CORRESPONDENCE PAPER

TITLE : The Association between Unhealthy Food Consumption and Impaired Glucose Metabolism among Adults with Overweight or Obesity: A Cross-Sectional Analysis of the Indonesian Population

JOURNAL : Journal of Obesity

STATUS : Q2

No	Activity	Date	Page
1	Submit to the journal “Journal of Obesity”	16-10-2022	2
2	First revision : with major revision	21-10-2022	3-4
3	Responses to reviewer comments	9-2-2023	5-10
4	Final revision	18-2-2023	11-36

Mail FK UNDIP

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Manuscript submitted to Journal of Obesity

1 pesan

Journal of Obesity <rhea.lumbres@hindawi.com> 16 Oktober 2022 pukul 14.17
Kepada: adriyanpramono@fk.undip.ac.id

Hindawi

Dear Dr. Pramono,

The manuscript titled "The Association between Unhealthy Foods Consumption and Impaired Glucose Metabolism among Adults with Overweight/Obesity: A Cross-Sectional Analysis from Indonesia Population" has been submitted to Journal of Obesity by Ahmad Syauqy.

To confirm the submission and view the status of the manuscript, please verify your details by clicking the link below.

Thank you for submitting your work to Journal of Obesity.

LOGIN

Kind regards,
Rhea Lumbres
Journal of Obesity

Mail FK UNDIP **Adriyan Pramono <adriyanpramono@fk.undip.ac.id>**

Re: 2885769: Changes Required (1st Reminder)

1 pesan

Kisslena Ferreras <rhea.lumbres@hindawi.com> 21 Oktober 2022 pukul 09.26
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Dear Dr. Ahmad Syauqy,

Please confirm the receipt of my previous email and provide your response at your earliest convenience.

Your assistance is appreciated.

Best Regards,

Kisslena Ferreras

Editorial Screener

On Wed, 19 Oct at 4:35 PM , Ahmad Syauqy <syauqy@fk.undip.ac.id> wrote:
Dear Kisslena Ferreras,
Many thanks for your email. We replay the issues as:
[1] The supplementary material file that we upload is the STROBE checklist. We will delete it in the submission process.
[2] This study was funded by Institute for Research and Community Services (LPPM-RPIBT), Diponegoro University (185-95/UN7.6.1/PP/2022). We checked it, and it is correct. The Funding is similar in the file and in the system
[3] Our study is a cross-sectional study using population-based study among Indonesians. The study is not a part of trial study or RCTs. Therefore, we do not have a clinical trial registration (check #[3]). We already wrote the ethical approval from the Ethical Committee of Health Research, NIHRD, Ministry of Health, Republic of Indonesia No. LB.02.01/2/KE.267/2017.
Should we continue the submission with these issues? Thank you.

Best regards,

Ahmad Syauqy

Pada tanggal Sel, 18 Okt 2022 pukul 14.40 Kisslena Ferreras <kisslena.ferreras@hindawi.com> menulis:

Hindawi

Dear Dr. Ahmad Syauqy,

We have reviewed your manuscript "The Association between Unhealthy Foods Consumption and Impaired Glucose Metabolism among Adults with Overweight/Obesity: A Cross-Sectional Analysis from Indonesia Population" with ID No. 2885769 and found the following issues which need to be solved before moving on:

3

- **Relevance Check**
  - [1.] While checking your manuscript we found that there are supplementary materials submitted along with your manuscript. Please email me a concise description of each supplementary material file so we can include it in the PDF of the manuscript. Supplementary materials are not modified by our production team. Authors are responsible for providing the final supplementary materials files that will be published along with the article. [2.] Upon checking your manuscript I noticed that the Funding is different in the PDF and in the system. Kindly update your records and ensure that all data provided in the system should be matched in your main PDF file. [3.] Upon checking manuscript 2885769 titled "The Association between Unhealthy Foods Consumption and Impaired Glucose Metabolism among Adults with Overweight/Obesity: A Cross-Sectional Analysis from Indonesia Population" we've noticed that a registration number has not been included. Hindawi complies with the recommendations of the International Committee of Medical Journal Editors (ICMJE) on trial registrations when publishing clinical studies. Accordingly authors are required to include their registration number at the end of the manuscript. Please can you provide me with an updated PDF including the trial registration number?

Additional Comments:

This paper has been returned to draft for the reasons listed above. Please could you log into your account in https://review.hindawi.com/login and address these points as soon as possible? The changes should be made on this submission ID 2885769, Please do not submit a new manuscript.

Please log into your account to make the required updates. Follow the steps outlined below, and we kindly ask that you do not submit a brand new manuscript.

1. Click on the manuscript tile for The Association between Unhealthy Foods Consumption and Impaired Glucose Metabolism among Adults with Overweight/Obesity: A Cross-Sectional Analysis from Indonesia Population, which will show the status "Complete submission".
2. You will see all 4 submission steps. All the information will be pre-filled as you submitted the manuscript, so you will not need to complete the entire submission again. Click through the steps until you reach the area that needs updating.
3. If the manuscript file needs updating then go to step 4, and click the small bin icon next to the manuscript file. This will delete the file. You can then upload the new updated file.
4. When all necessary changes have been made, click the green "Submit manuscript" button at the bottom of step 4, and this will return the manuscript to the Hindawi team.

Kind regards,
Kisslena Ferreras

Reviewer Comments

Recommendation

Minor Revision Requested

Claire Stocker

AE

09.02.2023

Message for Author

Reviewer 2 has requested further minor revision (see below). Please address all points.

Report

This manuscript has improved, although there are still some additional improvements to be made.

Another round of proofreading for typos is suggested. Additionally, specific issues are listed below:

The authors use the term "fat foods" often, this should be changed to "high fat foods" or "fatty foods".

Response: we thank you for the reviewer’s suggestion. We have changed and used high-fat foods as a term to replace fat foods throughout the manuscript

Lines 45-46: " We found that consumption of sweet, grilled, and processed foods were associated with fasting plasma glucose (IFG)..." I think author's left out the word "impaired"

Response: we thank you for the reviewer’s correction. We have added the word ‘impaired’ before …fasting plasma glucose (IFG) in lines 45-46.

Line 68-10: " In contrast, individuals with IGT have normal to slightly reduced hepatic insulin resistance and show moderate to severe reduced skeletal muscle insulin sensitivity [6]" Do the authors mean to say "slightly reduced hepatic insulin sensitivity" not "resistance"?

Response: we thank you for the reviewer's correction. We mean to write 'slightly reduced hepatic insulin sensitivity'. Therefore, we have corrected that in line 68.

Line 149-152: "Subsequently, multiple regression analysis was performed with body mass index (BMI) added as an independent variable (model 2). Next, multiple regression analysis was performed with physical activity level added as independent variables (model 2) and BMI and physical activity level added together (model 3)." It seems that something is off with the labeling of models as modal 2 is listed twice for two different regressions (BMI alone and physical activity alone).

Response: we thank you for the reviewer's suggestion. We have checked again to match with the results, and we corrected these in lines 149-152 as described below:

Subsequently, multiple regression analysis was performed with body mass index (BMI) added as an independent variable (model 2). Next, multiple regression analysis was performed with physical activity level added as independent variables (model 3) and BMI and physical activity level added together (model 4).

Line 167-174: "Impaired glucose tolerance in obese, overweight, middle-aged, young, female, urban, and rural individuals, frequent consumption of sweet foods, rare consumption of sweet foods, frequent consumption of salty foods, rare consumption of salty foods, frequent consumption of fat foods, rare consumption of fat foods, frequent consumption of grilled foods, rare consumption of grilled foods, rare consumption of processed foods, less consumption of fruit and vegetables, sufficient consumption of fruit and vegetables, lack of physical activity, and sufficient physical activity were the most common glucose metabolism impairments."

This sentence is very long and is unclear, perhaps rearranging the sentence to the following is clearer: "Impaired glucose tolerance was the most common glucose metabolism impairment in the obese, overweight, middle-aged, young, female, urban, rural , frequent consumption of sweet foods, rare consumption of sweet foods, frequent consumption of salty foods, rare consumption of salty foods, frequent consumption of fat foods, rare consumption of fat foods, frequent consumption of grilled foods, rare consumption of grilled foods, rare consumption of processed foods, less consumption of fruit and vegetables, sufficient consumption of fruit and vegetables, lack of physical activity, and sufficient physical activity groups."

Response: we thank you for the reviewer's suggestion. We have replaced the sentences with reviewer's suggestion in lines 167-174.

Please add the definitions of each acronym in Figure 1 in the figure legend.

Response: we thank you for the reviewer’s suggestion. We have added the acronym in the text legend of Figure 1.

Response by response to reviewer comments:

Reviewer 1

Overall the study is of interest, valid, and well designed, however, the manuscript could use significant proofreading particularly with regards to English grammar and consistency.

Response: We would like to thank the reviewer's suggestions. Therefore, we have done proofreading for the English grammar throughout the manuscript.

Specific concerns:

There is a lack of consistency between the model numbers described in the materials and methods, results, and tables (for example Model 1 in the tables are the unadjusted model, but "model 1" in the Materials and methods section is described as adjusted for BMI). Please carefully go over these and be sure to consistently refer to each Model number in the same way.

Response: Thank you for this constructive suggestion. We have corrected in the methods section lines 142 to 148.

On line 189 there are typos with regards to the OR and CI numbers, there are currently commas where decimals points should be.

Response: We apologize for this mistake. Thank you for your constructive correction. We have corrected it on line 189.

Figure 1 does not make sense. If the units of the y axis are%, all of the bars added together should equal 100% and this is not the case. Perhaps this is mislabeled and is some sort of count? Please double check the units here and explain.

Response: We apologize for this mistake. Thank you for your constructive correction. We have corrected the figure 1 and replaced the previous mistaken figure.

Reviewer 2

The keywords must be chosen according to MeSH.

Response: Thank you for this suggestion. We have used the MeSH terms throughout the manuscript.

"a recent study indicates that Indonesia is among countries with a high prevalence of T2D ". What are the basic reasons?

Response: Thank you for this suggestion. Recent data from IDF 2021, Diabetes prevalence in South East Asia, Indonesia is one of the highest T2D prevalences. This has been added in the manuscript in line 59.

There are some typing mistakes throughout the text.

Response: Thank you for this constructive suggestion. We have checked and corrected the manuscript.

The aim of the study needs to be written in more detail.

Response: Thank you for this constructive suggestion. We have added in line the manuscript lines 95-97.

The inclusion and exclusion criteria are not complete.

Response: Thank you for this constructive suggestion. We have added in manuscript lines 107-112.

Some references are very old.

Response: Thank you for this constructive suggestion. We have replaced some old references with relatively new ones (less than 5-10 years from 2022) in manuscript.

The Association between Unhealthy Food Consumption and Impaired Glucose Metabolism among Adults with Overweight or Obesity: A Cross-Sectional Analysis of the Indonesian Population

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Abstract

Background. It has been shown that dietary patterns are associated with glucose control. However, the association between the types of food consumed and blood glucose in overweight or obese individuals is still unclear. The present study aimed to determine the association between unhealthy food consumption and impaired glucose metabolism in adults with overweight or obesity. *Methods*. The analysis presented in this study was based on the data from a population-based, cross-sectional, nationally representative survey (Indonesian Basic Health Research 2018/RISKESDAS 2018). The body mass index (BMI) was calculated as weight (kg) /height squared (m^2) and was determined based on the World Health Organization (WHO) criteria for the Asian population. A validated questionnaire and food card were used to assess the diet. Fasting plasma glucose and 2-h postprandial glucose were employed to determine blood glucose markers. *Results*. In total, 8752 adults with overweight or obesity were included in this analysis. We found that consumption of sweet, grilled, and processed foods were associated with impaired fasting plasma glucose (IFG) before and after adjustment ($p < 0.05$). Consumption of high-fat foods was also associated with impaired glucose tolerance (IGT) for all models tested ($p < 0.05$). Furthermore, all models showed a link between processed food consumption and combined glucose intolerance (CGI) ($p < 0.05$). *Conclusions.* Differential food group consumption was associated with IFG, IGT, and CGI in Indonesian adults who were overweight or obese.

Keywords: Sweet food, high-fat foods, Processed food, Prediabetes, Impaired glucose tolerance, Obesity

1. Introduction

Various epidemiological studies indicate a trend toward an increase in the prevalence of type 2 diabetes (T2D) worldwide. Furthermore, the World Health Organization (WHO) predicts that 350 million people will have T2D in the forthcoming years [1]. Type 2 diabetes prevalence has increased sharply in developed and developing countries [2, 3]. Interestingly, the prevalence of T2D in Southeast Asia is considerably higher than in other developed countries. More specifically, a recent study indicates that Indonesia is among the countries with a high prevalence of T2D [4].

A prediabetes condition often initiates type 2 diabetes. Prediabetes is defined as a condition with impaired glucose tolerance (IGT) defined by a 2-h glucose concentration between 140 and 199 mg/dl and/or an impaired fasting plasma glucose (IFG) level [i.e., between 100 and 125 mg/dl] [5]. A recent review describes that individuals with IFG mainly show hepatic insulin resistance and normal or slightly lower whole-body insulin sensitivity. In contrast, individuals with IGT have normal to slightly reduced hepatic insulin sensitivity and show moderate to severe reduced skeletal muscle insulin sensitivity [6]. Insulin resistance contributes to hyperglycemia and hyperlipidemia, all risk factors for developing T2D and cardiovascular diseases (CVDs) [7].

Dietary pattern management is an essential determinant of blood glucose control, even in people without T2D [8]. According to a recent study on the Iranian population, long-term healthy diet quality is associated with a lower risk of CVDs [9]. In addition, a study on China’s population also showed that high salt intake was associated with T2D [10]. Among US adults, increased consumption of added sugar worsens the risk of CVD death in a dose-dependent manner [11]. Moreover, among men and women in the US, fried food consumption was associated with T2D and CVDs. More interestingly, the association was mediated by obesity status in that study [12].

In addition, the findings regarding the relationship between fruit consumption and metabolic disease are also inconsistent. Meta-analyses of randomized controlled trials showed that fruit juice consumption was not associated with T2D risk [13]. However, fruit consumption (whole fruit) was associated with a lower incidence of T2D in a prospective study and meta-analysis [14, 15]. Consumption of fruits and vegetables was linked to better glucose control [16]. A meta-analysis has recently shown that ultra-processed food increases the risk of T2D [17].

However, the extent to which dietary characteristics affect glucose metabolism has yet to be entirely understood. Indeed, higher caloric intake is associated with increased blood glucose and T2D [18], but the association between the types of food consumed and blood glucose levels still needs to be determined. Furthermore, obesity status may influence the interpretation, since obesity is strongly linked to the impairment of blood glucose and the development of insulin resistance.

Therefore, we used nationally representative data from the 2018 Indonesia Basic Health Research (Riskesdas 2018/Riset Kesehatan Dasar 2018) to investigate the association between unhealthy foods and glucose metabolism. This study aimed to determine the link between several components of unhealthy foods and glucose metabolism markers in Indonesian adults with overweight or obesity.

2. Materials and Methods

2.1. Data sources. This study used a population-based, cross-sectional, nationally representative survey (Indonesia Basic Health Research 2018/Riskesdas 2018/Riset Kesehatan Dasar 2018) conducted by the National Institute of Health Research Development (NIHRD), Ministry of Health, Indonesia. In this analysis, up to 2500 censuses from 26 provinces, including 1446 urban and 1054 rural sites, were sub-sampled to represent the national level of biomedical data collection. The sampling and survey methods have been described in detail [19].

Inclusion criteria of this study were individuals aged 18-50 years with a BMI of >23 kg/m^2 were eligible for this study, as were those who had completed data on food frequency consumption, those who had completed data on physical activity questionnaire,and those who had completed data on fasting glucose and 2-hours post-prandial glucose. The data were excluded if (1) respondents had a BMI ≤23 kg/m^2, and (2) the respondent was sick or did not complete all measurements during the study.

2.2. Measurements. Basic characteristics and anthropometric measurements (height and weight) were collected using a standardized protocol by well-trained interviewers. A multi-function brand Stadiometer with a capacity of 2 m and a precision of 0.1 cm was used to measure the standing height. The body weight was measured on a Camry digital weight scale with a capacity of 150 kg. The weight scale was calibrated daily before use. The body mass index (BMI) was calculated as weight (kg) /height squared (m^2) and was determined based on WHO criteria for the Asian population: healthy weight (18.5 to <23 kg/m^2), overweight (23.0 to <27.5 kg/m^2), and obese (≥27.5 kg/m^2) [20]. Several self-reported covariates were collected through interviews: age, gender (men and women), and rural-urban living area.

The respondents were asked about the frequency of sweet, salty, high-fat, grilled, processed, and fruit and vegetable intake in the last week using a validated questionnaire and food card. Food frequency was recorded as >one time (1x)/day, 1x/day, 3–6x/week, 1–2x/week, ≤3x/month, and never. It was categorized in a binary form: frequently (≥1x/day) and rarely (<1x/day) [21]. In food questionnaires, refined carbohydrates included flour-processed foods with added sugar, such as flavored bread. Sweet foods include high-sugar foods with additional natural sugar, e.g., cakes and canned fruit. High-fat and fried foods include high-fat foods, e.g., fatty meats, oxtail soup, fried foods, foods containing coconut milk and margarine, and high-cholesterol foods, such as innards (intestines, tripe), eggs, and shrimp.

To determine blood glucose markers, fasting plasma glucose and 2-h postprandial glucose were employed. According to the American Diabetic Association (ADA) [22, 23], IFG is defined as fasting blood glucose levels of 100–125 mg/dl with normal oral glucose tolerance test (OGTT) results of < 140 mg/dl; IGT is defined as OGTT results of 140–199 mg/dl with normal fasting blood glucose levels of < 100 mg/dl; or both IFG and IGT.

2.3. Statistical Analysis. Pearson's Chi-square test was used to describe the IFG/IGT status based on age groups, gender, sedentary activities, unhealthy food intake, and living area (rural or urban) as categorical variables. First, a simple regression analysis (unadjusted model) was performed with unhealthy foods (refined carbohydrates, salty food, high-fat and fried foods, grilled food, fruit, and vegetables, as well as ultra-processed foods) as independent variables, and IFG/IGT/combination between IFG and IGT as dependent variables (model 1).

Subsequently, multiple regression analysis was performed with body mass index (BMI) added as an independent variable (model 2). Next, multiple regression analysis was performed with physical activity level added as independent variables (model 3) and BMI and physical activity level added together (model 4). Finally, multiple regression analysis was performed to relate unhealthy foods (refined carbohydrates, salty food, high-fat and fried foods, grilled food, fruit, and vegetables, as well as ultra-processed foods) and IFG/IGT or combinations of IFG and IGT adjusted by BMI, physical activity level, age, and sex (model 5). All data were analyzed using SPSS for Mac, version 22.0 (IBM Inc.), and statistical significance was set at $P < 0.05$.

2.4. Ethical Approval. All procedures performed in this study were in accordance with the ethical standards of the institutional research committee, the 1964 Helsinki Declaration and its later amendments, or comparable ethical standards.

3. Results

3.1. Participant characteristics. A total of 8752 subjects were included in this study's analysis. Of these, 16.6% had IFG, 25.6% had IGT, 13.9% had combined glucose intolerance (CGI), and the rest had normal glucose regulations. The majority of individuals in the study were overweight (49.6%). Impaired glucose tolerance was the most common glucose metabolism impairment in the obese, overweight, middle-aged, young, female, urban, rural , frequent consumption of sweet foods, rare consumption of sweet foods, frequent consumption of salty foods, rare consumption of salty foods, frequent consumption of fat foods, rare consumption of fat foods, frequent consumption of grilled foods, rare consumption of grilled foods, rare consumption of processed foods, less consumption of fruit and vegetables, sufficient consumption of fruit and vegetables, lack of physical activity, and sufficient physical activity groups. Interestingly, in the male and frequently consumed processed foods sub-group, IFG was dominant glucose metabolism disorder (Table 1).

Obesity affects 22.6% of the 8752 individuals in the study. In the obese group, the highest percentage of people had impaired glucose metabolism, namely IGT, CGI, and IFG (28.4%, 16.5%, and 16.3%, respectively). While in the overweight group, the highest proportions were IGT, IFG, and CGI (26.2%, 16.6%, and 14.3%, respectively) (Table 1). IFG and CGI are the most prevalent in the 46–50 year-old age group, while IGT is most common in the 41–45 year-old age group (Figure 1).

3.2. Association between the dietary patterns of specific food groups and IFG.

Consumption of sweet, grilled, and processed foods was significantly associated with IFG for all models tested. After adjustment for physical activity (model 2) and BMI and physical activity (model 4), frequent consumption of sweet foods had a risk of IFG of approximately 15% (OR = 1.153, 95% CI = 1.047-1.268). Frequent consumption of grilled food had higher odds of developing IFG than rare consumption of grilled food (model 2, OR = 1.350, 95% CI = 1.056-1.725). The eating pattern with the highest probability of IFG is the consumption of processed foods. In model 5, after adjusting for BMI, physical activity, age, and gender, consumption of processed food >1x/day had a risk of IFG of approximately 72% (OR = 1.729, 95% CI = 1.311-2.280) (Table 2).

3.3. Association between the dietary patterns of specific food groups and IGT. The association test between sweet foods and IGT was found to have significant results in model 1 (unadjusted, p = 0.031); however, frequent consumption of sweet foods was not a risk factor for IGT (OR = 0.924, 95% CI = 0.859-0.993). Different results were shown in the high-fat food group. Interestingly, in unadjusted model 1, consumption of high-fat foods >1x/day had the highest odds of being IGT, which were approximately 12% (OR = 1.124, 95% CI = 1.032-1.225) (Table 3).

3.4. Association between the dietary patterns of specific food groups and CGI. Consumption of sweet foods was associated with CGI (model 2, p=0.013; model 3, p = 0.013; model 4, p = 0.013; model 5, p = 0.016). In models 2, 3, and 4, frequent consumption of sweet foods had a greater probability of developing CGI (OR = 1.173, 95% CI = 1.034-1.331). All models indicate an association between processed food consumption and CGI. In model 5, after adjusting for BMI, physical activity, age, and gender, frequent consumption of processed foods had the highest odds of CGI, approximately 62% (OR = 1,620, 95% CI = 1,150-2.283) (Table 4).

4. Discussion

This study aimed to determine the association between unhealthy eating habits, fruit and vegetable consumption, and impaired glucose status in adults. This study's analysis revealed that eating processed foods > once per day was the strongest risk factor for IFG and CGI, whereas eating high-fat foods frequently was the highest risk factor for IGT. Consistent with the results of the present study, other investigators have reported that consuming foods rich in saturated fat and cholesterol may increase the risk of impaired glucose and insulin regulation [24, 25]. In contrast, a diet high in fruits, vegetables, and whole grains can prevent or control conditions related to insulin resistance, including IFG and IGT [25, 26].

Processed foods and high-fat foods, including fried foods, are high in salt, saturated fat, and cholesterol. The World Health Organization and most nutritional professionals today recognize that a diet rich in salt, saturated fat, and excess sugar is disease-causing. An association between a Western diet characterized by high consumption of red meat, processed meat, fast food, alcoholic beverages, and sugar-sweetened beverages and a higher risk of prediabetes, has also been reported [27, 28]. A study also found that poor dietary quality, excessive consumption of cereals and salt, and insufficient consumption of vegetables, fish, and diet variety, were all associated with an increased risk of prediabetes [29]. Furthermore, several studies have shown a correlation between eating green leafy vegetables (rich in vitamins, trace elements, and soluble dietary fiber) and a reduced risk of T2D [30, 31].

A healthier diet can lower the risk of the development of prediabetes into diabetes by 40% to 70% [32]. The Mediterranean and DASH (Dietary Approaches to Stop Hypertension) diets protect against the development of insulin resistance and T2D [33]. This lends credence to the theory that a plant-based diet with a balanced glycemic index and load, high in soluble fiber and phytochemicals, might be useful in lowering the risk of dysglycemia and prediabetes. The Mediterranean and DASH diets are relatively high in fat from vegetable sources (extra-virgin olive oil, tree nuts). They include an abundance of minimally processed plant foods (vegetables, fruits, whole grains, legumes), moderate fish consumption, low consumption of meat and meat products, and wine in moderation, usually with meals. It has been hypothesized that their positive impact is related to their components [34]. A biological explanation is possible. The antioxidant profile of the diet may prevent the accumulation of oxidative stress, which has been linked to the development of insulin resistance and β-cell dysfunction [35].

In this study, 72.17% of participants were overweight or obese; 16.53% developed IFG, 26.87% had IGT, and 14.99% developed CGI. IFG occurs due to inadequate glucose control, resulting in higher blood glucose even after an overnight fast. In contrast, IGT develops due to an individual's inability to respond to glucose taken as part of a meal, resulting in increased postprandial blood glucose. While both IFG and IGT contribute to insulin resistance, the former is caused by hepatic insulin resistance, while the latter is caused predominantly by insulin resistance in skeletal muscle. Notably, pancreatic β-cell dysfunction is shared by both IFG and IGT [36, 37].

It is well established that IFG can be reverted to normal blood glucose homeostasis with effective intervention. Compared to earlier lifestyle intervention research, intensive lifestyle intervention plays a significant role in educating individuals and assisting them in achieving glycemic control [38]. Without lifestyle modifications and adequate assistance, roughly 9% of patients with IFG will acquire type 2 diabetes within three years [39]. Intensive lifestyle programs, which include diet and physical activity interventions, significantly improve fasting plasma glucose, weight, BMI, triglycerides, high-density lipoprotein cholesterol, and total cholesterol in individuals with IFG [40].

IGT is pre-diabetic hyperglycemia characterized by peripheral insulin resistance, and it has been demonstrated that weight loss and increases in daily energy expenditure reduce the incidence of insulin resistance [41, 42]. In IGT patients, lifestyle changes focused on physical or nutritional therapies, or both, are related to improvements in 2-hour plasma glucose and FPG levels. Furthermore, all individuals with IGT, whether normal or low FPG levels, may benefit from lifestyle changes to delay the development and reduce the incidence of T2DM [43, 44].

The strength of this study is that it uses a large and representative sample in Indonesia and data on dietary intake obtained through interviews using questionnaires and dietary intake cards to minimize bias. This study has limitations, including the fact that it was conducted in a cross-sectional design, prospective cohort studies, or RCTs of diet type modification and its effect on glucose control in overweight/obese people should be conducted. In addition, the data on unhealthy food intake was obtained only from frequency data, so the exact weight of the food consumed (in grams) and energy intake (in kcal) could not be determined. Finally, we do not have data on additional confounding biomarkers such as IGF-1 levels.

5. Conclusions

This population-based study found that eating unhealthy diets increased the risk of impaired glucose metabolism among adults with overweight or obese in Indonesia. Longitudinal studies should be considered to investigate the various impacts of food patterns on glucose metabolism in overweight and obese people. More importantly, health promotions on nutrition and physical activities should be encouraged among overweight and obese individuals, as they can play an essential role in developing healthy eating habits and increasing healthy living behaviors.

Data Availability

The data may be available from the Data Management Laboratory of NIHRD, the Ministry of Health, and the Republic of Indonesia, on reasonable request with prior officially written permission.

Ethical Approval

Ethics and permissions for conducting this study followed the Ethical Approval for RISKESDAS 2018 from the Ethical Committee of Health Research, NIHRD, Ministry of Health, Republic of Indonesia No. LB.02.01/2/KE.267/2017. As RISKESDAS 2018 allowed the authors to analyze the dataset through the data management laboratory in the NIHRD, the ethics referred to the ethical clearance of RISKESDAS 2018. All respondents have provided written approval for their involvement during data collection.

Conflicts of interest

The authors declare no conflict of interest.

Funding

This study was funded by the Institute for Research and Community Services (LPPM-RPIBT), Diponegoro University (185-95/UN7.6.1/PP/2022).

Authors' Contributions

AP, DYF, KHN, MAS, and AS contributed to the conceptualization and methodology. AP analyzed the data and drafted the manuscript. AP and AS reviewed and edited the drafted manuscript. All authors have read and approved the submission of the present version of the manuscript.

5. References

1. Cosentino, F., Grant, P.J., Aboyans, V., Bailey, C.J., Ceriello, A., Delgado, V., Federici, M., Filippatos, G., Grobbee, D.E., Hansen, T.B.*, et al.* 2020. 2019 Esc Guidelines on Diabetes, Pre-Diabetes, and Cardiovascular Diseases Developed in Collaboration with the Easd. *Eur Heart J 41*, 255-323. doi:10.1093/eurheartj/ehz486
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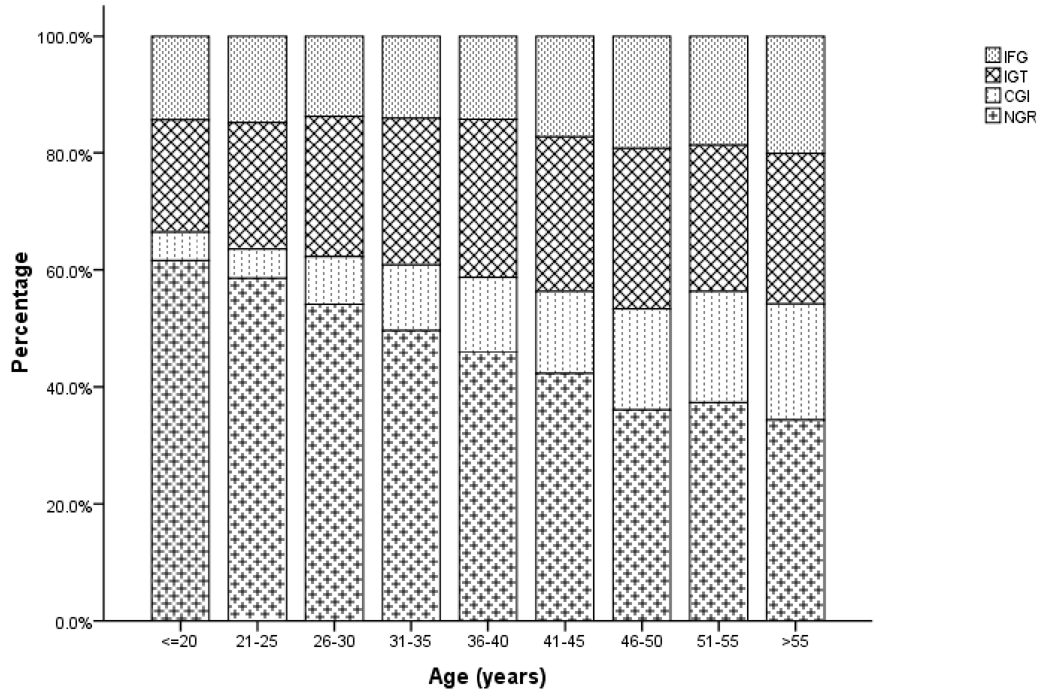

Figure 1: The prevalence of IFG, IGT, and CGI in participants according to a different catgories of age. IFG, impaired fasting glucose; IGT, impaired glucose tolerance; CGI, combined glucose intolerance; NGR, normal glucose tolerance.

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Table 1: Characteristics of the study participants (n=8752)

Characteristics	IFG (n=1452)	IGT (n=2243)	CGI (n=1215)	NGR (n=3842)
BMI				
Obesity, n (%)	1027 (16.6)	1666 (26.9)	934 (15.1)	2577 (41.5)
Overweight, n (%)	425 (16.7)	577 (22.6)	281 (11.0)	1265 (49.6)
Age				
Middle Age, n (%)	938 (18.5)	1335 (26.3)	867 (17.1)	1929 (38.1)
Young, n (%)	514 (14.0)	908 (24.7)	348 (9.4)	1913 (51.9)
Gender				
Male, n (%)	497 (21.1)	454 (19.2)	300 (12.7)	1109 (47.0)
Female, n (%)	955 (14.9)	1789 (28.0)	915 (14.3)	2733 (42.8)
Living Area				
Urban, n (%)	772 (16.8)	1063 (23.1)	648 (14.1)	2124 (46.1)
Rural, n (%)	680 (16.4)	1180 (28.5)	567 (13.7)	1718 (41.4)
Sweet Foods				
Frequent, n (%)	509 (17.3)	682 (23.2)	446 (15.2)	1303 (44.3)
Rare, n (%)	943 (16.2)	1561 (26.9)	769 (13.2)	2539 (43.7)
Salty Foods				
Frequent, n (%)	476 (16.3)	723 (24.8)	405 (13.9)	1317 (45.1)
Rare, n (%)	976 (16.7)	1520 (26.1)	810 (13.9)	2525 (43.3)
High-Fat Foods				
Frequent, n (%)	693 (16.2)	1136 (26.6)	614 (14.4)	1831 (42.8)
Rare, n (%)	759 (16.9)	1107 (24.7)	601 (13.4)	2011 (44.9)
Grilled Foods				
Frequent, n (%)	60 (21.1)	63 (22.1)	45 (15.8)	117 (41.1)
Rare, n (%)	1392 (16.4)	2180 (25.7)	1170 (13.8)	3725 (44.0)
Processed Foods				

Characteristics	IFG (n=1452)	IGT (n=2243)	CGI (n=1215)	NGR (n=3842)
Frequent, n (%)	48 (22.0)	45 (20.6)	43 (19.7)	82 (37.6)
Rare, n (%)	1404 (16.5)	2198 (25.8)	1172 (13.7)	3760 (44.1)
Fruits &Vegetables				
Deficient, n (%)	1340 (16.8)	2025 (25.4)	1113 (13.9)	3504 (43.9)
Sufficient, n (%)	112 (14.5)	218 (28.3)	102 (13.2)	338 (43.9)
Physical Activities				
Deficient, n (%)	207 (19.9)	232 (22.3)	133 (12.8)	470 (45.1)
Sufficient, n (%)	1245 (16.1)	2011 (26.1)	1082 (14.0)	3372 (43.7)

IFG, impaired fasting glucose; IGT, impaired glucose tolerance; CGI, combined glucose impaired; NGR, normal glucose regulation; BMI, body mass index; MET, metabolic equivalent of task; Frequent, ≥1x/ day; Rare, <1x/ day; Deficient, <5 potion/ day or <150 minutes/ week; Sufficient, ≥5 portion/ day or >150 minutes/ week

Table 2: Association between the dietary patterns of specific food groups and IFG

Food Groups	Model 1[a]			Model 2[b]			Model 3[c]			Model 4[d]			Model 5[e]		
	OR	95% CI	*p*	OR	95% CI	*p*	OR	95% CI	*p*	OR	95% CI	*p*	OR	95% CI	*p*
Sweet foods															
Rare	1			1			1			1			1		
Frequent	1.099	1.019 – 1.186	0.015*	1.153	1.047 – 1.268	0.004*	1.152	1.047 – 1.268	0.004*	1.153	1.047 – 1.268	0.004*	1.148	1.042 – 1.264	0.005*
Salty Foods															
Rare	1			1			1			1			1		
Frequent	0.978	0.888 – 1.077	0.653	0.978	0.888 – 1.078	0.657	0.978	0.888 – 1.078	0.657	0.979	0.888 – 1.078	0.660	1.003	0.909 – 1.106	0.960
High-Fat Foods															
Rare	1			1			1			1			1		
Frequent	1.010	0.922 – 1.106	0.831	1.007	0.919 – 1.103	0.883	1.011	0.923 – 1.107	0.814	1.008	0.920 – 1.104	0.866	1.024	0.933 – 1.122	0.621
Grilled Foods															
Rare	1			1			1			1			1		
Frequent	1.344	1.052 – 1.718	0.018*	1.350	1.056 – 1.725	0.017*	1.337	1.046 – 1.708	0.020*	1.342	1.050 – 1.716	0.019*	1.347	1.051 – 1.727	0.019*
Processed Foods															
Rare	1			1			1			1			1		
Frequent	1.657	1.261 – 2.178	0.000*	1.650	1.255 – 2.169	0.000*	1.655	1.259 – 2.175	0.000*	1.648	1.254 – 2.166	0.000*	1.729	1.311 – 2.280	0.000*
Fruits & Vegetables															
Sufficient	1			1			1			1			1		
Deficient	1.153	0.978 – 1.359	0.091	1.142	0.968 – 1.346	0.115	1.147	0.973 – 1.353	0.102	1.136	0.964 – 1.340	0.129	1.146	0.970 – 1.354	0.109

[a]Unadjusted; [b]Adjusted for BMI; [c]Adjusted for physical acticvity; [d]Adjusted for BMI and physical activity; [e]Adjusted for BMI, physical activity, age, and gender; *significant, p<0.05

Table 3: Association between the dietary patterns of specific food groups and IGT

Food Groups	Model 1[a]			Model 2[b]			Model 3[c]			Model 4[d]			Model 5[e]		
	OR	95% CI	*p*	OR	95% CI	*p*	OR	95% CI	*p*	OR	95% CI	*p*	OR	95% CI	*p*
Sweet foods															
Rare	1			1			1			1			1		
Frequent	0.924	0.859 – 0.993	0.031*	0.930	0.849 – 1.019	0.120	0.930	0.849 – 1.019	0.120	0.930	0.849 – 1.019	0.120	0.927	0.846 – 1.016	0.107
Salty Foods															
Rare	1			1			1			1			1		
Frequent	0.945	0.863 – 1.035	0226	0.945	0.863 – 1.036	0.228	0.945	0.863 – 1.035	0.222	0.945	0.862 – 1.035	0.224	0.940	0.857 – 1.031	0.187
High-Fat Foods															
Rare	1			1			1			1			1		
Frequent	1.124	1.032 – 1.225	0.007*	1.120	1.027 – 1.220	0.010*	1.122	1.030 – 1.223	0.008*	1.117	1.025 – 1.218	0.011*	1.111	1.018 – 1.211	0.018*
Grilled Foods															
Rare	1			1			1			1			1		
Frequent	0.932	0.731 – 1.189	0.570	0.937	0.734 – 1.196	0.601	0.943	0.739 – 1.203	0.635	0.948	0.742 – 1.210	0.668	0.965	0.754 – 1.235	0.779
Processed Foods															
Rare	1			1			1			1			1		
Frequent	1.037	0.789 – 1.364	0.793	1.029	0.782 – 1.354	0.840	1.041	0.791 – 1.369	0.777	1.032	0.784 – 1.358	0.823	1.068	0.809 – 1.409	0.644
Fruits & Vegetables															
Sufficient	1			1			1			1			1		
Deficient	0.911	0.784 – 1.059	0.224	0.896	0.771 – 1.042	0.154	0.919	0.791 – 1.068	0.271	0.904	0.778 – 1.051	1.051	0.898	0.771 – 1.045	0.165

[a]Unadjusted; [b]Adjusted for BMI; [c]Adjusted for physical acticvity; [d]Adjusted for BMI and physical activity; [e]Adjusted for BMI, physical activity, age, and gender; *significant, p<0.05

Table 4: Association between the dietary patterns of specific food groups and CGI

Food Groups	Model 1[a]			Model 2[b]			Model 3[c]			Model 4[d]			Model 5[e]		
	OR	95% CI	*p*	OR	95% CI	*p*	OR	95% CI	*p*	OR	95% CI	*p*	OR	95% CI	*p*
Sweet Foods															
Rare	1			1			1			1			1		
Frequent	1.067	0.961 – 1.184	0.225	1.173	1.034 – 1.331	0.013*	1.173	1.034 – 1.331	0.013*	1.173	1.034 – 1.331	0.013*	1.169	1.030 – 1.328	0.016*
Salty Foods															
Rare	1			1			1			1			1		
Frequent	0.998	0.877 – 1.135	0.973	0.998	0.878 – 1.135	0.979	0.998	0.971 – 1.134	0.971	0.998	0.878 – 1.135	0.976	1.012	0.889 – 1.152	0.855
High-Fat Foods															
Rare	1			1			1			1			1		
Frequent	1.082	0.959	0.201	1.078	0.954 – 1.217	0.228	1.081	0.958 – 1.221	0.207	1.076	0.953 – 1.215	0.234	1.084	0.959 – 1.224	0.198
Grilled Foods															
Rare	1			1			1			1			1		
Frequent	1.169	0.845 – 1.617	0.344	1.175	0.849 – 1.625	0.332	1.176	0.850 – 1.627	0.326	1.181	0.854 – 1.635	0.315	1.196	0.862 – 1.659	0.285
Processed Foods															
Rare	1			1			1			1			1		
Frequent	1.543	1.099 – 2.167	0.012*	1.533	1.091 – 2.153	0.014*	1.546	1.101 – 2.170	0.012*	1.535	1.093 – 2.156	0.013*	1.620	1.150 – 2.283	0.006*
Fruits & Vegetables															
Sufficient	1			1			1			1			1		
Deficient	1.061	0.853 – 1.319	0.593	1.045	0.840 – 1.299	0.694	1.066	0.857 – 1.326	0.565	1.050	0.844 – 1.306	0.664	1.051	0.844 – 1.309	0.655

[a]Unadjusted; [b]Adjusted for BMI; [c]Adjusted for physical acticvity; [d]Adjusted for BMI and physical activity; [e]Adjusted for BMI, physical activity, age, and gender; *significant, p<0.05