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

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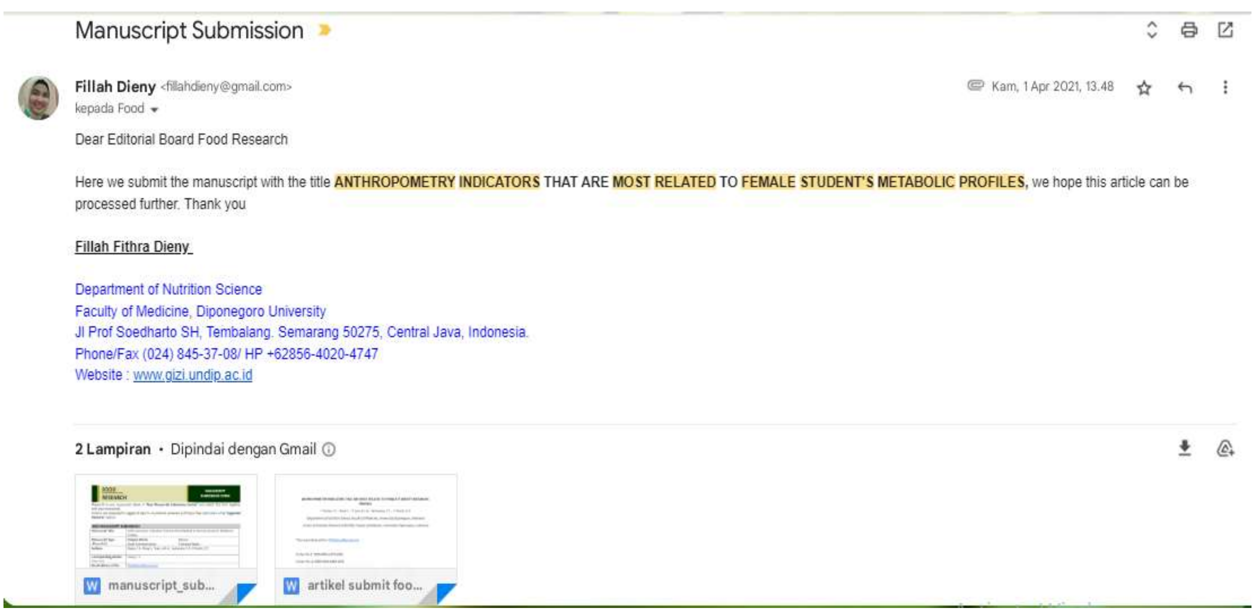
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Here we submit the manuscript with the title ANTHROPOMETRY INDICATORS THAT ARE MOST RELATED TO FEMALE STUDENT'S METABOLIC PROFILES, we hope this article can be processed further. Thank you

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ANTHROPOMETRY INDICATORS THAT ARE MOST RELATED TO FEMALE STUDENT'S METABOLIC PROFILES

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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 early detection of metabolic syndrome. This study aims to analyse the anthropometric indicators related to metabolic syndrome in female students. This cross-sectional study with a total of 163 female 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 (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

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

Abstract

The prevalence of obesity in adolescent girls is increasing each year. Several anthropometric measurements can be used to detect the incidence of insulin resistance. This study aims to observe the 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 between 18 and 21 years old, who have waist circumference >80 cm. They were chosen by a simple random sampling technique. Anthropometric profile data taken ~~was~~ has consisted of waist circumference, hip circumference, waist-hip circumference ratio (WHR), waist-to-height ratio (WHtR), neck circumference, ~~wrist~~ waist circumference, thigh circumference, and 2D:4D digit ratio. Insulin 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 experienced insulin resistance. High WHtR was found in 98.3% of total subjects as many as 90.8% of subjects were at risk based on WHR values. Based on 2D:4D ratio digits, neck circumference, wrist circumference <50% of subjects were found as at risk. There was no correlation between waist circumference, WHR, wrist circumference, 2D:4D digit ratio with HOMA-IR ($p>0.05$). However, there was a positive correlation between WHtR, neck circumference, and thigh circumference with HOMA-IR ($p<0.05$) Anthropometric profiles such as WHtR, neck circumference, and thigh circumference were ~~correlation~~ correlated of insulin resistance in female adolescent with obesity.

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

1. Introduction

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 influence their nutritional status (Brown et al., 2011). However, nutritional status problems in adolescents are still fairly high, including obesity. The Prevalence of central obesity 15 years adolescents and older has increased from 26.6% in 2013 to 31% in 2018 (Badan Penelitian dan Pengembangan Kesehatan, 2018). Obesity incidence will later be associated with degenerative diseases. Women ~~is~~ are at higher risk of suffering from degenerative disease, while Indonesian Basic Health Research 2018 results reports the prevalence of stroke, diabetes mellitus, heart disease, and hypertension is found higher in women than men (Badan Penelitian dan Pengembangan Kesehatan, 2018). Indonesian Basic Health Research 2018 results also ~~states~~ state that women and people live in urban areas of all ages have high prevalence of diabetes mellitus (Badan Penelitian dan 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

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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).

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 the indicator. 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. Some studies~~y~~ show correlation 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).

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) (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 a low digit ratio is associated with high testosterone levels in men, while a high digit ratio is associated with low testosterone levels in women (Kumar et al., 2016). The size of digit ratio occurs since the end of the first trimester of fetal development (Oyeyemi et al., 2014). Inappropriate exposure ~~of~~ to androgen hormone can cause Polycystic Ovary Syndrome (PCOS), causing infertility 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

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with obesity, which is a risk factor for metabolic disease (Gölge et al., 2016). There aren't many 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.

2. Materials and methods

2.1 *Design, location, and time*

This is an observational study and is 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 a 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.

2.3 Data collected

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).

WHR data was obtained from the waist circumference to hip circumference ratio. Measurement of pelvic circumference was done by medical measuring tape with 0.1 cm precision. The Pelvic circumference is measured by determining the widest points on the buttock (Fitriyanti, Tjahjono, et al., 2019). Subjects are categorized as risky when WHR was more than 0.85 (Saklayen, 2018).

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

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

Wrist circumference da ta ~~was~~ were measured using medical measuring tape with 0.1 cm precision. Its measurement was done by placing the medical measuring tape horizontally on the distal side of the ulna protrusion, around the wrist. Wrist circumference measurement results ~~was~~ 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 cm, subjects whose height more than 163 cm had wrist circumference less than 15.9 cm; moderate if subjects whose height less than 155 cm had wrist circumference 14-14.6 cm, subjects whose height 155-163 cm had wrist circumference 15.2-15.9 cm, subjects whose height more than 163 cm had wrist circumference 15.9-16.5 cm; large if subjects whose height less than 155 cm had wrist circumference more 14.6 cm, subjects whose height 155-163 cm had wrist circumference more than 15.9 cm, subjects had height more than 163 cm have wrist circumference more than 16.5 cm (Nabila et al., 2018).

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

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

Insulin resistance data was determined using HOMA-IR values. Measurement of Homeostasis Insulin Resistance Assessment Model (HOMA-IR) based on fasting blood glucose and fasting insulin 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.

2.4 Data analysis

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

~~3.~~ Results and ~~discussion~~

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

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

4. Discussion

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).

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

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

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

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

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

WHtR plays a role in measuring central obesity which is often associated with metabolic disorders. An ~~I~~increase in fat tissue will promote increase in adipokine secretion. This can increase insulin resistance. The most important adipokines is TNF-α which plays a role in inducing insulin resistance through glucose transporter 4 (GLUT-4) and increasing the release of free fatty acids. Increased transfer of free fatty acids to muscles results in increased intracellular fatty acid metabolites such as diacylglycerol, ceramide, and acetyl-CoA. These metabolites will activate the serine pathway or threonine kinase that reduces the ability to activate insulin receptors. Hence, it can cause insulin resistance when occurs in the long term~~as~~ it can damage visceral adipocyte β cells (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 the 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~~ another study in Korea explains that the measurement of thigh circumference is an indicator of diabetes marker (Jung et al., 2013). The ~~S~~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

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

Based on the study analysis, no correlation is found between neither waist circumference nor waist-hip circumference ratio with insulin resistance. This finding is contradictory to a study conducted on adolescents in Korea which shows the results that waist circumference and waist-hip circumference ratio have a significant correlation to HOMA-IR (Lim et al., 2015). Waist circumference and waist-hip circumference ratio can be used as a screening tool to detect the incidence of abdominal obesity which can cause metabolic disorders such as insulin resistance (Fitriyanti, Sulchan, et al., 2019).b

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

Wrist circumference is a strong predictor of diabetes (Jahangiri Noudeh et al., 2013). Wrist circumference is an easily measured anthropometric parameter that can determine body frame and 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 HOMA-IR. Inconsistent with the study conducted by Kusmiyati et al. in 18 years old adolescents, which demonstrates a correlation between wrist circumference and fasting insulin and HOMA-IR in both male and female adolescents (Fitriyanti, Tjahjono, et al., 2019). However, the study conducted by Rumaisha et al. about the correlation of wrist circumference and the blood glucose level among obese women shows no correlation between wrist circumference with fasting blood glucose.~~ Other~~ another study conducted at Public Senior High School 6 Semarang also results in no correlation between wrist circumference with fasting blood glucose levels (Arifin ~~&~~ and Panunggal, 2014). Factors influencing HOMA-IR values were fasting blood glucose and fasting insulin levels, where higher glucose levels fasting blood means higher the HOMA-IR value in the subject (Mitrea et al., 2013).

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

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

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

The authors declare no conflict of interest.

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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 (WHR)	0.84	0.6	3.33
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**	***p***
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)

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

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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 early detection of metabolic syndrome. This study aims to analyse the anthropometric indicators related to metabolic syndrome in female students. This cross-sectional study with a total of 163 female 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 (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 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.

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

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).

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 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).

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 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 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 it 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 so that it takes 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

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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 body, especially in the abdominal. This measurement is three times better than BMI in reflecting the presence of harmful fats in the abdominal. Measurement of waist circumference is performed by determining the lower part of arcus costae and crista iliaca (Sri Rahayu and Maulina, 2017).

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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.

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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 *et al.*, 2013). Based on the abovementioned problems, our study aims to analyse the anthropometric indicators related to metabolic syndrome in female students.

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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.

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.

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. Bodyweight was measured using a digital scale to the nearest 0.01 kg, height was measured using a microtoise to the nearest 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 90^o (Firouzi *et al.*, 2018).

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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 ≥0.50 for WHtR (Zhang *et al.*, 2016), ≥ 0.85 for WHR (Rokhmah, *et al.*, 2015) , > 19.3 cm for (Dieny *et al.*, 2020), and have the normal to overweight BMI (18.5 - 25 kg/m^2) or obese BMOI (≥25.0 kg/m^2) (Susetyowati, 2016).

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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 on 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 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 (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.

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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

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.

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^2; the mean of SAD was 16.79 cm; and the mean of waist circumference was 79.44 cm.

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 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 FBG 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. In addition, we found 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 ≥ 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.

If we are considering metabolic type based on nutritional status (subjects with non-obese BMI (<25kg/m^2) with metabolic healthy and metabolic unhealthy and subjects with obese BMI (> 25kg/m^2) 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, blood pressure, GDP and triglyceride levels, and low HDL levels. Based on these criteria, we found that 10.4% of the subjects had metabolic unhealthy normal weight (MUNW) and 23.3% of the subjects had metabolic unhealthy obesity weight (MUOW). In non-obese subjects, 54% of them were metabolic healthy.

Table 3 and Table 4 show the results of statistical analyses on anthropometric indicators related to the 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 on 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 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.

4. Discussion

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 behaviours 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 Diponegoro University, 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). Therefore, we conclude that there is a trend of Metabolic Syndrome Score (cMetS) among young women in Semarang.

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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 (WHtR), 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 RLPP are strongly associated with cMetS.

According to the metabolic type, most of the subjects (54%) in this study had metabolic healthy normal weight (MHNW) metabolic type. In this type, the individuals have a normal BMI and does not show any metabolic risk. 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).

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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).

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We 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 a*l 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 (Camhi *et al.*, 2015).

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 conducted by 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 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 by Adrian et al on 15-year-old 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 has not yet been determined (Ofer *et al.*, 2019). Obesity in adolescents is generally assessed using a BMI of ≥25.0 kg/m^2. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m^2) and obesity (≥25.0 kg/m^2), and we found that 35.6% of the subjects were obese. The finding is in line with the research conducted by Sophia et al 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 in the metabolic syndrome. The limit of the WHR value for female is ≥ 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.

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.

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

The authors declare no conflict of interest.

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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. 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/m^2)	*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 [acer25]: If these are decimal points, revise ALL ‘,” to “.”
Use standardized value

Table 2. Anthropometric Overview and Components of Metabolic Syndrome

Characteristics	**n**	**%**
Anthropometric		
Body Mass Index (BMI)		
Underweight (< 18.5 kg/m^2)	6	3.7
Normal (18.5 – 22.9 kg/m^2)	71	43.6
Overweight (23-24.9 kg/m^2)	28	17.2
Obese (≥25.0 kg/m^2)	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		
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

Commented [acer26]: revise

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

Variable	Sistolic BP		Distolic BP		TG		Blood Glucose		HDL		cMetS	
	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*
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**
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**

Commented [A27]: revised

Commented [acer28]: revise

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

Variable	***Sistolic BP***				
	Konstanta	*USC*[a]	*p1*[b]	*p2*[c]	[d]*Adjusted R^2*
BMI	*91.759*	*0.951*	*<0.001*	*<0.001*	*0.158*
	Blood Glucose Levels				
	Konstanta	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted R^2*
BMI	*83.454*	*0.355*	*0.005*	*<0.001*	*0.043*
	HDL				
	Konstanta	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted R^2*
BMI	*81.429*	*-0.819*	*<0.001*	*<0.001*	*0.080*
	Triglycerides				
	Konstanta	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted R^2*
WC	*-6.614*	*1.195*	*<0.001*	*<0.001*	*0.078*
	Score of Metabolic Syndrome				
	Konstanta	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted R^2*
WC	*-13.163*	*0.166*	*<0.001*	*<0.001*	*0.375*

[a]*Unstandardized Coefficient*, [b] p-value, [c] p Uji F (ANOVA), [d] Koefisien Determinasi

PROSES REVIEW DAN REVISI

Food Research <foodresearch.my@outlook.com> 18 Mei 2021, 02.47
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Inggris > Indonesia Terjemahkan pesan Nonaktifkan untuk: Inggris x

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 Research, has been reviewed. The comments of the reviewer(s) are included in the attached file.

The reviewer(s) have recommended publication, but also suggest some revisions to your manuscript. Therefore, I invite you to respond to the reviewer(s)' comments and revise your manuscript. Once the revised manuscript is prepared, please send it back to me for further processing.

Because we are trying to facilitate timely publication of manuscripts submitted to Food Research, your revised manuscript should be submitted before or by 25th May 2021. If it is not possible for you to submit your revision by this date, please let us know.

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

From: Food Research <foodresearch.my@outlook.com>
Sent: Friday, 9 April, 2021 5:19 PM
To: Fillah Dieny <fillahdieny@gmail.com>
Subject: Manuscript ID: FR-2021-250

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Food Research <foodresearch.my@outlook.com> 12 Jun 2021, 12.52
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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

12 Jun 2021, 17.41

Yes, I am working on it but I need more time, thank you 🙏

•••

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12 Jun 2021, 18.29

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Dear Dr Fillah,

Thank you for informing us. We will wait for your manuscript.

Best regards,
Son Radu, PhD
Chief Editor

Fillah Dieny <fillahdieny@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 hope this article can be processed further. Thank you

Fillah Fithra Dieny

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

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13 Jun 2021, 21.09

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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

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19 Jun 2021, 21.57

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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 consideration of their comments for better improvements on the manuscript.

Best regards,
Son Radu, PhD
Chief Editor

From: Food Research <foodresearch.my@outlook.com>
Sent: Sunday, 13 June, 2021 10:09 PM
To: Fillah Dieny <fillahdieny@gmail.com>

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Fillah Dieny <fillahdieny@gmail.com>
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7 Jul 2021, 14.50

Dear Editorial Board Food Research

Well received with thanks.
Here We send attached revised manuscript FR-2021-250 entitled **Anthropometry indicators that are most related to metabolic profiles in female college students.** We hope this article can be processed further. Thank you

Fillah Fithra Dieny

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

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8 Jul 2021, 01.14

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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>
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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 female college students.** We hope this article can be processed further. Thank you

Fillah Fithra Dieny

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

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8 Jul 2021, 15.59

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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

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RESEARCH

MANUSCRIPT EVALUATION FORM

Date : 9th April 2021

Manuscript ID : FR-2021-250

Please return by : 9th 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).

Evaluation Criteria	Grade				
	A (Excellent)	B	C	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		

<table>
<tr><th colspan="2" rowspan="2">(REVIEWER’S SECTION)
REVIEWER’S COMMENTS/SUGGESTIONS</th><th>(AUTHOR’S SECTION)
AUTHOR’S ACTION/RESPONSE</th></tr>
<tr><th>*NOTE FOR AUTHOR: Please state your response to the reviewer’s comments/suggestion below</th></tr>
<tr><td>1.</td><td>Title
It should reflect the article

Good, lowercase in title</td><td>Revised , already written in line 1-2</td></tr>
<tr><td>2.</td><td>Abstract
Background, Aim, Methodology and Conclusion

No
Clear enough</td><td></td></tr>
<tr><td>3.</td><td>Keywords
Min. 3 and Max. 6

No word “adolescent” in abstract so delete as a keyword</td><td>because female students is a late adolescents period</td></tr>
<tr><td>4.</td><td>Introduction
Concise with sufficient background

Please revise from oldest to latest “et al” should be italicized , Apply to ALL citations

Replace “&” with “and”Apply to alll

Why use female student?

Just first author surname Author et al., year</td><td>Revised , (Sri Rahayu and Maulina, 2017).

Revised to all

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

(Eisenmann et al., 2010; Okosun, Boltri, et al., 2010; Rose et al., 2020).</td></tr>
<tr><td>5.</td><td>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</td><td>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</td></tr>
</table>

		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.	**Conclusion** *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	
10.	**Additional comments/suggestions by the reviewer about the article** Minor revision	

Overall Evaluation

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Minor Revision	**V**	**Reject**	

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MANUSCRIPT EVALUATION FORM

Date : 9th April 2021

Manuscript ID : FR-2021-250

Please return by : 9th May 2021

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

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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)	B	C	D	E (Worst)
7. Appropriateness of Contents		v			
8. Originality of Topic		v			
9. Manuscript Format			v		
10. Research Methodology		v			
11. Data Analysis		v			
12. 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
11.	**Title** *It should reflect the article* Consize and modify the sentence without using 'that are'. Specify the subjects. Is it in college students ?	Anthropometry indicators that are most related to metabolic profiles in female college students **Revised, already written in line 1-2**
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). **Revised, already written in line 33-34**
	can these results be generalized?). Metabolic syndrome in female students in Semaran (line 18)	Metabolic syndrome in female college students can be identified (**Revised, already written in line 30-31)**

13.	**Keywords** *Min. 3 and Max. 6*	-
14.	**Introduction** *Concise with sufficient background* Mention in what subjects. Several sentence need to be modified	Revised all
15.	**Research design/Methodology** *Clearly described and reproducible* Mention the technique how to perform SAD. State the type and the brand of digital scale What is FBG? Line 163	SAD measurements were performed with the subject in a supine position on a flat surface with both knees forming an angle of 90^o Anthropometric data were collected by trained enumerators. **Revised, already written in line 140-142** 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** Revised, Fasting blood glucose
16.	**Data Analysis** *Results well presented and discussed* Available in the article Mention what statistical analysis in this research	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. **Revised, already written in line 173-179**
17.	**Conclusion** *A clear summary of the study* can these results be generalized? You can add the reason in the discussion section	Revised, already written in lines 233-268
18.	**References** *References should follow the journal's format* replace with 'and' a lot of the 'and' are missing from the authors list. Please include to the references below	Revised in all references based on review, already written in lines 311-417

	Journal names should be written in full , Apply to all references	
19.	**English Proficiency** 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**	

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MANUSCRIPT EVALUATION FORM

Date	:	9th April 2021
Manuscript ID	:	FR-2021-250
Please return by	:	9th 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).

Evaluation Criteria	Grade				
	A (Excellent)	B	C	D	E (Worst)
13. Appropriateness of Contents		√			
14. Originality of Topic	√				
15. Manuscript Format	√				
16. Research Methodology	√				
17. Data Analysis	√				
18. Relevance to the Journal	√				

<table>
<tr><td colspan="2" rowspan="2">(REVIEWER'S SECTION)
REVIEWER'S COMMENTS/SUGGESTIONS</td><td>(AUTHOR'S SECTION)
AUTHOR'S ACTION/RESPONSE</td></tr>
<tr><td>*NOTE FOR AUTHOR: Please state your response to the reviewer's comments/suggestion below</td></tr>
<tr><td>21.</td><td>Title
It should reflect the article</td><td>Good</td></tr>
<tr><td>22.</td><td>Abstract
Background, Aim, Methodology and Conclusion

No</td><td>Good</td></tr>
<tr><td>23.</td><td>Keywords
Min. 3 and Max. 6</td><td>Good</td></tr>
<tr><td>24.</td><td>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)</td><td>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, 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 it can be performed using portable and calibrated instruments with standardized methods (Rokhmah, et al., 2015).</td></tr>
</table>

		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). **Already written In lines 53-60**
	What is the differences or similarity between BMI and previous indicator ?	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.
	What is the differences or similarity between SAD and previous indicator ? or what is the advantages of using SAD compare to other indicators.. etc	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 *et al.*, 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	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

	Mention health protocols that has been applied when collecting data 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 Please add the meaning BMOI	**Already written In lines 107-113** 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. **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 90o (Firouzi et al., 2018). **Already written 124-127** Revised, obese BMI (≥25.0 kg/m^2) in line 135
26.	**Data Analysis** *Results well presented and discussed* 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 **Results and discussion/Results** 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. Use sentence which can show the finding more clearly. Author can use comparation sentence 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)	Results and Discussion, line 169 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^2; the mean of SAD was 16.79 cm; and the mean of waist circumference was 79.44 cm. **Already revised in lines 172-174** 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 **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) Please add r value (line 62) How many time? Line 65	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 *et al.*, 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. **Already written in lines 257-264** 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). **Already written in lines 274-275** Not available data
28.	**Conclusion** *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. **Already written in lines 287-290**
29.	**References** *References should follow the journal's format* 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.	**English Proficiency** Please check your grammar and spelling	Revised all

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

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 early detection of metabolic syndrome. This study aims to analyse the anthropometric indicators related to metabolic syndrome in female students. This cross-sectional study with a total of 163 female 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 (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 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.

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

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).

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 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).

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 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 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 it 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 so that it takes 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 ≥1.0 for men and ≥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 abdominal. This measurement is three times better than BMI in reflecting the presence of harmful fats in the abdominal. 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 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 *et al.*, 2013). Based on the abovementioned problems, our study aims to analyse the anthropometric indicators related to metabolic syndrome in female students.

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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.

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.

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. Bodyweight was measured using a digital scale to the nearest 0.01 kg, height was measured using a microtoise to the nearest 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 90° (Firouzi *et al.*, 2018).

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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 ≥0.50 for WHtR (Zhang *et al.*, 2016), ≥ 0.85 for WHR (Rokhmah, *et al.*, 2015) , > 19.3 cm for (Dieny *et al.*, 2020), and have the normal to overweight BMI (18.5 - 25 kg/m^2) or obese BMOI (≥25.0 kg/m^2) (Susetyowati, 2016).

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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 on 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 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 (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.

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

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.

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^2; the mean of SAD was 16.79 cm; and the mean of waist circumference was 79.44 cm.

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 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 FBG 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. In addition, we found 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 ≥ 3 risk factors of

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

If we are considering metabolic type based on nutritional status (subjects with non-obese BMI (<25kg/m^2) with metabolic healthy and metabolic unhealthy and subjects with obese BMI (> 25kg/m^2) 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, blood pressure, GDP and triglyceride levels, and low HDL levels. Based on these criteria, we found that 10.4% of the subjects had metabolic unhealthy normal weight (MUNW) and 23.3% of the subjects had metabolic unhealthy obesity weight (MUOW). In non-obese subjects, 54% of them were metabolic healthy.

Table 3 and Table 4 show the results of statistical analyses on anthropometric indicators related to the 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 on 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 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.

4. Discussion

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 behaviours 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 Diponegoro University, 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). Therefore, we conclude that 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 (WHtR), 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 RLPP are strongly associated with cMetS.

According to the metabolic type, most of the subjects (54%) in this study had metabolic healthy normal weight (MHNW) metabolic type. In this type, the individuals have a normal BMI and does not show any metabolic risk. 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 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).

We 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 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 (Camhi *et al.*, 2015).

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 conducted by 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 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 by Adrian et al on 15-year-old adolescents in South Africa found that central obesity as measured by

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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 has not yet been determined (Ofer *et al.*, 2019). Obesity in adolescents is generally assessed using a BMI of ≥25.0 kg/m^2. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m^2) and obesity (≥25.0 kg/m^2), and we found that 35.6% of the subjects were obese. The finding is in line with the research conducted by Sophia et al 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).

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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 the metabolic syndrome. The limit of the WHR value for female is ≥ 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.

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.

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

The authors declare no conflict of interest.

Acknowledgments

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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. 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/m^2)	*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*

Table 2. Anthropometric Overview and Components of Metabolic Syndrome

Characteristics	**n**	**%**
Anthropometric		
Body Mass Index (BMI)		
Underweight (< 18.5 kg/m^2)	6	3.7
Normal (18.5 – 22.9 kg/m^2)	71	43.6
Overweight (23-24.9 kg/m^2)	28	17.2
Obese (≥25.0 kg/m^2)	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		
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

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

Variable	Sistolic BP		Distolic BP		TG		Blood Glucose		HDL		cMetS	
	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*
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 4. Anthropometric indicators most associated with metabolic components and metabolic syndrome scores

Variable	***Sistolic BP***				
	Konstanta	*USC*[a]	*p1*[b]	*p2*[c]	[d]*Adjusted R^2*
BMI	*91.759*	*0.951*	*<0.001*	*<0.001*	*0.158*
	Blood Glucose Levels				
	Konstanta	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted R^2*
BMI	*83.454*	*0.355*	*0.005*	*<0.001*	*0.043*
	HDL				
	Konstanta	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted R^2*
BMI	*81.429*	*-0.819*	*<0.001*	*<0.001*	*0.080*
	Triglycerides				
	Konstanta	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted R^2*
WC	*-6.614*	*1.195*	*<0.001*	*<0.001*	*0.078*
	Score of Metabolic Syndrome				
	Konstanta	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted R^2*
WC	*-13.163*	*0.166*	*<0.001*	*<0.001*	*0.375*

[a]*Unstandardized Coefficient*, [b] p-value, [c] p Uji F (ANOVA), [d] Koefisien Determinasi

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

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 early detection of metabolic syndrome. This study aims to analyse the anthropometric indicators related to metabolic syndrome in female students. This cross-sectional study with a total of 163 female 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 (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 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.

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

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).

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 score is a z-score resulting from the assessment of all components of the metabolic syndrome (Pratiwi, *et al.*, 2017). The

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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).

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 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 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 it 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).

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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 so that it takes 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).

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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 ≥1.0 for men and ≥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 abdominal. This measurement is three times better than BMI in reflecting the presence of harmful fats in the abdominal. Measurement of waist circumference is performed by determining the lower part of arcus costae and crista iliaca (Sri Rahayu and Maulina, 2017).

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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 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 *et al.*, 2013). Based on the abovementioned problems, our study aims to analyse the anthropometric indicators related to metabolic syndrome in female students.

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.

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.

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. Bodyweight was measured using a digital scale to the nearest 0.01 kg, height was measured using a microtoise to the nearest 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 90° (Firouzi *et al.*, 2018).

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 ≥0.50 for WHtR (Zhang *et al.*, 2016), ≥ 0.85 for WHR (Rokhmah, *et al.*, 2015) , $>$ 19.3 cm for (Dieny *et al.*, 2020), and have the normal to overweight BMI (18.5 - 25 kg/m^2) or obese BMOI (≥25.0 kg/m^2) (Susetyowati, 2016).

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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 on 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 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 (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.

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

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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.

3. Results and discussion/Results

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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^2; the mean of SAD was 16.79 cm; and the mean of waist circumference was 79.44 cm.

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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 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 FBG 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. In addition, we found 33.1% of the subjects had high metabolic syndrome (cMetS) scores. This proportion was similar to the

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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.

If we are considering metabolic type based on nutritional status (subjects with non-obese BMI (<25kg/m^2) with metabolic healthy and metabolic unhealthy and subjects with obese BMI (> 25kg/m^2) 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, blood pressure, GDP and triglyceride levels, and low HDL levels. Based on these criteria, we found that 10.4% of the subjects had metabolic unhealthy normal weight (MUNW) and 23.3% of the subjects had metabolic unhealthy obesity weight (MUOW). In non-obese subjects, 54% of them were metabolic healthy.

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Table 3 and Table 4 show the results of statistical analyses on anthropometric indicators related to the 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 on 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 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.

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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.

4. Discussion

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 behaviours 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 Diponegoro University, 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). Therefore, we conclude that 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 (WHtR), 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 RLPP are strongly associated with cMetS.

According to the metabolic type, most of the subjects (54%) in this study had metabolic healthy normal weight (MHNW) metabolic type. In this type, the individuals have a normal BMI and does not show any metabolic risk. 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).

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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).

We 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 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 (Camhi *et al.*, 2015).

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 conducted by 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 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 by Adrian et al on 15-year-old 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 has not yet been determined (Ofer *et al.*, 2019). Obesity in adolescents is generally assessed using a BMI of ≥25.0 kg/m^2. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m^2) and obesity (≥25.0 kg/m^2), and we found that 35.6% of the subjects were obese. The finding is in line with the research conducted by Sophia et al 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 in the metabolic syndrome. The limit of the WHR value for female is ≥ 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.

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.

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

The authors declare no conflict of interest.

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.

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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. 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/m^2)	*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*

Table 2. Anthropometric Overview and Components of Metabolic Syndrome

Characteristics	n	%
Anthropometric		
Body Mass Index (BMI)		
Underweight (< 18.5 kg/m^2)	6	3.7
Normal (18.5 – 22.9 kg/m^2)	71	43.6
Overweight (23-24.9 kg/m^2)	28	17.2
Obese (≥25.0 kg/m^2)	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		
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

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

Variable	Sistolic BP		Distolic BP		TG		Blood Glucose		HDL		cMetS	
	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*
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 4. Anthropometric indicators most associated with metabolic components and metabolic syndrome scores

Variable	***Sistolic BP***				
	Konstanta	*USC*[a]	*p1*[b]	*p2*[c]	[d]*Adjusted* R^2
BMI	*91.759*	*0.951*	*<0.001*	*<0.001*	*0.158*
	Blood Glucose Levels				
	Konstanta	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
BMI	*83.454*	*0.355*	*0.005*	*<0.001*	*0.043*
	HDL				
	Konstanta	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
BMI	*81.429*	*-0.819*	*<0.001*	*<0.001*	*0.080*
	Triglycerides				
	Konstanta	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
WC	*-6.614*	*1.195*	*<0.001*	*<0.001*	*0.078*
	Score of Metabolic Syndrome				
	Konstanta	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
WC	*-13.163*	*0.166*	*<0.001*	*<0.001*	*0.375*

[a]*Unstandardized Coefficient*, [b] p-value, [c] p Uji F (ANOVA), [d] Koefisien Determinasi

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

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 early detection of metabolic syndrome. This study aims 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 (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.

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

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

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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).

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 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 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 it 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).

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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 so that it takes 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 ≥1.0 for men and ≥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 abdominal. This measurement is three times better than BMI in reflecting the presence of harmful fats in the abdominal. 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 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 *et al.*, 2013). Based on the above mentioned problems, our study aims to analyse the anthropometric indicators related to metabolic syndrome in female college students.

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2. Materials and methods

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

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. 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.

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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.

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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 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 90° (Firouzi *et al.*, 2018).

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 ≥0.50 for WHtR (Zhang *et al.*, 2016), ≥ 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^2) or obese BMI (≥25.0 kg/m^2) (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 on 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 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 (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.

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 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.

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3. Results and Discussion

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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^2; the mean of SAD was 16.79 cm; and the mean of waist circumference was 79.44 cm.

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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 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. In addition, we found 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 ≥ 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.

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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 behaviours 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). Therefore, we conclude that 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 (WHtR), 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 we are considering metabolic type based on nutritional status (subjects with non-obese BMI (<25kg/m^2) with metabolic healthy and metabolic unhealthy and subjects with obese BMI (> 25kg/m^2) 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, blood pressure, GDP and triglyceride levels, and low HDL levels. Based on these criteria, we found that 10.4% of the subjects had metabolic unhealthy normal weight (MUNW) and 23.3% of the subjects had metabolic unhealthy obesity weight (MUOW). In non-obese subjects, 54% of them were metabolic healthy. Our study also shows that 10.4% of the subjects were classified as metabolic unhealthy

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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).

We 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 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 (Camhi *et al.*, 2015).

Table 3 and Table 4 show the results of statistical analyses on anthropometric indicators related to the 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 on 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 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 R^2 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.

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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 *et al.*, 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 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).

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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 has not yet been determined (Ofer *et al.*, 2019). Obesity in adolescents is generally assessed using a BMI of ≥25.0 kg/m^2. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m^2) and obesity (≥25.0 kg/m^2), 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).

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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 the metabolic syndrome. The limit of the WHR value for female is ≥ 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.

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

The authors declare no conflict of interest.

Acknowledgments

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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. Minimum, Maximum, Average and Standard Deviation

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/m^2)	*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*

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Table 2. Anthropometric Overview and Components of Metabolic Syndrome

Characteristics	**n**	**%**
Anthropometric		
Body Mass Index (BMI)		
Underweight (< 18.5 kg/m^2)	6	3.7
Normal (18.5 – 22.9 kg/m^2)	71	43.6
Overweight (23-24.9 kg/m^2)	28	17.2
Obese (≥25.0 kg/m^2)	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		
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		
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

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

Variable	Sistolic BP		Distolic BP		TG		Blood Glucose		HDL		cMetS	
	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*
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 4. Anthropometric indicators most associated with metabolic components and metabolic syndrome scores

Variable	***Sistolic BP***				
	Constant	*USC*[a]	*p1*[b]	*p2*[c]	[d]*Adjusted* R^2
BMI	*91.759*	*0.951*	*<0.001*	*<0.001*	*0.158*
	Blood Glucose Levels				
	Constant	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
BMI	*83.454*	*0.355*	*0.005*	*<0.001*	*0.043*
	HDL				
	Constant	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
BMI	*81.429*	*-0.819*	*<0.001*	*<0.001*	*0.080*
	Triglycerides				
	Constant	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
WC	*-6.614*	*1.195*	*<0.001*	*<0.001*	*0.078*
	Score of Metabolic Syndrome				
	Constant	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
WC	*-13.163*	*0.166*	*<0.001*	*<0.001*	*0.375*

[a]*Unstandardized Coefficient*, [b] p-value, [c] p F-Test (ANOVA), [d] coefficient of determination

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

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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 early detection of metabolic syndrome. This study aims 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 (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.

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

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

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).

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 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 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 it 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 so that it takes 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 ≥1.0 for men and ≥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 abdominal. This measurement is three times better than BMI in reflecting the presence of harmful fats in the abdominal. 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 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 *et al.*, 2013). Based on the above mentioned problems, our study aims to analyse the anthropometric indicators related to metabolic syndrome in female college students.

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2. Materials and methods

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

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. 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.

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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.

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 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 90^o (Firouzi *et al.*, 2018).

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 ≥0.50 for WHtR (Zhang *et al.*, 2016), ≥ 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^2) or obese BMI (≥25.0 kg/m^2) (Susetyowati, 2016).

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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 on 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 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 (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.

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 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.

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3. Results and Discussion

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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^2; the mean of SAD was 16.79 cm; and the mean of waist circumference was 79.44 cm.

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 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. In addition, we found 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 ≥ 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.

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 behaviours 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). Therefore, we conclude that 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 (WHtR), 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 we are considering metabolic type based on nutritional status (subjects with non-obese BMI (<25kg/m^2) with metabolic healthy and metabolic unhealthy and subjects with obese BMI (> 25kg/m^2) 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, blood pressure, GDP and triglyceride levels, and low HDL levels. Based on these criteria, we found that 10.4% of the subjects had metabolic unhealthy normal weight (MUNW) and 23.3% of the subjects had metabolic unhealthy obesity weight (MUOW). In 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).

We 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 the 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 on 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 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 R^2 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.

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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 *et al.*, 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 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).

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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 has not yet been determined (Ofer *et al.*, 2019). Obesity in adolescents is generally assessed using a BMI of ≥25.0 kg/m^2. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m^2) and obesity (≥25.0 kg/m^2), 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).

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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 the metabolic syndrome. The limit of the WHR value for female is ≥ 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 - Disclose any potential conflict of interest appropriately.

The authors declare no conflict of interest.

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.

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Table 1. Minimum, Maximum, Average and Standard Deviation

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/m^2)	*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*

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Table 2. Anthropometric Overview and Components of Metabolic Syndrome

Characteristics	**n**	**%**
Anthropometric		
Body Mass Index (BMI)		
Underweight (< 18.5 kg/m^2)	6	3.7
Normal (18.5 – 22.9 kg/m^2)	71	43.6
Overweight (23-24.9 kg/m^2)	28	17.2
Obese (≥25.0 kg/m^2)	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		
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		
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

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

Variable	Sistolic BP		Distolic BP		TG		Blood Glucose		HDL		cMetS	
	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*
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 4. Anthropometric indicators most associated with metabolic components and metabolic syndrome scores

Variable	***Sistolic BP***				
	Constant	*USC*[a]	*p1*[b]	*p2*[c]	[d]*Adjusted* R^2
BMI	*91.759*	*0.951*	*<0.001*	*<0.001*	*0.158*
	Blood Glucose Levels				
	Constant	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
BMI	*83.454*	*0.355*	*0.005*	*<0.001*	*0.043*
	HDL				
	Constant	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
BMI	*81.429*	*-0.819*	*<0.001*	*<0.001*	*0.080*
	Triglycerides				
	Constant	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
WC	*-6.614*	*1.195*	*<0.001*	*<0.001*	*0.078*
	Score of Metabolic Syndrome				
	Constant	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
WC	*-13.163*	*0.166*	*<0.001*	*<0.001*	*0.375*

[a]*Unstandardized Coefficient*, [b] p-value, [c] p F-Test (ANOVA), [d] coefficient of determination

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

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 early detection of metabolic syndrome. This study aims to analyse the anthropometric indicators related to metabolic syndrome in female students. This cross-sectional study with a total of 163 female 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 (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 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.

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

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).

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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 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

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

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 Riskesdas 2018 showed that the prevalence of stroke, diabetes mellitus, heart disease, and hypertension is higher in women than men.

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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 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, *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).

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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 so that it takes 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).

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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 ≥1.0 for men and ≥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 abdominal. This measurement is three times better than BMI in reflecting the presence of harmful fats in the abdominal. Measurement of waist circumference is performed by determining the lower part of arcus costae and crista iliaca (Sri Rahayu and Maulina, 2017).

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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 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 *et al.*, 2013). Based on the abovementioned problems, our study aims to analyse the anthropometric indicators related to metabolic syndrome in female students.

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.

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.

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. Bodyweight was measured using a digital scale to the nearest 0.01 kg, height was measured using a microtoise to the nearest 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 90° (Firouzi *et al.*, 2018).

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 ≥0.50 for WHtR (Zhang *et al.*, 2016), ≥ 0.85 for WHR (Rokhmah, *et al.*, 2015) , > 19.3 cm for (Dieny *et al.*, 2020), and have the normal to overweight BMI (18.5 - 25 kg/m^2) or obese BMOI (≥25.0 kg/m^2) (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 on cMetS> 2.21 (Rose *et*

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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 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 (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.

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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

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.

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^2; the mean of SAD was 16.79 cm; and the mean of waist circumference was 79.44 cm.

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 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 FBG 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. In addition, we found 33.1% of the subjects had high metabolic syndrome (cMetS) scores. This proportion was similar to the assessment based on the metabolic type theof unhealthy subjects (subjects who had ≥ 3 risk factors

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

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If we are considering metabolic type based on nutritional status (subjects with non-obese BMI (<25kg/m^2) with metabolic healthy and metabolic unhealthy and subjects with obese BMI (> 25kg/m^2) 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, blood pressure, GDP and triglyceride levels, and low HDL levels. Based on these criteria, we found that 10.4% of the subjects had metabolic unhealthy normal weight (MUNW) and 23.3% of the subjects had metabolic unhealthy obesity weight (MUOW). In non-obese subjects, 54% of them were metabolic healthy.

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Table 3 and Table 4 show the results of statistical analyses on anthropometric indicators related to the 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 on 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 that was not associated with diastolic blood pressure ($p>0.005$).

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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.

4. Discussion

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 behaviours 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 Diponegoro University, 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). Therefore, we conclude that there is a trend of Metabolic Syndrome Score (cMetS) among young women in Semarang.

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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 (WHtR), 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 RLPP are strongly associated with cMetS.

According to the metabolic type, most of the subjects (54%) in this study had metabolic healthy normal weight (MHNW) metabolic type. In this type, the individuals have a normal BMI and does not show any metabolic risk. 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).

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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).

We 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 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 (Camhi *et al.*, 2015).

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 conducted by 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 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 by Adrian et al on 15-year-old 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 has not yet been determined (Ofer *et al.*, 2019). Obesity in adolescents is generally assessed using a BMI of ≥25.0 kg/m^2. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m^2) and obesity (≥25.0 kg/m^2), and we found that 35.6% of the subjects were obese. The finding is in line with the research conducted by Sophia et al 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).

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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 the metabolic syndrome. The limit of the WHR value for female is ≥ 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.

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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.

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

The authors declare no conflict of interest.

Acknowledgments

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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. 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*	*11.93*	*0.01*	*2.90*

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Table 2. Anthropometric Overview and Components of Metabolic Syndrome

Characteristics	n	%
Anthropometric		
Body Mass Index (BMI)		
Underweight (< 18.5 kg/m^2)	6	3.7
Normal (18.5 – 22.9 kg/m^2)	71	43.6
Overweight (23-24.9 kg/m^2)	28	17.2
Obese (≥25.0 kg/m^2)	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		
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

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

Variable	Sistolic BP		Distolic BP		TG		Blood Glucose		HDL		cMetS	
	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*
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 4. Anthropometric indicators most associated with metabolic components and metabolic syndrome scores

Variable	***Sistolic BP***				
	Konstanta	*USC*[a]	*p1*[b]	*p2*[c]	[d]*Adjusted* R^2
BMI	*91.759*	*0.951*	*<0.001*	*<0.001*	*0.158*
	Blood Glucose Levels				
	Konstanta	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
BMI	*83.454*	*0.355*	*0.005*	*<0.001*	*0.043*
	HDL				
	Konstanta	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
BMI	*81.429*	*-0.819*	*<0.001*	*<0.001*	*0.080*
	Triglycerides				
	Konstanta	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
WC	*-6.614*	*1.195*	*<0.001*	*<0.001*	*0.078*
	Score of Metabolic Syndrome				
	Konstanta	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
WC	*-13.163*	*0.166*	*<0.001*	*<0.001*	*0.375*

[a]*Unstandardized Coefficient*, [b] p-value, [c] p Uji F (ANOVA), [d] Koefisien Determinasi

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

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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 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 (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.

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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 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).

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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

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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).

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~~ Riskesdas 2018 showed that the prevalence of stroke, diabetes mellitus, heart disease, and hypertension is higher in women than men.

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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 it 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).

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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 so that it takes 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).

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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 ≥1.0 for men and ≥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 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 a standing position (Pajunen *et al.*, 2013). Based on the above mentioned problems, our study aims to analyze the anthropometric indicators related to metabolic syndrome in female college students.

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2. Materials and methods

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

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. 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.

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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.

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 was measured using a measuring tape (Medline) to the nearest 1 mm and abdominal height was measured using the Abawerk Schaffenburg abdominal caliper 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 ≥0.50 for WHtR (Zhang *et al.*, 2016), ≥ 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^2) or obese BMI (≥25.0 kg/m^2) (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 on 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, 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.

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 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.

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3. Results and Discussion

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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^2; the mean of SAD was 16.79 cm; and the mean of waist circumference was 79.44 cm.

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 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. In addition, we found 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 ≥ 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.

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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 behavior 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). Therefore, we conclude that 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 (WHtR), 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 we are considering metabolic type based on nutritional status (subjects with non-obese BMI (<25kg/m^2) with metabolic healthy and metabolic unhealthy and subjects with obese BMI (> 25kg/m^2) with metabolic healthy and metabolic unhealthy), subjects are categorized as metabolic unhealthy (experiencing metabolic syndrome) if they fulfil ≥ 3 risk factors including high waist circumference, blood pressure, ~~GDP~~ Fasting blood glucose and triglyceride levels, and low HDL levels. Based on these criteria, we found that 10.4% of the subjects had metabolic unhealthy normal weight (MUNW) and 23.3% of the subjects had metabolic unhealthy obesity weight (MUOW). In non-obese subjects, 54%

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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).

We 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 ~~the~~ 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 on 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 ~~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 R^2 value on the metabolic syndrome score, we found that 37.5% of the metabolic syndrome score was

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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 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). 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 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).

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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 has not yet been determined (Ofer *et al.*, 2019). Obesity in adolescents is generally assessed using a BMI of ≥25.0 kg/m^2. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m^2) and obesity (≥25.0 kg/m^2), 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).

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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 ~~the~~ metabolic syndrome. The limit of the WHR value for female is ≥ 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.

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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 - Disclose any potential conflict of interest appropriately.

The authors declare no conflict of interest.

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.

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Table 1. Minimum, Maximum, Average and Standard Deviation

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/m^2)	*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*

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Table 2. Anthropometric Overview and Components of Metabolic Syndrome

Characteristics	n	%
Anthropometric		
Body Mass Index (BMI)		
Underweight (< 18.5 kg/m^2)	6	3.7
Normal (18.5 – 22.9 kg/m^2)	71	43.6
Overweight (23-24.9 kg/m^2)	28	17.2
Obese (≥25.0 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 (≤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		
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

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

Variable	Sistolic BP		Distolic BP		TG		Blood Glucose		HDL		cMetS	
	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*
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 4. Anthropometric indicators most associated with metabolic components and metabolic syndrome scores

Variable	***Sistolic BP***				
	Constant	*USC*[a]	*p1*[b]	*p2*[c]	[d]*Adjusted* R^2
BMI	*91.759*	*0.951*	*<0.001*	*<0.001*	*0.158*
	Blood Glucose Levels				
	Constant	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
BMI	*83.454*	*0.355*	*0.005*	*<0.001*	*0.043*
	HDL				
	Constant	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
BMI	*81.429*	*-0.819*	*<0.001*	*<0.001*	*0.080*
	Triglycerides				
	Constant	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
WC	*-6.614*	*1.195*	*<0.001*	*<0.001*	*0.078*
	Score of Metabolic Syndrome				
	Constant	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
WC	*-13.163*	*0.166*	*<0.001*	*<0.001*	*0.375*

[a]*Unstandardized Coefficient*, [b] p-value, [c] p F-Test (ANOVA), [d] coefficient of determination

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

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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 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 (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.

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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 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 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).

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~~ 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 it 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 so that it takes 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 ≥1.0 for men and ≥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 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 a standing position (Pajunen *et al.*, 2013). Based on the above mentioned problems, our study aims 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 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

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. 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.

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 was measured using a measuring tape (Medline) to the nearest 1 mm and abdominal height was measured using the Abawerk Schaffenburg abdominal caliper 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^o (Firouzi *et al.*, 2018). Anthropometric data were collected by trained enumerators.

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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 ≥0.50 for WHtR (Zhang *et al.*, 2016), ≥ 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^2) or obese BMI (≥25.0 kg/m^2) (Susetyowati, 2016).

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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 on 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, 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.

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 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.

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^2; the mean of SAD was 16.79 cm; and the mean of waist circumference was 79.44 cm.

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 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. In addition, we found 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 ≥ 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 behavior 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). Therefore, we conclude that 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 (WHtR), 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 we are considering metabolic type based on nutritional status (subjects with non-obese BMI ($<25kg/m^2$) with metabolic healthy and metabolic unhealthy and subjects with obese BMI ($> 25kg/m^2$) with metabolic healthy and metabolic unhealthy), subjects are categorized as metabolic unhealthy (experiencing metabolic syndrome) if they fulfil ≥ 3 risk factors including high waist circumference, blood pressure, ~~GDP~~ Fasting blood glucose and triglyceride levels, and low HDL levels. Based on these criteria, we found that 10.4% of the subjects had metabolic unhealthy normal weight (MUNW) and 23.3% of the subjects had metabolic unhealthy obesity weight (MUOW). In 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).

We 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.

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Table 3 and Table 4 show the results of statistical analyses on anthropometric indicators related to ~~the~~ 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 on 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 ~~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 R^2 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.

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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 *et al.*, 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 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 has not yet been determined (Ofer *et al.*, 2019). Obesity in adolescents is generally assessed using a BMI of ≥25.0 kg/m^2. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m^2) and obesity (≥25.0 kg/m^2), 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 in ~~the~~ metabolic syndrome. The limit of the WHR value for female is ≥ 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 - Disclose any potential conflict of interest appropriately.

The authors declare no conflict of interest.

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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. Minimum, Maximum, Average and Standard Deviation

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/m^2)	*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*

Table 2. Anthropometric Overview and Components of Metabolic Syndrome

Characteristics	n	%
Anthropometric		
Body Mass Index (BMI)		
Underweight (< 18.5 kg/m^2)	6	3.7
Normal (18.5 – 22.9 kg/m^2)	71	43.6
Overweight (23-24.9 kg/m^2)	28	17.2
Obese (≥25.0 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 (≤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		
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

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

Variable	Sistolic BP		Distolic BP		TG		Blood Glucose		HDL		cMetS	
	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*
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 4. Anthropometric indicators most associated with metabolic components and metabolic syndrome scores

Variable	***Sistolic BP***				
	Constant	*USC*[a]	*p1*[b]	*p2*[c]	[d]*Adjusted* R^2
BMI	*91.759*	*0.951*	*<0.001*	*<0.001*	*0.158*
	Blood Glucose Levels				
	Constant	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
BMI	*83.454*	*0.355*	*0.005*	*<0.001*	*0.043*
	HDL				
	Constant	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
BMI	*81.429*	*-0.819*	*<0.001*	*<0.001*	*0.080*
	Triglycerides				
	Constant	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
WC	*-6.614*	*1.195*	*<0.001*	*<0.001*	*0.078*
	Score of Metabolic Syndrome				
	Constant	*USC*[a]	*p1*[b]	*p2*[c]	*Adjusted* R^2
WC	*-13.163*	*0.166*	*<0.001*	*<0.001*	*0.375*

[a]*Unstandardized Coefficient*, [b] p-value, [c] p F-Test (ANOVA), [d] coefficient of determination

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

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27th September 2021

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ACCEPTANCE LETTER

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

Manuscript Title	:	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,

Professor Dr. Son Radu
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Before we can proceed with the article production, I would like to clarify a few points that I have commented in the manuscript. Please refer to the attachment. Please address the issues raised in the comments.

Please use the attached copy to make your revisions as it has been corrected to the Journal's format. Once you have done, kindly revert the copy to me as soon as possible. Please note the faster you respond, the quicker we will process your manuscript.

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Department of Nutrition Science
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Faculty of Medicine, Diponegoro University
Jl Prof Soedharto SH, Tembalang. Semarang 50275, Central Java, Indonesia.
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Department of Nutrition Science
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Jl Prof Soedharto SH, Tembalang. Semarang 50275, Central Java, Indonesia.
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Thanks & Regards
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Anthropometry indicators that are most related to metabolic profiles in female college students

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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 (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.

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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 (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 cut-off points for WHR are ≥1.0 for men and ≥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 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 (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^o (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 ≥0.50 for WHtR (Zhang *et al.*, 2016), ≥ 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^2) or obese BMI (≥25.0 kg/m^2) (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.

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

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^2; 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 ≥ 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 (WHtR), 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 subjects with obese BMI ($> 25kg/m^2$) with metabolic healthy and metabolic unhealthy), subjects are categorized as metabolic unhealthy (experiencing metabolic syndrome) if they fulfil ≥ 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^2 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 ≥25.0 kg/m^2. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m^2) and obesity (≥25.0 kg/m^2), 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 ≥ 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.

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Table 1. Minimum, maximum, average and standard deviation

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^2)	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 2. Anthropometric overview and components of metabolic syndrome

Characteristics	n	%
Anthropometric		
Body Mass Index (BMI)		
Underweight (< 18.5 kg/m^2)	6	3.7
Normal (18.5 – 22.9 kg/m^2)	71	43.6
Overweight (23-24.9 kg/m^2)	28	17.2
Obese (≥25.0 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 (≤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		

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

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		cMetS	
	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*
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**

Commented [VN3]: Rather than bold the p-value that showed significant difference, you should indicate in the table note, p-value<0.05/0.01 indicates significant difference.

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

Variable	**Systolic BP**				
	Constant	USC[a]	p1[b]	p2[c]	[d]Adjusted R^2
BMI	91.759	0.951	<0.001	<0.001	0.158
	Blood Glucose Levels				
	Constant	USC[a]	p1[b]	p2[c]	Adjusted R^2
BMI	83.454	0.355	0.005	<0.001	0.043
	HDL				
	Constant	USC[a]	p1[b]	p2[c]	Adjusted R^2
BMI	81.429	-0.819	<0.001	<0.001	0.080
	Triglycerides				
	Constant	USC[a]	p1[b]	p2[c]	Adjusted R^2
WC	-6.614	1.195	<0.001	<0.001	0.078
	Score of Metabolic Syndrome				
	Constant	USC[a]	p1[b]	p2[c]	Adjusted R^2
WC	-13.163	0.166	<0.001	<0.001	0.375

[a]*Unstandardized Coefficient*, [b] p-value, [c] p F-Test (ANOVA), [d] coefficient of determination

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

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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 (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 cut-off points for WHR are ≥1.0 for men and ≥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 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 (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^o (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 ≥0.50 for WHtR (Zhang *et al.*, 2016), ≥ 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^2) or obese BMI (≥25.0 kg/m^2) (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 WHtR value in this study was 0.51. Meanwhile, the mean WHR was 0.80; the mean BMI was 24.04 kg/m^2; 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 ≥ 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 (WHtR), 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 subjects with obese BMI ($> 25kg/m^2$) with metabolic healthy and metabolic unhealthy), subjects are categorized as metabolic unhealthy (experiencing metabolic syndrome) if they fulfil ≥ 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^2 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 ≥25.0 kg/m^2. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m^2) and obesity (≥25.0 kg/m^2), 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 ≥ 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.

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Table 1. Minimum, maximum, average and standard deviation

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^2)	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 2. Anthropometric overview and components of metabolic syndrome

Characteristics	n	%
Anthropometric		
Body Mass Index (BMI)		
Underweight (< 18.5 kg/m^2)	6	3.7
Normal (18.5 – 22.9 kg/m^2)	71	43.6
Overweight (23-24.9 kg/m^2)	28	17.2
Obese (≥25.0 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 (≤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		

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

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		cMetS	
	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*
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**

Commented [VN1]: Rather than bold the p-value that showed significant difference, you should indicate in the table note, p-value<0.05/0.01 indicates significant difference.

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

Variable	**Systolic BP**				
	Constant	USC[a]	p1[b]	p2[c]	[d]Adjusted R^2
BMI	91.759	0.951	<0.001	<0.001	0.158
	Blood Glucose Levels				
	Constant	USC[a]	p1[b]	p2[c]	Adjusted R^2
BMI	83.454	0.355	0.005	<0.001	0.043
	HDL				
	Constant	USC[a]	p1[b]	p2[c]	Adjusted R^2
BMI	81.429	-0.819	<0.001	<0.001	0.080
	Triglycerides				
	Constant	USC[a]	p1[b]	p2[c]	Adjusted R^2
WC	-6.614	1.195	<0.001	<0.001	0.078
	Score of Metabolic Syndrome				
	Constant	USC[a]	p1[b]	p2[c]	Adjusted R^2
WC	-13.163	0.166	<0.001	<0.001	0.375

[a]*Unstandardized Coefficient*, [b] p-value, [c] p F-Test (ANOVA), [d] coefficient of determination

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

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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 (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 (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 cut-off points for WHR are ≥1.0 for men and ≥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 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 (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^o (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 ≥0.50 for WHtR (Zhang *et al.*, 2016), ≥ 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^2) or obese BMI (≥25.0 kg/m^2) (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 WHtR value in this study was 0.51. Meanwhile, the mean WHR was 0.80; the mean BMI was 24.04 kg/m^2; 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 ≥ 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 (WHtR), 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 subjects with obese BMI (> 25kg/m^2) with metabolic healthy and metabolic unhealthy), subjects are categorized as metabolic unhealthy (experiencing metabolic syndrome) if they fulfil ≥ 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^2 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 ≥25.0 kg/m^2. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m^2) and obesity (≥25.0 kg/m^2), 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 ≥ 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.

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Table 1. Minimum, maximum, average and standard deviation

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^2)	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 2. Anthropometric overview and components of metabolic syndrome

Characteristics	n	%
Anthropometric		
Body Mass Index (BMI)		
Underweight (< 18.5 kg/m^2)	6	3.7
Normal (18.5 – 22.9 kg/m^2)	71	43.6
Overweight (23-24.9 kg/m^2)	28	17.2
Obese (≥25.0 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 (≤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		

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

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		cMetS	
	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*
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**

Commented [VN1]: Rather than bold the p-value that showed significant difference, you should indicate in the table note, p-value<0.05/0.01 indicates significant difference.

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

Variable	**Systolic BP**				
	Constant	USC[a]	p1[b]	p2[c]	[d]Adjusted R^2
BMI	91.759	0.951	<0.001	<0.001	0.158
	Blood Glucose Levels				
	Constant	USC[a]	p1[b]	p2[c]	Adjusted R^2
BMI	83.454	0.355	0.005	<0.001	0.043
	HDL				
	Constant	USC[a]	p1[b]	p2[c]	Adjusted R^2
BMI	81.429	-0.819	<0.001	<0.001	0.080
	Triglycerides				
	Constant	USC[a]	p1[b]	p2[c]	Adjusted R^2
WC	-6.614	1.195	<0.001	<0.001	0.078
	Score of Metabolic Syndrome				
	Constant	USC[a]	p1[b]	p2[c]	Adjusted R^2
WC	-13.163	0.166	<0.001	<0.001	0.375

[a]*Unstandardized Coefficient*, [b] p-value, [c] p F-Test (ANOVA), [d] coefficient of determination

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

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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 (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 (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 cut-off points for WHR are ≥1.0 for men and ≥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 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 (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^o (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 ≥0.50 for WHtR (Zhang *et al.*, 2016), ≥ 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^2) or obese BMI (≥25.0 kg/m^2) (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 WHtR value in this study was 0.51. Meanwhile, the mean WHR was 0.80; the mean BMI was 24.04 kg/m^2; 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 ≥ 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 (WHtR), 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 subjects with obese BMI ($> 25kg/m^2$) with metabolic healthy and metabolic unhealthy), subjects are categorized as metabolic unhealthy (experiencing metabolic syndrome) if they fulfil ≥ 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^2 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 ≥25.0 kg/m^2. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m^2) and obesity (≥25.0 kg/m^2), 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 ≥ 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.

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Table 1. Minimum, maximum, average and standard deviation

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^2)	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 2. Anthropometric overview and components of metabolic syndrome

Characteristics	n	%
Anthropometric		
Body Mass Index (BMI)		
Underweight (< 18.5 kg/m^2)	6	3.7
Normal (18.5 – 22.9 kg/m^2)	71	43.6
Overweight (23-24.9 kg/m^2)	28	17.2
Obese (≥25.0 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 (≤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		

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

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		cMetS	
	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*
WHtR	0.358	<0.001[s]	0.306	<0.001[s]	0.289	<0.001[s]	0.210	0.007[s]	-0.266	0.001[s]	0.599	<0.001
BMI	0.370	<0.001[s]	0.313	<0.001[s]	0.315	<0.001[s]	0.221	0.005[s]	-0.292	<0.001[s]	0.600	<0.001[s]
SAD	0.352	<0.001[s]	0.284	<0.001[s]	0.278	<0.001[s]	0.191	0.015[s]	-0.264	0.001[s]	0.575	<0.001[s]
WC	0.377	<0.001[s]	0.284	<0.001[s]	0.295	<0.001[s]	0.212	0.005[s]	-0.243	0.002[s]	0.616	<0.001[s]
HC	0.369	<0.001[s]	0.332	<0.001[s]	0.302	<0.001[s]	0.179	0.002[s]	-0.273	<0.001[s]	0.581	<0.001[s]
WHR	0.244	0.002[s]	0.128	0.104	0.194	0.013[s]	0.172	0.028[s]	-0.149	0.048[s]	0.415	<0.001[s]

[s] = Significant, p-value <0.05 indicates there is a significant relationship

Commented [VN1]: Rather than bold the p-value that showed significant difference, you should indicate in the table note, p-value<0.05/0.01 indicates significant difference.

Commented [A2R1]: revised

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

Variable	**Systolic BP**				
	Constant	USC[a]	p1[b]	p2[c]	[d]Adjusted R^2
BMI	91.759	0.951	<0.001	<0.001	0.158
	Blood Glucose Levels				
	Constant	USC[a]	p1[b]	p2[c]	Adjusted R^2
BMI	83.454	0.355	0.005	<0.001	0.043
	HDL				
	Constant	USC[a]	p1[b]	p2[c]	Adjusted R^2
BMI	81.429	-0.819	<0.001	<0.001	0.080
	Triglycerides				
	Constant	USC[a]	p1[b]	p2[c]	Adjusted R^2
WC	-6.614	1.195	<0.001	<0.001	0.078
	Score of Metabolic Syndrome				
	Constant	USC[a]	p1[b]	p2[c]	Adjusted R^2
WC	-13.163	0.166	<0.001	<0.001	0.375

[a]*Unstandardized Coefficient*, [b] p-value, [c] p F-Test (ANOVA), [d] coefficient of determination

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FULL PAPER

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

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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 (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.

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, Lyn, Smith *et al.*, 2010).

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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 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 (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 cut-off points for WHR are ≥1.0 for men and ≥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 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 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^o (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 ≥0.50 for WHtR (Zhang *et al.*, 2016), ≥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^2) or obese BMI (≥25.0 kg/m^2) (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, 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 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, 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

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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^2; 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 ≥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 (WHtR), 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

Table 1. Minimum, maximum, average and standard deviation

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
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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
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Systolic Blood Pressure (mmHg)	84.00	144.00	114.63	11.13
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Normal (18.5 – 22.9 kg/m^2)	71	43.6
Overweight (23-24.9 kg/m^2)	28	17.2
Obese (≥25.0 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 (≤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 (≥110 mg/dL)	27	16.6
Triglycerides		
Normal (<150 mg/dL)	149	914.0
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		
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	54.0
Metabolic Unhealthy Obese Weight (MUOW)	38	23.3
Metabolic Healthy Obese Weight (MHOW)	20	12.3

subjects with obese BMI (>25kg/m^2) with metabolic healthy and metabolic unhealthy), subjects are categorized as metabolic unhealthy (experiencing metabolic syndrome) if they fulfil ≥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

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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		cMetS	
	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*
WHtR	0.358	<0.001[s]	0.306	<0.001[s]	0.289	<0.001[s]	0.210	0.007[s]	-0.266	0.001[s]	0.599	<0.001[s]
BMI	0.370	<0.001[s]	0.313	<0.001[s]	0.315	<0.001[s]	0.221	0.005[s]	-0.292	<0.001[s]	0.600	<0.001[s]
SAD	0.352	<0.001[s]	0.284	<0.001[s]	0.278	<0.001[s]	0.191	0.015[s]	-0.264	0.001[s]	0.575	<0.001[s]
WC	0.377	<0.001[s]	0.284	<0.001[s]	0.295	<0.001[s]	0.212	0.005[s]	-0.243	0.002[s]	0.616	<0.001[s]
HC	0.369	<0.001[s]	0.332	<0.001[s]	0.302	<0.001[s]	0.179	0.002[s]	-0.273	<0.001[s]	0.581	<0.001[s]
WHR	0.244	0.002[s]	0.128	0.104	0.194	0.013[s]	0.172	0.028[s]	-0.149	0.048[s]	0.415	<0.001[s]

[s]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				
	Constant	USC[a]	p1[b]	p2[c]	[d]Adjusted R^2
BMI	91.759	0.951	<0.001	<0.001	0.158
	Blood Glucose Levels				
	Constant	USC[a]	p1[b]	p2[c]	Adjusted R^2
BMI	83.454	0.355	0.005	<0.001	0.043
	HDL				
	Constant	USC[a]	p1[b]	p2[c]	Adjusted R^2
BMI	81.429	-0.819	<0.001	<0.001	0.08
	Triglycerides				
	Constant	USC[a]	p1[b]	p2[c]	Adjusted R^2
WC	-6.614	1.195	<0.001	<0.001	0.078
	Score of Metabolic Syndrome				
	Constant	USC[a]	p1[b]	p2[c]	Adjusted R^2
WC	-13.163	0.166	<0.001	<0.001	0.375

[a]Unstandardized Coefficient, [b] p-value, [c] p F-Test (ANOVA), [d] coefficient of determination

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^2 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 ≥25.0 kg/m^2. In this study, we only divided the subjects into normal nutritional status (18.5-25 kg/m^2) and obesity (≥25.0 kg/m^2), 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 ≥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.

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

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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 (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.