.org/10.29333/ejgm/7882
- Eckel, N., Mühlenbruch, K., Meidtner, K., Boeing, H., Stefan, N. and Schulze, M. B. (2015). Characterization of metabolically unhealthy normal-weight individuals: Risk factors and their associations with type 2 diabetes. *Metabolism: Clinical and Experimental*, 64(8), 862–871. https://doi.org/10.1016/j.metabol.2015.03.009

- Eisenmann, J.C., Laurson, K.R., Dubose, K.D., Smith, B.K. and Donnelly, J.E. (2010). Construct validity of a continuous metabolic syndrome score in children. *Diabetology and Metabolic Syndrome*, 2(1). https://doi.org/10.1186/1758-5996-2-8
- Firouzi, S.A., Tucker, L.A., LeCheminant, J.D. and Bailey, B.W. (2018). Sagittal abdominal diameter, waist circumference, and BMI as predictors of multiple measures of glucose metabolism: An NHANES investigation of US adults. *Journal of Diabetes Research*, 2018(9-10), 1–14. https://doi.org/10.1155/2018/3604108
- Hadaegh, F., Bozorgmanesh, M., Safarkhani, M., Khalili, D. and Azizi, F. (2011). Predictability of body mass index for diabetes: Affected by the presence of metabolic syndrome? *BMC Public Health*, 11(1), 383. https://doi.org/10.1186/1471-2458-11-383
- Heianza, Y., Kato, K., Kodama, S., Ohara, N., Suzuki, A., Tanaka, S., Hanyu, O., Sato, K. and Sone, H. (2015).
  Risk of the development of Type 2 diabetes in relation to overall obesity, abdominal obesity and the clustering of metabolic abnormalities in Japanese individuals: Does metabolically healthy overweight really exist? The Niigata Wellness Study. *Diabetic Medicine*, 32(5), 665–672. https://doi.org/10.1111/dme.12646
- Herningtyas, E.H. and Ng, T.S. (2019). Prevalence and distribution of metabolic syndrome and its components among provinces and ethnic groups in Indonesia. *BMC Public Health*, 19(1), 377. https://doi.org/10.1186/s12889-019-6711-7
- Hinnouho, G.M., Czernichow, S., Dugravot, A., Nabi, H., Brunner, E.J., Kivimaki, M. and Singh-Manoux, A. (2015). Metabolically healthy obesity and the risk of cardiovascular disease and type 2 diabetes: The Whitehall II cohort study. *European Heart Journal*, 36(9), 551–559. https://doi.org/10.1093/eurheartj/ehu123
- Jung, H.S., Chang, Y., Eun, Y.K., Kim, C.W., Choi, E.S., Kwon, M.J., Cho, J., Zhang, Y., Rampal, S., Zhao, D., Soo, K.H., Shin, H., Guallar, E. and Ryu, S. (2014). Impact of body mass index, metabolic health and weight change on incident diabetes in a Korean population. *Obesity*, 22(8), 1880–1887. https://doi.org/10.1002/oby.20751
- Karimah, M. (2018). Waist-Hip Circumference Ratio as Strongest Factor Correlation with Blood Glucose Level. Jurnal Berkala Epidemiologi, 6(3), 219–226. https://doi.org/10.20473/jbe.V6l32018.219-226
- Kim, M., Paik, J.K., Kang, R., Kim, S.Y., Lee, S.H. and Lee, J.H. (2013). Increased oxidative stress in normalweight postmenopausal women with metabolic syndrome compared with metabolically healthy overweight/obese individuals. *Metabolism: Clinical and Experimental*, 62(4), 554–560. https://doi.org/10.1016/j.metabol.2012.10.006

- Leone, A., Vizzuso, S., Brambilla, P., Mameli, C., Ravella, S., De Amicis, R., Battezzati, A., Zuccotti, G., Bertoli, S. and Verduci, E. (2020). Evaluation of different adiposity indices and association with metabolic syndrome risk in obese children: Is there a winner? *International Journal of Molecular Sciences*, 21(11), 4083. https://doi.org/10.3390/ijms21114083
- Li, Y., Zhao, L., Yu, D., Wang, Z. and Ding, G. (2018). Metabolic syndrome prevalence and its risk factors among adults in China: A nationally representative cross-sectional study. *PLoS ONE*, 13(6), e0199293. https://doi.org/10.1371/journal.pone.0199293
- Moore, L.M., Fals, A.M., Jannelle, P.J., Green, J.F., Pepe, J. and Richard, T. (2015). Analysis of Pediatric Waist to Hip Ratio Relationship to Metabolic Syndrome Markers. *Journal of Pediatric Health Care*, 29(4), 319–324. https://doi.org/10.1016/j.pedhc.2014.12.003
- Ofer, K., Leiba, R., Avizohar, O. and Karban, A. (2019). Normal body mass index (BMI) can rule out metabolic syndrome: An Israeli cohort study. *Medicine*, 98(9), e14712. https://doi.org/10.1097/MD.000000000014712
- Okosun, I.S., Boltri, J.M., Lyn, R. and Smith, M.D. (2010a). Continuous metabolic syndrome risk score, body mass index percentile, and leisure time physical activity in American children. *Journal of Clinical Hypertension*, 12(8), 636–644. https://doi.org/10.1111/j.1751-7176.2010.00338.x
- Okosun, I.S., Lyn, R., Smith, D.M., Eriksen, M. and Seale, P. (2010b). Validity of a Continuous Metabolic Risk Score as an Index for Modeling Metabolic Syndrome in Adolescents. *Annals of Epidemiology*, 20(11), 843–851. https://doi.org/10.1016/j.annepidem.2010.08.001
- Okura, T., Nakamura, R., Fujioka, Y., Kitao, S.K., Ito, Y., Matsumoto, K., Shoji, K., Sumi, K., Matsuzawa, K., Izawa, S., Ueta, W., Kato, M., Imamura, T., Taniquchi, I. and Yamamoto, K. (2018). Body mass index ≥23 is a risk factor for insulin resistance and diabetes in Japanese people: A brief report. *PLOS ONE*, 13(7), e0201052. https://doi.org/10.1371/journal.pone.0201052
- Pajunen, P., Rissanen, H., Laaksonen, M.A., Heliövaara, M., Reunanen, A. and Knekt, P. (2013). Sagittal abdominal diameter as a new predictor for incident diabetes. *Diabetes Care*, 36(2), 283–288. https://doi.org/10.2337/dc11-2451
- Pratiwi, Z.A., Hasanbasri, M. and Huriyati, E. (2017). Determination of cutoff points for metabolic syndrome scores in Indonesian adolescents and assessment of the diagnostic validity of anthropometric parameters. Jurnal Gizi *Klinik Indonesia*, 14(2), 80. https://doi.org/10.22146/ijcn.25590
- Prybyla, O. (2020). Metabolic phenotyping: is it so important? Journal of Cognitive Neuropsychology, 4(1), 1-3.

- Rodea-Montero, E.R., Evia-Viscarra, M.L. and Apolinar-Jiménez, E. (2014). Waist-to-height ratio is a better anthropometric index than waist circumference and BMI in predicting metabolic syndrome among obese mexican adolescents. *International Journal of Endocrinology*, 2014, 195407. https://doi.org/10.1155/2014/195407
- Rokhmah, F.D., Handayani, D. and Al-Rasyid, H. (2015). Correlation between waist circumference (WC) and waist-hip ratio (WHR) with plasma glucose levels using oral glucose tolerance test method. Jurnal Gizi Klinik Indonesia, 12(1), 28–35. https://doi.org/10.22146/ijcn.22425
- Rose, S., Dieny, F.F., Nuryanto, N. and Tsani, A.F.A. (2020). The correlation between waist-to-height ratio (wHtR) and second to fourth digit ratio (2D:4D) with an increase in metabolic syndrome scores in obese adolescent girls. *Electronic Journal of General Medicine*, 17(3), em211. https://doi.org/10.29333/ejgm/7872
- Samocha-Bonet, D., Dixit, V.D., Kahn, C.R., Leibel, R.L., Lin, X., Nieuwdorp, M., Pietiläinen, K.H., Rabasa-Lhoret, R., Roden, M., Scherer, P.E., Klein, S. and Ravussin, E. (2014). Metabolically healthy and unhealthy obese - The 2013 stock conference report. *Obesity Reviews*, 15(9), 697–708. https://doi.org/10.1111/obr.12199
- Soewondo, P., Purnamasari, D., Oemardi, M., Waspadji, S. and Soegondo, S. (2010). Prevalence of Metabolic Syndrome Using NCEP/ATP III Criteria in Jakarta, Indonesia: The Jakarta Primary Noncommunicable Disease Risk Factors Surveillance 2006. Acta Medica Indonesiana - The International Journal of Medicine, 42(4), 199–203.
- Sri Rahayu, M. and Maulina, M. (2017). The relationship between hip and waist circumference ratio with the incidence of coronary heart disease. Jurnal Aceh Medika, 1(1), 1–10. Retrieved April 8, 2021 from www.jurnal.abulyatama.ac.id/acehmedika (Accessed: 8 April 2021).
- Srikanthan, K., Feyh, A., Visweshwar, H., Shapiro, J.I. and Sodhi, K. (2016). Systematic review of metabolic syndrome biomarkers: A panel for early detection, management, and risk stratification in the West Virginian population. *International Journal of Medical Sciences*, 13(1), 25–38. https://doi.org/10.7150/ijms.13800
- Suliga, E., Kozieł, D., Cieśla, E. and Głuszek, S. (2015). Association between dietary patterns and metabolic syndrome in individuals with normal weight: A cross-sectional study. *Nutrition Journal*, 14(1), 55. https://doi.org/10.1186/s12937-015-0045-9
- Sumardiyono, S., Pamungkasari, E.P., Mahendra, A.G., Utomo, O.S., Mahajana, D., Cahyadi, W.R. and Ulfia,
   M. (2018). Hubungan Lingkar Pinggang dan Lingkar Panggul dengan Tekanan Darah pada Pasien
   Program Pengelolaan Penyakit Kronis (Prolanis). *Smart Medical Journal*, 1(1), 26.

#### https://doi.org/10.13057/smj.v1i1.24504

Susetyowati, S. (2016). Gizi Remaja, in *Ilmu Gizi: Teori dan Aplikasi*. Jakarta, Indonesia: EGC, 160–164.

- Zhang, Y.X., Wang, Z.X., Chu, Z.H. and Zhao, J.S. (2016). Profiles of body mass index and the nutritional status among children and adolescents categorized by waist-to-height ratio cut-offs. *International Journal of Cardiology*, 223, 529–533. https://doi.org/10.1016/j.ijcard.2016.07.303
- Zhou, D., Yang, M., Yuan, Z. P., Zhang, D.D., Liang, L., Wang, C.L., Zhang, S., Zhu, H.H., Lai, M.D. and Zhu,
  Y.M. (2014). Waist-to-Height Ratio: A simple, effective and practical screening tool for childhood obesity and metabolic syndrome. *Preventive Medicine*, 67, 35–40. https://doi.org/10.1016/j.ypmed.2014.06.025

Variable	Minimum	Maximum	Mean	SD
Anthropometric Indicators				
WHtR (ratio)	0.37	0.71	0.51	0.07
WHR (ratio)	0.67	0.96	0.80	0.06
BMI (kg/m²)	15.81	39.30	24.04	4.72
Sagital Abdominal Diameter (cm)	11.35	25.50	16.79	2.42
Hip Circumference (cm)	80.60	138.45	98.96	9.30
Waist Circumference (cm)	58.00	112.10	79.44	10.78
Metabolic Profiles				
Blood Glucose Levels (mg/dL)	66.00	110.00	92.00	7.59
Trygliceride Levels (mg/dL)	29.00	309.00	88.35	44.68
Cholesterol HDL Levels (mg/dL)	36.00	109.00	61.73	26.43
Systolic Blood Pressure (mmHg)	84.00	144.00	114.63	11.13
Diastolic Blood Pressure (mmHg)	55.00	178.00	82.40	55.52
cMetS (Score of Metabolic Syndrome)	-7.10	11.93	0.01	2.90

Table 1. Minimum, maximum, average and standard deviation

Characteristics	n	%
Anthropometric		
Body Mass Index (BMI)		
Underweight (< 18.5 kg/m²)	6	3.7
Normal (18.5 – 22.9 kg/m²)	71	43.6
Overweight (23-24.9 kg/m²)	28	17.2
Obese (≥25.0 kg/m²)	58	35.6
Waist Height Ratio (WHtR)		
Normal (<0.50)	45	27.6
At Risk (≥0.50)	118	72.4
Waist Hip Ratio		
Normal (<0.85)	127	77.9
Central Obesity (≥0.85)	36	22.1
Sagital Abdominal Diameter (SAD)		
Normal (≤19.3 cm)	143	87.7
At Risk (>19.3 cm)	20	12.3
Wait Circumference		
Normal (<80 cm)	73	44.8
Obese (≤80 cm)	90	55.2
Metabolic Profiles		
Blood Glucose Levels		
Normal (<110 mg/dL)	136	83.4
High (≥110 mg/dL)	27	16.6
Triglycerides		
Normal (<150 mg/dL)	149	914
High (≥150 mg/dL)	14	8.6
Cholesterol HDL		
Normal (≥150 mg/dL)	135	82.8
Low (<150 mg/dL)	28	17.2
Sistolic Blood Pressure		

Table 2. Anthropometric overview and components of metabolic syndrome

Normal (<130 mg/dL)	136	83.4
High (≥130 mg/dL)	27	16.6
Diastolic Blood Pressure		
Normal (<85 mg/dL)	128	78.5
High (≥85 mg/dL)	35	21.5
cMetS (Score of Metabolic Syndrome)		
Normal (<2.21)	109	66.9
At Risk (≥2.21)	54	33.1
Metabolic Types		
Metabolic Unhealthy Normal Weight (MUNW)	17	10.4
Metabolic Healthy Normal Weight (MHNW)	88	54
Metabolic Unhealthy Obese Weight (MUOW)	38	23.3
Metabolic Healthy Obese Weight (MHOW)	20	12.3

			triglycerides, blood sugar, HDL and metabolic syndrome scores)							Commented [VN1]: Rather than bold the p-value that		
Variable Sys	Systolic	Systolic BP		Diastolic BP		TG		Blood Glucose		HDL		showed significant difference, you should indicate in the table note, p-value<0.05/0.01 indicates significant
	r	p	r	p	r	р	r	р	r	р	r	p difference.
WHtR	0.358	<0.001 <sup>s</sup>	0.306	<0.001 <sup>s</sup>	0.289	<0.001s	0.210	0.007 <sup>s</sup>	-0.266	0.001 <sup>s</sup>	0.599	<0.001
BMI	0.370	<0.001 <sup>s</sup>	0.313	<0.001 <sup>s</sup>	0.315	<0.001 <sup>s</sup>	0.221	0.005 <sup>s</sup>	-0.292	<0.001 <sup>s</sup>	0.600	<0.001 <sup>s</sup>
SAD	0.352	<0.001 <sup>s</sup>	0.284	<0.001 <sup>s</sup>	0.278	<0.001 <sup>s</sup>	0.191	0.015 <sup>s</sup>	-0.264	0.001 <sup>s</sup>	0.575	<0.001 <sup>s</sup>
WC	0.377	<0.001 <sup>s</sup>	0.284	<0.001 <sup>s</sup>	0.295	<0.001 <sup>s</sup>	0.212	0.005 <sup>s</sup>	-0.243	0.002 <sup>s</sup>	0.616	<0.001 <sup>s</sup>
HC	0.369	<0.001 <sup>s</sup>	0.332	<0.001 <sup>s</sup>	0.302	<0.001 <sup>s</sup>	0.179	0.002 <sup>s</sup>	-0.273	<0.001 <sup>s</sup>	0.581	<0.001 <sup>s</sup>
WHR	0.244	0.002 <sup>s</sup>	0.128	0.104	0.194	0.013 <sup>s</sup>	0.172	0.028 <sup>s</sup>	-0.149	0.048 <sup>s</sup>	0.415	<0.001 <sup>s</sup>

Table 3. The relationship between anthropometric indicators and metabolic profiles (blood pressure,

<sup>s</sup> = Significant, p-value <0.05 indicates there is a significant relationship

		syndrome scores						
Variable	Systolic BP							
	Constant	USCª	p1 <sup>b</sup>	p2 <sup>c</sup>	<sup>d</sup> Adjusted R <sup>2</sup>			
BMI	91.759	0.951	<0.001	<0.001	0.158			
	Blood Gluc	ose Levels						
	Constant	USC <sup>a</sup>	p1 <sup>b</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>			
BMI	83.454	0.355	0.005	<0.001	0.043			
	HDL							
	Constant	USC <sup>a</sup>	p1 <sup>b</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>			
BMI	81.429	-0.819	<0.001	<0.001	0.080			
	Triglyceride	Triglycerides						
	Constant	USC <sup>a</sup>	p1 <sup>b</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>			
WC	-6.614	1.195	<0.001	<0.001	0.078			
	Score of M	etabolic Syn	drome					
	Constant	USC <sup>a</sup>	p1 <sup>b</sup>	p2 <sup>c</sup>	Adjusted R <sup>2</sup>			
WC	-13.163	0.166	<0.001	<0.001	0.375			
-								

Table 4. Anthropometric indicators most associated with metabolic components and metabolic

<sup>a</sup>Unstandardized Coefficient, <sup>b</sup> p-value, <sup>c</sup> p F-Test (ANOVA), <sup>d</sup> coefficient of determination

# Anthropometry indicators that are most related to metabolic profiles in female college students

<sup>1,2,</sup>\*Dieny, F.F., <sup>1</sup>Rose S., <sup>1,2</sup>Tsani, A.F.A., <sup>1</sup>Jauharany, F.F. and <sup>1,2</sup>Fitranti, D.Y.

<sup>1</sup>Department of Nutrition Science, Faculty of Medicine, Universitas Diponegoro, Indonesia <sup>2</sup>Center of Nutrition Research (CENURE), Faculty of Medicine, Universitas Diponegoro, Indonesia

#### Abstract

*Article history:* Received: 2 June 2021 Received in revised form: 8 July 2021 Accepted: 27 September 2021 Available Online:

#### Keywords:

Adolescent, Anthropometric indicator, Female, Metabolic profile, Metabolic syndrome

DOI:

Metabolic syndrome is not a disease but is a set of several disorders and causes an increased risk of cardiovascular disease and diabetes mellitus complications. Several studies have shown that non-invasive approaches such as anthropometric measurements can be used for the early detection of metabolic syndrome. This study aimed to analyse the anthropometric indicators related to metabolic syndrome in female college students. The design of this research was cross sectional, with the number of subjects involved were as many as 163 female college students aged 19 to 24 years old. Purposive sampling was used in the sampling of this research. The independent variables in this study were the Waist-to-Height Ratio (WHR), Waist-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference. The dependent variable in this study is the metabolic syndrome component that has been converted into a metabolic syndrome score (cMetS). The analysis results showed that all anthropometric indicators, namely WHtR, BMI, SAD, waist circumference, hip circumference and WHR have a strong positive relationship with the metabolic syndrome score (p < 0.001). BMI was the anthropometric indicator that is most associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood sugar (p<0.05), and HDL (p<0.001). Waist circumference was the anthropometric indicator that is most associated with triglycerides and metabolic syndrome score (p<0.001). Metabolic syndrome in female college students can be identified using anthropometric measurements, one of which is BMI and WHR which are very easy to measure and efficient. BMI and WHR have the strongest relationship and can be used to detect early risk of metabolic syndrome in female college students.

# 1. Introduction

Metabolic syndrome is a set of body metabolic such disorders as dvslipidemia. hyperglycemia. hypertension, and central obesity (Srikanthan et al., 2016; Devi et al., 2017; Christijani, 2019). Metabolic syndrome is not a disease but is a set of several disorders that causes an increased risk of cardiovascular disease complications. and diabetes mellitus Some epidemiological studies have shown that metabolic syndrome doubles the risk of cardiovascular diseases (Sri Rahayu and Maulina, 2017).

Indonesia as a developing country cannot be separated from the existing nutritional problems in the world, including the incidence of obesity and metabolic syndrome. Several studies found that the prevalence of metabolic syndrome keeps increasing every year. A study in China showed the prevalence of metabolic

syndrome in adults was 24.2% (Li et al., 2018). Another study indicated that the prevalence of metabolic syndrome in Indonesia was 21.66% (Herningtyas and Ng, 2019). In recent studies, metabolic syndrome can be assessed using the continuous value of metabolic syndrome (cMets) or the metabolic syndrome score recommended by the American Diabetic Association of Diabetes. The metabolic syndrome score is a z-score resulting from the assessment of all components of the metabolic syndrome (Pratiwi, et al., 2017). The advantages of using cMetS are (1) reducing dichotomization factors because cardiovascular disease is a progression of several components of the metabolic syndrome, (2) cMetS is more sensitive and less errorprone than categoric metabolic syndrome assessments, (3) increasing the statistical power (Okosun, Lyn, Smith et al., 2010).

FULL PAPER

2

Central obesity is one of the components of metabolic syndrome parameters. Central obesity is associated with increased blood pressure, serum triglycerides, decreased HDL, and glucose intolerance. Based on the National Basic Health Research (Riskesdas) in 2018, the prevalence of obesity in adults was 21.8%, and the prevalence of central obesity at age of more than 15 years increased from 26.6% in 2013 to 31% in 2018 (Badan Penelitian dan Pengembangan Kesehatan, 2018). Obesity is closely related to degenerative diseases. The prevalence of stroke, diabetes mellitus, heart disease, and hypertension is higher in women than men (Badan Penelitian dan Pengembangan Kesehatan, 2018).

Several studies have shown that non-invasive approaches such as anthropometric measurements can be used for the early detection of metabolic syndrome (Pratiwi, et al., 2017). Anthropometric measurements are described as the measurements of body dimensions and The body composition to assess nutritional status. of anthropometric advantages measurements are relatively fast and easy, as they can be performed using portable and calibrated instruments with standardized methods (Rokhmah, et al., 2015). Some anthropometric measurements that can be used for early detection of metabolic syndrome are Waist-to-Height Ratio (WHtR), waist-to-hip ratio (WHR), hip circumference, Body Mass Index (BMI), Sagital Abdominal Diameter (SAD).

One of the anthropometric measurements which can be a parameter for central obesity is the ratio of waist circumference to height (WHtR). The instruments used in the measurement are microtoise and measuring tape, which take a longer time. Studies on waist circumference have been shown to have a strong correlation with abdominal fat deposits (Zhou et al., 2014). The distribution of abdominal adipose tissue (central obesity) in adults is associated with a component of the metabolic syndrome (Rodea-Montero, et al., 2014). A study on adult subjects has shown that people who have the same waist circumference but are shorter in height have a greater risk of developing metabolic syndrome than taller people (Zhou et al., 2014). Therefore, WHtR can be used as a simple and effective anthropometric index to identify the metabolic risk associated with obesity (Rodea-Montero, et al., 2014).

The Waist-To-Hip Ratio (WHR) is a measurement that may indicate central obesity (Karimah, 2018). The higher the WHR value, the higher the risk level for several metabolic diseases. The Waist-To-Hip Ratio is calculated by dividing the measurement of the waist circumference by the circumference of the hip. The cutoff points for WHR are  $\geq 1.0$  for men and  $\geq 0.85$  for women (Rokhmah *et al.*, 2015). Individuals with a high waist and hip circumference will also have a higher distribution of fat in their abdominal area. Irregular fats distribution in the abdominal area indirectly causes higher triglyceride levels circulating in the blood, which will affect blood pressure (Sumardiyono *et al.*, 2018). WHR measurement is more sensitive in assessing the distribution of fat in the body, especially in the abdomen. This measurement is three times better than BMI in reflecting the presence of harmful fats in the abdomen. Measurement of waist circumference is performed by determining the lower part of arcus costae and crista iliaca (Sri Rahayu and Maulina, 2017).

Body Mass Index (BMI) is a practical and easy measurement to perform, but it cannot distinguish between fat mass, bone mass and muscle mass. BMI is calculated as body weight (kg)/height squared ( $m^2$ ) (Okura *et al.*, 2018). BMI can be used as the first measurement before any other anthropometric measurements.

Sagittal Abdominal Diameter (SAD) or the height of the abdomen while the subjects are in a lying position. This anthropometric measurement has not been widely used to measure fat tissue in the abdominal area. SAD measurements using computed tomography or magnetic resonance imaging, and are associated with components of metabolic syndrome. The measurements of SAD are taken when the subject is lying down on the examination table with a naked upper body. SAD is related to central obesity in individuals with obesity and normal nutritional status. Furthermore, SAD is associated with diabetes mellitus and a predictor of cardiovascular disease incidence, even when SAD is measured in a standing position (Pajunen et al., 2013). Based on the abovementioned problems, our study aimed to analyze the anthropometric indicators related to metabolic syndrome in female college students.

# 2. Materials and methods

# 2.1 Design, location, and time

A cross-sectional study design and this research was conducted from March to July 2020. Anthropometric and biochemical data were collected at the Cito Laboratory, Banyumanik Semarang with health protocols applied. This study was approved by the Medical/Health Research Bioethics Commission, Faculty of Medicine, Sultan Agung Islamic University Semarang with Number No.296 /IX /2020 /Bioethical Commission.

# 2.2 Samplings

This study was conducted during the SARS-CoV-2 outbreak, which later was named COVID-19 by the WHO, hence the registration for study participants was done online. Purposive sampling was used in this study and the total number of subjects required was 163. Samples are selected based on inclusion criteria, such as voluntary to be research subjects, female college students in Semarang City, aged 19-24 years in Semarang, not consuming alcohol, not smoking, and voluntary to follow a series of study instructions. Exclusion criteria are subjects who withdraw and those who are ill during the research study. Based on the exclusion criteria mentioned, no subjects are included in the exclusion criteria. Subjects were asked to fill in personal data using a Google Form, and eligible subjects will be contacted by the researchers to plan a direct meeting.

The health protocol applied during the anthropometric and biochemical data collection process, consisted of the subject filling out a COVID-19 signs and symptoms screening questionnaire, the subject was checked for temperature, the subject washed hands before entering the room, the distance between subjects was at least 1 meter, the subject and researcher used a mask and face shield. Researchers used gloves and protective clothing. During the study, hand sanitisers were provided, and anthropometric tools that were on the subject's skin were wiped with alcohol.

# 2.3 Data collected

The independent variables in this study were the Waist-to-Height Ratio (WHtR), Waist-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference. Weight and height data were obtained through direct measurements using a digital stamp scale GEA brand with an accuracy of 0.1 kg and microtoise with an accuracy of 0.1 cm. Waist circumference and hip circumference were measured using a measuring tape (Medline) to the nearest 1 mm and abdominal height was measured using the Abawerk Schaffenburg abdominal calliper to the nearest 1 mm. SAD measurements were performed with the subject in a supine position on a flat surface with both knees forming an angle of 90° (Firouzi et al., 2018). Anthropometric data were collected by trained enumerators.

The cut-off point used in this study refers to previous studies because it had been adjusted for the Asian race (Rose *et al.*, 2020). Each anthropometric measurement is stated as "at-risk" if the individuals have  $\geq 0.50$  for WHtR (Zhang *et al.*, 2016),  $\geq 0.85$  for WHR (Rokhmah *et al.*, 2015), >19.3 cm for Sagital Abdominal Diameter (SAD) (Dieny *et al.*, 2020), and have the normal to overweight BMI (18.5 - 25 kg/m<sup>2</sup>) or obese BMI ( $\geq$ 25.0 kg/m<sup>2</sup>) (Susetyowati, 2016).

The dependent variable in this study is the metabolic

syndrome component that has been converted into a metabolic syndrome score (cMetS) with the cut-off point of cMetS >2.21 (Rose et al., 2020). The guidelines for metabolic syndrome in this study are taken from the Cholesterol Education Program-Adult National Treatment Panel (NCEP-ATP III) 2005 which has been frequently used in Indonesia. There are 5 parameters to assess metabolic syndrome: (1) fasting blood glucose levels  $\geq 110 \text{ mg/dL}$ , (2) triglyceride levels  $\geq 150 \text{ mg/dL}$ (3) HDL cholesterol levels<50 mg/dL, (4) central obesity in women with waist circumference  $\geq 80$  cm, and (5) systolic and diastolic blood pressures ≥130 mmHg and  $\geq$ 85 mmHg, respectively (Soewondo *et al.*, 2010). The calculation of the metabolic syndrome score (cMetS) was done in the following steps: (1) after measuring all parameters of the metabolic syndrome, standardisation was carried out to obtain a Z-score; (2) the blood pressure must be converted into Mean Arterial Blood (MAP) by dividing the difference between systolic and diastolic blood pressure by three and summed with the diastolic blood pressure; (3) the HDL cholesterol standardization results were multiplied by (-1) because the parameter was inversely related to the risk of metabolic syndrome; (4) All Z-scores were added to obtain the cMetS values; (5) The final step was to compare the cMetS values with the cut-off point of  $\geq 2,21$ (Eisenmann et al., 2010; Okosun, Boltri, Lyn et al., 2010; Rose et al., 2020). The subjects were instructed to do fasting for at least 8 hrs, only drinking water was

Other than the cMetS score, metabolic syndrome risk can also be assessed from the classification of metabolic types. This classification combines the internal and external signs of the body such as biochemical parameters, the ratio of subcutaneous fat to abdominal fat, and blood pressure (Prybyla, 2020). The main phenotypes that reflect the possible combination of metabolic profile and the degree of obesity are metabolic healthy obese weight, metabolic healthy normal weight, metabolic unhealthy normal weight, and metabolic unhealthy normal weight.

# 2.4 Data analysis

permitted.

All data were analyzed using computer programs and statistical analyses were performed using SPSS statistical software version 22. Univariate analysis was used to describe subjects characteristics. The normality test of the data using the Kolmogorov-Smirnov test was carried out before testing the hypothesis. The relationship of anthropometric indicators with metabolic profile (Blood Pressure, Triglycerides, Blood Sugar, HDL and metabolic syndrome scores) was determined using the Person correlation test. Furthermore, Anthropometric

3

indicators that are most related to the metabolic component and metabolic syndrome score were analyzed using the Multiple Linear Regression test.

# 3. Results and discussion

The subject characteristics measured in female students aged 19-24 years include age, anthropometric indicators, and metabolic syndromes. Table 1 shows the characteristics of the study subjects. The mean WHtR value in this study was 0.51. Meanwhile, the mean WHR was 0.80; the mean BMI was 24.04 kg/m<sup>2</sup>; the mean SAD was 16.79 cm, and the mean waist circumference was 79.44 cm.

Table 2 shows the various nutritional status of the subjects based on BMI. It was found that 43.6% of the subjects had normal BMI, 17.2% were overweight and 35.6% were obese. Based on the WHtR anthropometric indicator, 72.4% of subjects were at risk of having obesity, based on WHR, 22.1% had central obesity, based on BMI, 35.6% were obese, based on SAD 12.3% of the subjects were at risk, and based on waist circumference 55.2% had central obesity. According to the metabolic profile that was assessed, 16.6% had high Blood Glucose Fasting levels, 8.6% had hypertriglycerides, 17.2% had low HDL, and 16.6% had high systolic blood pressure, and 21.5% had high diastolic blood pressure. In addition, we found that 33.1% of the subjects had high metabolic syndrome (cMetS) scores. This proportion was similar to the assessment based on the metabolic type of unhealthy subjects (subjects who had  $\geq 3$  risk factors of the metabolic profile), which was 33.7%. Moreover, two subjects had five risk factors: abdominal obesity, hypertension, hyperglycemia, hypertriglycerides, and low HDL.

The objective of this study was to determine the

anthropometric indicators associated with metabolic syndromes in female students. The study included 163 female students aged 19-24 years. The students are in their late adolescents who begin to have an independent life. Inappropriate and unhealthy eating behaviour will have an impact on the student's nutritional status. Excessive nutritional status and obesity will affect student's body metabolism. Based on the study results, 33.1% of the subjects had a high metabolic syndrome (cMetS) score. In line with the previous study conducted in 2019 on 18-to-21-year-old students at Universitas Diponegoro, 20% of the subjects had high cMetS (Rose et al., 2020). Meanwhile, a study conducted by Pratiwi et al in 2017 using secondary data from the National Basic Health Research 2013 found that 19.98% of adolescents aged 15-24 years had high cMetS (Pratiwi, et al., 2017). To conclude, there is a trend of Metabolic Syndrome Score (cMetS) among young women in Semarang.

The assessment of metabolic syndrome using a continuous type (scoring) rather than using a dichotomy or binary ("yes" and "no") is recommended (Christijani, 2019). An adolescent can be diagnosed with metabolic syndrome if their Metabolic Syndrome Score (cMetS) >2.21 (Pratiwi, *et al.*, 2017). Anthropometric indicators used in this study are Waist and Height Ratio (WHR), Waist-to-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and Waist Circumference. Based on the correlation analyses, all anthropometric indicators have a significant positive relationship with the Metabolic Syndrome Score (cMetS). Furthermore, the multivariate analyses show that the anthropometric indicators of BMI and WHR are strongly associated with cMetS.

If the metabolic type is considered based on nutritional status (subjects with non-obese BMI (<25kg/ $m^2$ ) with metabolic healthy and metabolic unhealthy and

, , , , , ,				
Variable	Minimum	Maximum	Mean	SD
Anthropometric Indicators				
WHtR (ratio)	0.37	0.71	0.51	0.07
WHR (ratio)	0.67	0.96	0.80	0.06
BMI (kg/m <sup>2</sup> )	15.81	39.30	24.04	4.72
Sagital Abdominal Diameter (cm)	11.35	25.50	16.79	2.42
Hip Circumference (cm)	80.60	138.45	98.96	9.30
Waist Circumference (cm)	58.00	112.10	79.44	10.78
Metabolic Profiles				
Blood Glucose Levels (mg/dL)	66.00	110.00	92.00	7.59
Trygliceride Levels (mg/dL)	29.00	309.00	88.35	44.68
Cholesterol HDL Levels (mg/dL)	36.00	109.00	61.73	26.43
Systolic Blood Pressure (mmHg)	84.00	144.00	114.63	11.13
Diastolic Blood Pressure (mmHg)	55.00	178.00	82.40	55.52
cMetS (Score of Metabolic Syndrome)	-7.10	11.93	0.01	2.90

Table 1. Minimum, maximum, average and standard deviation

4

Table 2. Anthropometric overview and components of metabolic syndrome

metabolic syndrome		
Characteristics	n	%
Anthropometric		
Body Mass Index (BMI)		
Underweight ( $< 18.5 \text{ kg/m}^2$ )	6	3.7
Normal $(18.5 - 22.9 \text{ kg/m}^2)$	71	43.6
Overweight $(23-24.9 \text{ kg/m}^2)$	28	17.2
Obese ( $\geq 25.0 \text{ kg/m}^2$ )	58	35.6
Waist Height Ratio (WHtR)		
Normal (<0.50)	45	27.6
At Risk (≥0.50)	118	72.4
Waist Hip Ratio		
Normal (<0.85)	127	77.9
Central Obesity (≥0.85)	36	22.1
Sagital Abdominal Diameter (SAD)		
Normal ( $\leq 19.3$ cm)	143	87.7
At Risk (>19.3 cm)	20	12.3
Waist Circumference		
Normal (<80 cm)	73	44.8
Obese (≤80 cm)	90	55.2
Metabolic Profiles		
Blood Glucose Levels		
Normal (<110 mg/dL)	136	83.4
High ( $\geq 110 \text{ mg/dL}$ )	27	16.6
Triglycerides		
Normal (<150 mg/dL)	149	914.0
High ( $\geq 150 \text{ mg/dL}$ )	14	8.6
Cholesterol HDL		
Normal ( $\geq 150 \text{ mg/dL}$ )	135	82.8
Low (<150 mg/dL)	28	17.2
Sistolic Blood Pressure		
Normal (<130 mg/dL)	136	83.4
High (≥130 mg/dL)	27	16.6
Diastolic Blood Pressure		
Normal (<85 mg/dL)	128	78.5
High ( $\geq 85 \text{ mg/dL}$ )	35	21.5
cMetS (Score of Metabolic Syndrome)		
Normal (<2.21)	109	66.9
At Risk (≥2.21)	54	33.1
Metabolic Types		
Metabolic Unhealthy Normal Weight	17	10.4
(MUNW)	1/	10.4
Metabolic Healthy Normal Weight	88	54.0
(MHNW) Metabolic Unhealthy Obese Weight		
(MUOW)	38	23.3
Metabolic Healthy Obese Weight (MHOW)	20	12.3
	-	

subjects with obese BMI (>25kg/m<sup>2</sup>) with metabolic and metabolic unhealthy), healthy subjects are categorized as metabolic unhealthy (experiencing metabolic syndrome) if they fulfil  $\geq 3$  risk factors including high waist circumference, blood pressure, fasting blood glucose and triglyceride levels, and low

HDL levels. Based on these criteria, it was found that 10.4% of the subjects had a metabolic unhealthy normal weight (MUNW) and 23.3% of the subjects had metabolic unhealthy obesity weight (MUOW). Of nonobese subjects, 54% of them were metabolic healthy. Our study also shows that 10.4% of the subjects were classified as metabolic unhealthy normal weight (MUNW). The subjects' BMI in this category is in the normal range but has a high percentage of body fat that makes them at high risk of developing metabolic disorders (Eckel et al., 2015; Suliga et al., 2015). Several recent cohort studies have shown a greater risk of type II diabetes mellitus in individuals with MUNW compared to individuals with MHNW (Ärnlöv et al., 2011; Hadaegh et al., 2011; Aung et al., 2014; Jung et al., 2014; Hinnouho et al., 2015). Other studies have shown that women with the MUNW type have a long-term impact of an increased risk of cardiovascular diseases such as higher blood pressure, triglyceride and glucose levels as well as lower levels of adiponectin, HDL, and LDL compared to women with the MHNW type (Kim et al., 2013).

In this study, 23.3% of the subjects belonged to the Metabolic Unhealthy Obese Weight (MUOW) type. Subjects with this metabolic type have an obese BMI and have a high risk of developing metabolic disorders. A study conducted in Japan on 29,564 subjects showed that individuals with MUOW had a greater risk of developing type II diabetes mellitus compared to individuals with MHOW (Heianza et al., 2015).

It was also found that 12.3% of the subjects were categorized as metabolic healthy obese weight (MHOW). Individuals in this metabolic type have an obese BMI but do not show any metabolic risks. Given the impact of obesity in relation to the risk of metabolic diseases, various studies have been conducted to examine the long-term effects of MHOW. Individuals with MHOW had a different fat distribution pattern (less ectopic and visceral fat), and lower inflammatory markers (Samocha-Bonet et al., 2014). Other studies also have shown that women with MHOW had lower blood pressure, triglyceride levels, and glucose levels, but higher levels of HDL, adiponectin, and LDL compared to women with MUNW (Kim et al., 2013). This condition was associated with good diet quality in individuals with MHOW. Based on National Health and Nutrition Examination Surveys (NHANES) data, Camhi et al. (2015) examined the quality of diet in obese subjects and found that adolescents and adult women with the MHOW metabolic type had higher diet quality scores due to high intake of fruit, whole grains, meat, and nuts.

FULL PAPER

5

eISSN: 2550-2166

Table 3 and Table 4 show the results of statistical

Table 3. The relationship between anthropometric indicators and metabolic profiles (blood pressure, triglycerides, blood sugar, HDL and metabolic syndrome scores)

Variable -	Systolic BP		Diastolic BP		TG		Blood Glucose		HDL		cN	letS
v artable	r	р	r	р	r	р	r	р	r	р	r	р
WHtR	0.358	< 0.001 <sup>s</sup>	0.306	< 0.001 <sup>s</sup>	0.289	< 0.001 <sup>s</sup>	0.210	$0.007^{s}$	-0.266	0.001 <sup>s</sup>	0.599	< 0.001 <sup>s</sup>
BMI	0.370	< 0.001 <sup>s</sup>	0.313	< 0.001 <sup>s</sup>	0.315	< 0.001 <sup>s</sup>	0.221	$0.005^{s}$	-0.292	< 0.001 <sup>s</sup>	0.600	< 0.001 <sup>s</sup>
SAD	0.352	< 0.001 <sup>s</sup>	0.284	< 0.001 <sup>s</sup>	0.278	< 0.001 <sup>s</sup>	0.191	0.015 <sup>s</sup>	-0.264	0.001 <sup>s</sup>	0.575	< 0.001 <sup>s</sup>
WC	0.377	< 0.001 <sup>s</sup>	0.284	< 0.001 <sup>s</sup>	0.295	< 0.001 <sup>s</sup>	0.212	$0.005^{s}$	-0.243	$0.002^{s}$	0.616	< 0.001 <sup>s</sup>
HC	0.369	< 0.001 <sup>s</sup>	0.332	< 0.001 <sup>s</sup>	0.302	< 0.001 <sup>s</sup>	0.179	$0.002^{s}$	-0.273	< 0.001 <sup>s</sup>	0.581	< 0.001 <sup>s</sup>
WHR	0.244	$0.002^{s}$	0.128	0.104	0.194	0.013 <sup>s</sup>	0.172	$0.028^{s}$	-0.149	$0.048^{s}$	0.415	< 0.001 <sup>s</sup>

<sup>s</sup>Significant, p-value<0.05 indicates there is a significant relationship

Table 4. Anthropometric indicators most associated with metabolic components and metabolic syndrome scores

Variable	Systolic BP				
variable	Constant	USC <sup>a</sup>	p1 <sup>b</sup>	p2°	<sup>d</sup> Adjusted R <sup>2</sup>
BMI	91.759	0.951	< 0.001	< 0.001	0.158
	Blood Glucose I	evels			
	Constant	USC <sup>a</sup>	p1 <sup>b</sup>	p2°	Adjusted R <sup>2</sup>
BMI	83.454	0.355	0.005	< 0.001	0.043
	HDL				
	Constant	USC <sup>a</sup>	p1 <sup>b</sup>	p2°	Adjusted R <sup>2</sup>
BMI	81.429	-0.819	< 0.001	< 0.001	0.08
	Triglycerides				
	Constant	USC <sup>a</sup>	p1 <sup>b</sup>	p2°	Adjusted R <sup>2</sup>
WC	-6.614	1.195	< 0.001	< 0.001	0.078
	Score of Metabo	lic Syndrome			
	Constant	USC <sup>a</sup>	p1 <sup>b</sup>	p2°	Adjusted R <sup>2</sup>
WC	-13.163	0.166	< 0.001	< 0.001	0.375
-		L .		L	

<sup>a</sup>Unstandardized Coefficient, <sup>b</sup> p-value, <sup>c</sup> p F-Test (ANOVA), <sup>d</sup> coefficient of determination

on anthropometric indicators related to analyses metabolic syndromes. Table 3 shows the bivariate statistical analysis using the Pearson correlation test. The analysis results showed that all anthropometric indicators, namely WHtR, BMI, SAD, waist circumference, hip circumference and WHR have a strong positive relationship with the metabolic syndrome score (p<0.001), which means that the higher the anthropometric value, the higher the metabolic syndrome score. In addition, the analysis of the relationship between anthropometric indicators and each metabolic profile revealed that almost all of the independent variables (WHtR, waist and hip circumference, WHR, BMI, and SAD) were associated with each metabolic profile, such as baseline systolic pressure, diastolic blood pressure, triglyceride levels, blood sugar levels, and HDL. Only WHR was not associated with diastolic blood pressure (p>0.005).

Table 4 shows the results of the analysis using multiple linear regression to determine anthropometric indicators that are most associated with each metabolic profile and metabolic syndrome score. The results showed that BMI was the anthropometric indicator that is most associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood sugar (p<0.05), and HDL (p<0.001). In addition, waist circumference

was the anthropometric indicator that is most associated with triglycerides and metabolic syndrome score (p<0.001). Based on the Adjusted R<sup>2</sup> value on the metabolic syndrome score, we found that 37.5% of the metabolic syndrome score was related to anthropometric indicators, such as WHtR, waist and hip circumference, WHR, BMI, and SAD. The rest may be influenced by other variables that are not included in this study.

The correlation test results indicated that all anthropometric indicators had a positive relationship with the metabolic syndrome scores with p<0.001. Meanwhile, the regression analyses show that BMI and WHR were inversely related to cMetS. This is in line with research that reported an increase in the WHR value could be associated with the risk of metabolic syndrome in children and adolescents in Florida (Moore et al., 2015). Another study revealed that there was a strong relationship between overweight and obese adolescents with metabolic syndrome (Al-Bachir and Bakir, 2017). Furthermore, a study on adolescents in South Africa found that central obesity as measured by the hip circumference could lead to an increased risk of cardiovascular diseases and death. Therefore, hip circumference and waist circumference can be used to predict the risk of cardiovascular diseases and death in the future (Cameron et al., 2012).

FULL PAPER

6

Body Mass Index (BMI) is the most widely used indicator of measurement in epidemiological studies and is used as a substitute for evaluating body composition. However, BMI cannot distinguish fat from fat mass and lean mass, and it fails to show the presence of adipose and body fat distribution (Ofer et al., 2019; Leone et al., 2020). However, the BMI cut-offs for metabolic syndrome have not yet been determined (Ofer et al., 2019). Obesity in adolescents is generally assessed using a BMI of  $\geq 25.0$  kg/m<sup>2</sup>. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m<sup>2</sup>) and obesity ( $\geq 25.0$  kg/m<sup>2</sup>), and we found that 35.6% of the subjects were obese. The finding is in line with the research on the subject of students at Universitas Diponegoro aged 18-21 years. They found that 40% of their study population had obesity level I and 36.3% had obesity level II (Rose et al., 2020).

Abdominal obesity is often assessed to determine a metabolic syndrome in people. One of the indicators used to measure abdominal obesity is the Waist-to-Hip Ratio (WHR) which is calculated by dividing the waist circumference and the hip circumference. Measurement of waist circumference is more sensitive in assessing the distribution of body fat in the abdominal wall, which is also a component of metabolic syndrome. The limit of the WHR value for a female is  $\geq 0.85$  (Rokhmah, *et al.*, 2015). This study shows that every 1% increase in the WHR value will increase the cMetS value by 10.411. Hip circumference is also an indicator that has a strong correlation with cMetS, but many studies have used it as a ratio along with waist circumference for assessing a person's central obesity status.

# 4. Conclusion

Metabolic syndrome in female students can be identified using anthropometric measurements, one of which is BMI and WHR which are very easy to measure and efficient. BMI and WHR have the strongest relationship and can be used to detect early risk of metabolic syndrome in female college students.

# **Conflict of interest**

The authors declare no conflict of interest.

# Acknowledgements \_\_\_\_

The authors would nike to thank all the subjects who participated in this study. We would also like to express our gratitude to The Ministry of Research, Technology and Higher Education, Indonesia" which was funded by the "Hibah Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) 2019.

# References

- Al-Bachir, M. and Bakir, M.A. (2017). Predictive value of body mass index to metabolic syndrome risk factors in Syrian adolescents. *Journal of Medical Case Reports*, 11, 170. https://doi.org/10.1186/ s13256-017-1315-2
- Ärnlöv, J., Sundström, J., Ingelsson, E. and Lind, L. (2011). Impact of BMI and the metabolic syndrome on the risk of diabetes in middle-aged men. *Diabetes Care*, 34(1), 61–65. https://doi.org/10.2337/dc10-0955
- Aung, K.K., Lorenzo, C., Hinojosa, M.A. and Haffner, S.M. (2014). Risk of developing diabetes and cardiovascular disease in metabolically unhealthy normal-weight and metabolically healthy obese individuals. *Journal of Clinical Endocrinology and Metabolism*, 99(2), 462–468. https://doi.org/10.1210/ jc.2013-2832
- Badan Penelitian dan Pengembangan Kesehatan. (2018). Riset Kesehatan Dasar (RISKESDAS) 2018. Jakarta, Indonesia: Badan Penelitian dan Pengembangan Kesehatan.
- Cameron, A.J., Magliano, D.J., Shaw, J.E., Zimmet, P.Z., Carstensen, B., Alberti, K.G.M.M., Tuomilehto, J., Barr, E.L.M., Pauvaday, V.K., Kowlessur, S. and Söderberg, S. (2012). The influence of hip circumference on the relationship between abdominal obesity and mortality. International Journal of Epidemiology, 41(2), 484– 494. https://doi.org/10.1093/ije/dyr198
- Camhi, S.M., Whitney Evans, E., Hayman, L.L., Lichtenstein, A.H. and Must, A. (2015). Healthy eating index and metabolically healthy obesity in U.S. adolescents and adults. *Preventive Medicine*, 77, 23–27. https://doi.org/10.1016/ j.ypmed.2015.04.023
- Christijani, R. (2019). Determination of Diagnosis of Metabolic Syndrome based on Assessment of Metabolic Syndrome and NCEP ATP-III Score in Adolescent. *The Journal of Nutrition and Food Research*, 42(1), 21–28. https://doi.org/10.22435/ pgm.v42i1.2418
- Devi, R., Manhas, S., Prasad, S., Sharma, S., Bhaskar, N. and Mahajan, S. (2017). Short Review of Metabolic Syndrome. *International Journal of Research and Review*, 4(2), 29-36.
- Dieny, F.F., Setyaningsih, R.F., Fitranti, D.Y., Jauharany, F.F., Putra, Y.D. and Tsani, A.F.A. (2020). Abdominal diameter profiles have relationship with insulin resistance in obese female adolescents. *Electronic Journal of General Medicine*, 17(5), em219. https://doi.org/10.29333/

8

**ULL PAPER** 

- Eckel, N., Mühlenbruch, K., Meidtner, K., Boeing, H., Stefan. N. and Schulze, M.B. (2015).Characterization of metabolically unhealthy normalweight individuals: Risk factors and their associations with type 2 diabetes. Metabolism: Clinical and Experimental, 64(8), 862-871. https:// doi.org/10.1016/j.metabol.2015.03.009
- Eisenmann, J.C., Laurson, K.R., Dubose, K.D., Smith, B.K. and Donnelly, J.E. (2010). Construct validity of a continuous metabolic syndrome score in children. *Diabetology and Metabolic Syndrome*, 2, 8. https:// doi.org/10.1186/1758-5996-2-8
- Firouzi, S.A., Tucker, L.A., LeCheminant, J.D. and Bailey, B.W. (2018). Sagittal abdominal diameter, waist circumference, and BMI as predictors of multiple measures of glucose metabolism: An NHANES investigation of US adults. *Journal of Diabetes Research*, 2018, 3604108. https:// doi.org/10.1155/2018/3604108
- Hadaegh, F., Bozorgmanesh, M., Safarkhani, M., Khalili, D. and Azizi, F. (2011). Predictability of body mass index for diabetes: Affected by the presence of metabolic syndrome? *BMC Public Health*, 11(1), 383. https://doi.org/10.1186/1471-2458-11-383
- Heianza, Y., Kato, K., Kodama, S., Ohara, N., Suzuki, A., Tanaka, S., Hanyu, O., Sato, K. and Sone, H. (2015). Risk of the development of Type 2 diabetes in relation to overall obesity, abdominal obesity and the clustering of metabolic abnormalities in Japanese individuals: Does metabolically healthy overweight really exist? The Niigata Wellness Study. *Diabetic Medicine*, 32(5), 665–672. https://doi.org/10.1111/ dme.12646
- Herningtyas, E.H. and Ng, T.S. (2019). Prevalence and distribution of metabolic syndrome and its components among provinces and ethnic groups in Indonesia. *BMC Public Health*, 19, 377. https:// doi.org/10.1186/s12889-019-6711-7
- Hinnouho, G.M., Czernichow, S., Dugravot, A., Nabi, H., Brunner, E.J., Kivimaki, M. and Singh-Manoux, A. (2015). Metabolically healthy obesity and the risk of cardiovascular disease and type 2 diabetes: The Whitehall II cohort study. *European Heart Journal*, 36(9), 551–559. https://doi.org/10.1093/eurheartj/ehu123
- Jung, H.S., Chang, Y., Eun, Y.K., Kim, C.W., Choi, E.S., Kwon, M.J., Cho, J., Zhang, Y., Rampal, S., Zhao, D., Soo, K.H., Shin, H., Guallar, E. and Ryu, S. (2014). Impact of body mass index, metabolic health and weight change on incident diabetes in a Korean population. *Obesity*, 22(8), 1880–1887. https://doi.org/10.1002/oby.20751

- Karimah, M. (2018). Waist-Hip Circumference Ratio as Strongest Factor Correlation with Blood Glucose Level. Jurnal Berkala Epidemiologi, 6, 219–226. https://doi.org/10.20473/jbe.V6I32018.219-226
- Kim, M., Paik, J.K., Kang, R., Kim, S.Y., Lee, S.H. and Lee, J.H. (2013). Increased oxidative stress in normal-weight postmenopausal women with metabolic syndrome compared with metabolically healthy overweight/obese individuals. *Metabolism: Clinical and Experimental*, 62(4), 554–560. https:// doi.org/10.1016/j.metabol.2012.10.006
- Leone, A., Vizzuso, S., Brambilla, P., Mameli, C., Ravella, S., De Amicis, R., Battezzati, A., Zuccotti, G., Bertoli, S. and Verduci, E. (2020). Evaluation of different adiposity indices and association with metabolic syndrome risk in obese children: Is there a winner? *International Journal of Molecular Sciences*, 21(11), 4083. https://doi.org/10.3390/ ijms21114083
- Li, Y., Zhao, L., Yu, D., Wang, Z. and Ding, G. (2018). Metabolic syndrome prevalence and its risk factors among adults in China: A nationally representative cross-sectional study. *Plos One*, 13(6), e0199293. https://doi.org/10.1371/journal.pone.0199293
- Moore, L.M., Fals, A.M., Jannelle, P.J., Green, J.F., Pepe, J. and Richard, T. (2015). Analysis of Pediatric Waist to Hip Ratio Relationship to Metabolic Syndrome Markers. *Journal of Pediatric Health Care*, 29(4), 319–324. https://doi.org/10.1016/ j.pedhc.2014.12.003
- Ofer, K., Leiba, R., Avizohar, O. and Karban, A. (2019). Normal body mass index (BMI) can rule out metabolic syndrome: An Israeli cohort study. *Medicine*, 98(9), e14712. https://doi.org/10.1097/ MD.0000000000014712
- Okosun, I.S., Boltri, J.M., Lyn, R. and Smith, M.D. (2010). Continuous metabolic syndrome risk score, body mass index percentile, and leisure time physical activity in American children. *Journal of Clinical Hypertension*, 12(8), 636–644. https://doi.org/10.1111/j.1751-7176.2010.00338.x
- Okosun, I.S., Lyn, R., Smith, D.M., Eriksen, M. and Seale, P. (2010). Validity of a Continuous Metabolic Risk Score as an Index for Modeling Metabolic Syndrome in Adolescents. *Annals of Epidemiology*, 20(11), 843–851. https://doi.org/10.1016/ j.annepidem.2010.08.001
- Okura, T., Nakamura, R., Fujioka, Y., Kitao, S.K., Ito, Y., Matsumoto, K., Shoji, K., Sumi, K., Matsuzawa, K., Izawa, S., Ueta, W., Kato, M., Imamura, T., Taniquchi, I. and Yamamoto, K. (2018). Body mass index ≥23 is a risk factor for insulin resistance and diabetes in Japanese people: A brief report. *Plos*

*One*, 13(7), e0201052. https://doi.org/10.1371/ journal.pone.0201052

- Pajunen, P., Rissanen, H., Laaksonen, M.A., Heliövaara, M., Reunanen, A. and Knekt, P. (2013). Sagittal abdominal diameter as a new predictor for incident diabetes. *Diabetes Care*, 36(2), 283–288. https:// doi.org/10.2337/dc11-2451
- Pratiwi, Z.A., Hasanbasri, M. and Huriyati, E. (2017). Determination of cutoff points for metabolic syndrome scores in Indonesian adolescents and of the diagnostic validity assessment of anthropometric parameters. Jurnal Gizi Klinik Indonesia, 14(2), 80. https://doi.org/10.22146/ ijcn.25590
- Prybyla, O. (2020). Metabolic phenotyping: is it so important? *Journal of Cognitive Neuropsychology*, 4 (1), 1-3.
- Rodea-Montero, E.R., Evia-Viscarra, M.L. and Apolinar-Jiménez, E. (2014). Waist-to-height ratio is a better anthropometric index than waist circumference and BMI in predicting metabolic syndrome among obese mexican adolescents. *International Journal of Endocrinology*, 2014, 195407. https:// doi.org/10.1155/2014/195407
- Rokhmah, F.D., Handayani, D. and Al-Rasyid, H. (2015). Correlation between waist circumference (WC) and waist-hip ratio (WHR) with plasma glucose levels using oral glucose tolerance test method. *Jurnal Gizi Klinik Indonesia*, 12(1), 28–35. https://doi.org/10.22146/ijcn.22425
- Rose, S., Dieny, F.F., Nuryanto, N. and Tsani, A.F.A. (2020). The correlation between waist-to-height ratio (wHtR) and second to fourth digit ratio (2D:4D) with an increase in metabolic syndrome scores in obese adolescent girls. *Electronic Journal of General Medicine*, 17(3), em211. https://doi.org/10.29333/ ejgm/7872
- Samocha-Bonet, D., Dixit, V.D., Kahn, C.R., Leibel, R.L., Lin, X., Nieuwdorp, M., Pietiläinen, K.H., Rabasa-Lhoret, R., Roden, M., Scherer, P.E., Klein, S. and Ravussin, E. (2014). Metabolically healthy and unhealthy obese - The 2013 stock conference report. *Obesity Reviews*, 15(9), 697–708. https:// doi.org/10.1111/obr.12199
- Soewondo, P., Purnamasari, D., Oemardi, M., Waspadji, S. and Soegondo, S. (2010). Prevalence of Metabolic Syndrome Using NCEP/ATP III Criteria in Jakarta, Indonesia: The Jakarta Primary Non-communicable Disease Risk Factors Surveillance 2006. Acta Medica Indonesiana - The International Journal of Medicine, 42(4), 199–203.
- Sri Rahayu, M. and Maulina, M. (2017). The relationship

between hip and waist circumference ratio with the incidence of coronary heart disease. *Jurnal Aceh Medika*, 1(1), 1–10.

- Srikanthan, K., Feyh, A., Visweshwar, H., Shapiro, J.I. and Sodhi, K. (2016). Systematic review of metabolic syndrome biomarkers: A panel for early detection, management, and risk stratification in the West Virginian population. *International Journal of Medical Sciences*, 13(1), 25–38. https:// doi.org/10.7150/ijms.13800
- Suliga, E., Kozieł, D., Cieśla, E. and Głuszek, S. (2015). Association between dietary patterns and metabolic syndrome in individuals with normal weight: A cross -sectional study. *Nutrition Journal*, 14(1), 55. https:// doi.org/10.1186/s12937-015-0045-9
- Sumardiyono, S., Pamungkasari, E.P., Mahendra, A.G., Utomo, O.S., Mahajana, D., Cahyadi, W.R. and Ulfia, M. (2018). Hubungan Lingkar Pinggang dan Lingkar Panggul dengan Tekanan Darah pada Pasien Program Pengelolaan Penyakit Kronis (Prolanis). *Smart Medical Journal*, 1(1), 26-31. https:// doi.org/10.13057/smj.v1i1.24504
- Susetyowati, S. (2016). Gizi Remaja, In Ilmu Gizi: Teori dan Aplikasi, p. 160–164. Jakarta, Indonesia: EGC
- Zhang, Y.X., Wang, Z.X., Chu, Z.H. and Zhao, J.S. (2016). Profiles of body mass index and the nutritional status among children and adolescents categorized by waist-to-height ratio cut-offs. *International Journal of Cardiology*, 223, 529–533. https://doi.org/10.1016/j.ijcard.2016.07.303
- Zhou, D., Yang, M., Yuan, Z. P., Zhang, D.D., Liang, L., Wang, C.L., Zhang, S., Zhu, H.H., Lai, M.D. and Zhu, Y.M. (2014). Waist-to-Height Ratio: A simple, effective and practical screening tool for childhood obesity and metabolic syndrome. *Preventive Medicine*, 67, 35–40. https://doi.org/10.1016/ j.ypmed.2014.06.025

q

# Article Published

	Food Research      foodresearch.my@outlook.com>     Min, 22 Mei 2022, 15.08       kepada saya +	☆	¢			
🛪 Inggris - > Indonesia - Terjemahkan pesan Nonaktifkan untuk: Ingg						
	Dear Dr Dieny					
3	Kindly be informed that your manuscript has been assigned to Food Research 2022, Vol. 6, Issue 3 (June). Your manuscript is currently available online and in pre	ss on	our			
1	website https://www.myfoodresearch.com. Alternatively, you can download a copy of the manuscript by clicking on the following link:					
-	https://doi.org/10.26656/fr.2017.6(3).250					
1	We encourage you to share your published work with your colleagues. Thank you for your fine contribution. We hope that you continue to submit other articles	to the	Jourr	na		
	Thanks & Regards,					
1	Dr Vivian New					
	Editor					
1						

Journal homepage: https://www.myfoodresearch.com

FOOD RESEARCH

# Anthropometry indicators that are most related to metabolic profiles in female college students

1.2.\*Dieny, F.F., <sup>1</sup>Rose S., <sup>1,2</sup>Tsani, A.F.A., <sup>1</sup>Jauharany, F.F. and <sup>1,2</sup>Fitranti, D.Y.

<sup>1</sup>Department of Nutrition Science, Faculty of Medicine, Universitas Diponegoro, Indonesia
<sup>2</sup>Center of Nutrition Research (CENURE), Faculty of Medicine, Universitas Diponegoro, Indonesia

Article history: Received: 2 June 2021 Received in revised form: 8 July 2021 Accepted: 27 September 2021 Available Online: 22 May 2022

Abstract

Keywords: Adolescent, Anthropometric indicator, Female, Metabolic profile, Metabolic syndrome

DOI: https://doi.org/10.26656/th.2017.6(2).250

Metabolic syndrome is not a disease but is a set of several disorders and causes an increased risk of cardiovascular disease and diabetes mellitus complications. Several studies have shown that non-invasive approaches such as anthropometric measurements can be used for the early detection of metabolic syndrome. This study aimed to analyse the anthropometric indicators related to metabolic syndrome in female college students. The design of this research was cross sectional, with the number of subjects involved were as many as 163 female college students aged 19 to 24 years old. Purposive sampling was used in the sampling of this research. The independent variables in this study were the Waist-to-Height Ratio (WHtR), Waist-Hip Ratio (WHR), Body Mass Index (BMI), Sagittal Abdominal Diameter (SAD), and hip circumference. The dependent variable in this study is the metabolic syndrome component that has been converted into a metabolic syndrome score (cMetS). The analysis results showed that all anthropometric indicators, namely WHtR, BMI, SAD, waist circumference, hip circumference and WHR have a strong positive relationship with the metabolic syndrome score (p<0.001). BMI was the anthropometric indicator that is most associated with the metabolic profiles, such as systolic blood pressure (p<0.001), blood sugar (p<0.05), and HDL (p<0.001). Waist circumference was the anthropometric indicator that is most associated with triglycerides and metabolic syndrome score (p<0.001). Metabolic syndrome in female college students can be identified using anthropometric measurements, one of which is BMI and WHR which are very easy to measure and efficient. BMI and WHR have the strongest relationship and can be used to detect early risk of metabolic syndrome in female college students.