ORIGINAL ARTICLE

Association of Anthropometric Parameters with Elevated Fasting Blood Sugar among Filipino Adults Aged 18–65 years in Highly Urbanized Cities in the Philippines

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ABSTRACT

Background and Objective. Type II Diabetes Mellitus remains a pressing public health concern among Filipino adults, particularly prevalent in urban households belonging to the middle to richest wealth population. As body composition influences glucose metabolism, understanding the potential of anthropometric parameters is vital in predicting fasting blood sugar. This study aims to generate and find the most appropriate model that can detect likelihood of elevated FBS using different anthropometric parameters.

Methods. The data set from 2018-2019, 2021 Expanded National Nutrition Survey of Department of Science and Technology - Food and Nutrition Research Institute, consisting of 14,655 adults aged 18–65 years from 33 highly urbanized cities (HUCs) was used in this study. While controlling for study variables, multiple logistic regression was used to determine significant predictors affecting the fasting blood sugar (FBS) status of these adults.

Results. The above normal status of each anthropometric parameter, in the models for BMI (aOR=2.33; p<0.01), waist circumference (aOR=2.25; p<0.01), waist-hip ratio (aOR=3.11; p<0.01), waist-to-height ratio (aOR=2.58; p<0.01), was associated with increased likelihood for elevated FBS. Age, sex, blood pressure status, and being a 4Ps recipient were all significantly associated with elevated FBS across the four adjusted final models. While the waist circumference model had the highest and an acceptable correct classification rate of detecting elevated FBS (78.57%), the waist-hip ratio model had the best goodness of fit (F: 29.56; p<0.01).

Conclusion. There is no single anthropometric parameter that can truly discern the status of elevated FBS. However, it appears the use of waist circumference and waist-hip ratio have the potential to be an indicator especially in settings where the evaluation of the actual FBS of the individuals is not feasible. Future research suggests exploring possible interaction of BP, and FBS, diet quality and adequacy, and the effectiveness of having multiple anthropometric parameters in one model.

Keywords: anthropometric parameters, fasting blood sugar, highly urbanized cities, Type II Diabetes Mellitus

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INTRODUCTION

Type II Diabetes Mellitus (T2DM) is an irreversible chronic condition that represents a significant global health challenge.[1] Various key risk factors contributing to the development of T2DM include poor lifestyle, obesity, physical inactivity, age, hormonal imbalance, family history, and hypertension.[2-4] One of the most evident factors related to T2DM is the increased abdominal and intra-abdominal fat, along with high levels of intrahepatic and intramuscular triglycerides causing insulin resistance, highlighting obesity as one of the major contributors of this metabolic disease.[5]

In relation to abdominal fat distribution, overweight/ obesity is one of the major causative factors leading to micronutrient deficiencies, T2DM, cardiovascular diseases, hypertension, and other lifestyle-related diseases. In the Philippines, the prevalence of overweight and obese has doubled, increasing from 16.6% (1993) to 36.6% (2018-2019) among adults.[6] Meanwhile, Mouri and Badireddy observed the highest incidences of high blood sugar in China, United States, Brazil, and Russia.[7] In the Philippines, 7 out of 10 adults had a higher than normal blood glucose levels, with the highest prevalence reported among the richest households and those in urban areas.[6]

One of the hallmarks of T2DM is hyperglycemia characterized by elevated fasting blood sugar (FBS) of 100 mg/dL to 125 mg/dL for pre-diabetes and above 125 mg/dL that occurs from either insufficient insulin production or the body's inability to utilize insulin effectively. This condition is characterized by a reduced production of insulin and competitive inhibition with excessive fatty acids can result in the build-up of sugar in the bloodstream. The uncontrolled blood sugar can lead to symptoms such as extreme thirst, frequent urination, extreme hunger, fatigue, and sudden weight loss.[8]

Hyperglycemia and obesity are linked to several lifestyle diseases including T2DM which ranks fourth among the leading health problems in the Philippines.[9] Several lifestyle practices including sedentary lifestyle and poor diet, as well as non-modifiable risk factors like genes and age have significant correlation on the occurrence of obesity and hyperglycemia.[10]

Understanding anthropometric parameters is vital in predicting FBS, as these measurements reflect aspects of body composition that influence glucose metabolism.[11,12] Studies have demonstrated that it can effectively indicate an individual's risk of T2DM by reflecting underlying metabolic changes.[13,14] These parameters provide different indices in assessing the risk of hyperglycemia. BMI is widely used to classify obesity, while waist and hip circumferences provide a better assessment of central adiposity. Evidence shows that high waist and hip circumferences correlates with prevalence of high blood sugar.[15,16] However, the use of BMI as an indicator for differentiating lean body mass from adipose tissue has less success due to poor prognosis.[17] Meanwhile, the use of waist-hip ratio and waist-to-height ratio are effective parameters in measuring the occurrence of hyperglycemia in women.[17,18]

In the Philippines, a significant research gap exists regarding the link between increasing obesity rates and the increasing prevalence of T2DM. Despite the upward trends in both conditions, there is a lack of specific studies examining the direct relation between these health concerns. The utility of anthropometric parameter in predicting the risk of elevated FBS among Filipino adults is potentially valuable in resource-limited settings, wherein evaluation of actual FBS is not feasible. It may also serve as a more convenient and non-invasive manner of screening adults who are at risk of having hyperglycemia. Hence, the study aims to generate and find the most appropriate model that can detect the likelihood of elevated blood glucose using different anthropometric parameters.

METHODS

Study Design

The study utilized analytic cross-sectional study design to determine the different factors associated with the elevated FBS. This enabled gathering of information on the exposure and outcomes simultaneously at a single point in time (duration of data collection). The cross-sectional design allowed the examination of several outcomes and evaluate a variety of risk factors. Moreover, it allowed the measurement of the prevalence of all variables under investigation and the comparison of variables at the same point in time, without incurring additional costs.

Furthermore, losses to follow up and attrition during the study was not an issue with a cross-sectional design and the researcher had good control over the ascertainment process. In this type of study, the completeness of key data is maximized compared to a retrospective study.

Study Setting

The study utilized data from HUCs in the Philippines due to the increasing rates of obesity and T2DM. As urbanization progresses, prevalence rates have emerged, largely due to changes in diet and physical activity driven by the spread of fast-food restaurants and multinational super-markets. This trend makes calorie-dense and sugary foods more accessible, while urban environments contribute to physical inactivity through sedentary jobs and reduced spaces for recreation.[19]

According to recent data, there has been a notable increase in trends of overweight and obesity in urbanized cities in the Philippines.[6] Food and physical environments promote unhealthy practices (e.g., increased consumption of calorie-dense foods and sedentary behavior), and contribute to higher rates of overweight and obesity among individuals with higher socio-economic status in urban areas.[20,21]

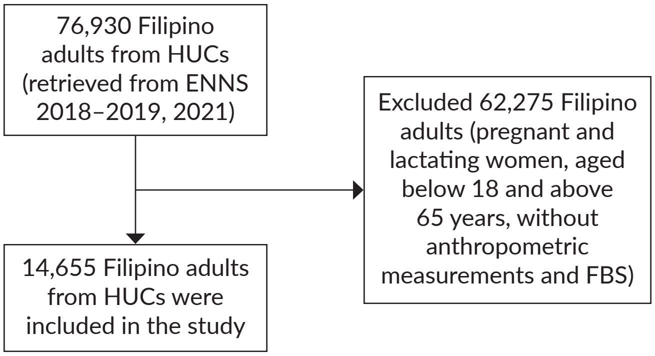

Figure 1. Process flow for the selection of study participants.

Sampling Design and Study Participants

This study utilized secondary data from the 2018–2019, 2021 Expanded National Nutrition Survey (ENNS), which employed the 2013 Master Sample (MS) of the Philippine Statistics Authority for its sampling design. This includes the identified 33 HUCs in the country and its details can be found elsewhere.[6] Population was divided into exhaustive, non-overlapping areas called PRUs, comprising roughly 100 to 400 households. Commonly, each PSU within a province or HUC is allocated 12 to 16 sample housing units or households.

This study focused on Filipino adults aged 18–65 years old from HUCs in the Philippines with complete data on anthropometric, biochemical, and dietary assessments. However, Filipino adults who were currently pregnant and lactating during the time of study were excluded. The records of 76,930 individuals were retrieved from the secondary data of the ENNS. After excluding participants who were pregnant, lactating, aged below 18 years and above 65 years, and without any anthropometric measures, only 30,295 participants were included. After excluding study participants without fasting blood sugar, only the data of 14,655 individuals were included in the study (Figure 1).

Data Collection and Processing

Training and Recruitment Process

Standards for qualifying potential field researchers/data collectors were established and distributed to the applicant pool. Job openings were advertised through the official website of FNRI, and various online recruitment sites and social media platforms. The selection process included screening, a month of in-depth training, field practicum, and reliability assessments facilitated by DOST-FNRI. The team of field researchers consisted of nutritionist-dietitians for anthropometric and dietary assessments, nurses and allied health professionals for clinical and health assessments, and medical technologists for the collection of biochemical samples.[6]

Calibration of Research Equipment and Tools

All the survey equipment and tools used in field operations, including the digital weighing scale, stadiometer, sphygmomanometer, and electric centrifuge, were calibrated according to the National Metrology Laboratory of the Industrial Technology Development Institute (ITDI) of DOST standards. Weekly air leak tests were conducted for the sphygmomanometers and both the maintenance and calibration procedures were carried out during field data collection. Also, spare parts and extra units of the survey instrument were kept on hand to promptly replace any damaged or malfunctioning equipment on-site.[6]

Orientation of the Participants about the Data Collection Procedure

Before the actual conduct of the ENNS, respondents were provided with informed consent forms to affirm their voluntary participation. These forms outlined the survey's objectives, types of data to be collected, methods of data collection, and included a confidentiality agreement to protect their information. Participation was entirely voluntary, and respondents had the right to withdraw from the survey at any time.[6]

Actual Survey Tools

The data were obtained using the following research instruments:

1. ***Socio-demographic and Lifestyle Characteristics Profile.*** The socio-demographic and lifestyle characteristics of the participants were obtained via face-to-face interview with the use of an electronic data collection system. The lifestyle characteristics (smoking, alcohol drinking, and physical inactivity) were operationally defined using the relevant WHO Guidelines.
2. ***Anthropometric Assessment.*** The participants' anthropometric measurements, i.e., weight, height, waist and hip circumferences, were obtained by trained allied health professionals (e.g., nutritionist-dietitians and nurses) following the standard set of protocols.
   a. *Height.* This was measured using a stadiometer featuring a vertical ruler and sliding horizontal rod, recorded to the nearest 0.1 cm. If the difference exceeded 0.5 cm, a third reading was taken.
   b. *Weight.* This was measured using a calibrated double window digital scale with 150–200-kilogram (kg) capacity. Each weight was recorded to the nearest 0.01 kg, and measurements were taken twice. If the difference between the two readings exceeded 0.3 kg, a third measurement was performed to ensure accuracy.
   c. *Waist and Hip circumferences.* Abdominal obesity was assessed using a non-stretchable tape measure. Waist circumference was measured at the narrowest point of the abdomen, midway between the lowest

rib and the iliac crest, while hip circumference was measured at the widest part of the hips, typically around the buttocks. Each measurement was repeated three times and recorded to the nearest 0.1 cm, with additional measurement/s if discrepancies exceeded 0.5 cm.

3. ***Fasting Blood Sugar.*** The venous blood drawn from the participants after a 10-hour overnight fasting through a venipuncture was collected in a vacutainer with lithium heparin anticoagulant. To determine the FBS levels, the blood samples were analyzed using an enzymatic colorimetric method through Roche COBAS Integra and Hitachi 912.

Operational Definition of Variables

The operational definitions of the different variables used in the study are detailed in Table 1.

Data Analysis

Study data were processed using the software STATA version 12. Proportions were used to estimate the point, and 95% confidence interval estimates of the prevalence of different outcomes (e.g., elevated FBS) among Filipino adults in HUCs. In addition, a series of chi-square tests of association and a set of crude and adjusted logistic regression models were created. In the process of arriving at the adjusted logistic regression models, the backward elimination was utilized. All available possible explanatory variables were first

Table 1. Definition and Measurement of Variables of the Study

Variables	Operational Definition	Categories
Fasting blood sugar status	The status of the participant's FBS levels after he/she has fasted for 10 hours, based on the 2006 WHO and IDF's cutoff for normal level: <110 mg/dL	Normal: <110 mg/dL Above Normal: ≥110 mg/dL
Blood pressure status	When the participant has an average blood pressure of at least 140/90 mm Hg as defined as Stage 1 Hypertension according to NIH: JNC VII, 2004	Optimal: <140/90 mm Hg Elevated: ≥140/90 mm Hg
BMI status	When the participant's BMI is higher than or equal to 25.00 kg/m^2, the WHO's classification for overweight	Healthy weight: <25.00 kg/m^2 Overweight/obese: ≥25.00 kg/m^2
Waist circumference	The average value after three measurements of the waist (around the smallest part of the abdomen) of the participant using a non-stretchable tape measure. Acceptable values are 90–101 cm among males, and 80–87 cm among females.	Males Normal: 90–101 cm Elevated: ≥102 cm Female Normal: 80–87 cm Elevated: ≥88 cm
Waist-to-hip ratio	When the ratio of the participant's waist and hip measurements (in cm) are at least 1.00 among males or 0.85 among females.	Males Normal: <1.00 High: ≥1.00 Females Normal: <0.85 High: ≥0.85
Waist-to-height ratio	When the ratio of the participant's waist and height measurements (in cm) is at least equal to 0.50.	High: ≥0.50 Normal: <0.50
Alcohol intake status	The participant's alcohol intake behavior, either if he/she has ever consumed any alcoholic drink (e.g., beer, wine, or spirits), (former drinker or abstainer) or if he/she has consumed an alcoholic drink within the past 12 months (current drinkers)	Abstainer Current drinker Former drinker
Smoking status	The status of the participant if he/she has ever smoked any tobacco products in the past week (current), in the past year prior to the survey (former), or never.	Non-smoker Current smoker Former smoker
General physical activity	The general physical activity classification of the participant as assessed using the WHO Global Physical Activity Questionnaire (GPAQ).	Low High
Ethnicity	The status of the participants if he/she belongs to an indigenous group as he/she claims.	Not belonging to indigenous people Belonging to indigenous people
Household wealth index	A proxy indicator for the long-term living standard of the participant's household; it is computed from several socio-economic variables (e.g., household assets, household characteristics, etc.)	Poorest Poor Middle Rich Richest
Recipient of Pantawid Pamilyang Pilipino Program (4Ps)	The status of being a recipient of the government's 4Ps	No Yes

included in the first model then the variable with the highest p-value was removed. More variables were removed until the reduced model, which best explained the data, was produced.

Satisfaction of regression models were ensured during the analysis. The level of significance for all statistical procedures performed used α=0.05.

Ethical Considerations

The data was requested through a Memorandum of Agreement with the DOST-Food and Nutrition Research Institute and University of the Philippines Manila, College of Public Health. The study protocol was registered with the Research Grants Administration Office (RGAO) with RGAO Reference Number 2023-1069. The conduct of the Expanded National Nutrition Survey was approved by the Ethics Committee of the DOST-FNRI with protocol number FIERC-2017-017. Informed consent from the surveyed households were obtained prior to participation in the study.

RESULTS

Demographic Profile of the Study Participants

The majority (44.22%) of participants were between 18 to 40 years old, with over half (55.39%) being female. Only a few (2.76%) of the participants belonged to a specific indigenous group. More than a quarter of the households were in the poor and middle quintiles, with only a few belonging to the rich and richest quintiles (16.55% and 14.43%, respectively). More than half (65.28%) of them did not smoke, while nearly half (48.36%) are current binge drinkers. Additionally, above half (59.31%) engage in high levels of physical activity. Details are shown in Table 2.

Prevalence of Select Outcomes among Adults in HUCs

The majority (92.26%) exhibited an optimal blood pressure (BP). Similarly, 67% of the participants were of normal nutritional status based on their BMI. In terms of waist and hip measurements, including waist circumference, waist-hip ratio, and waist-to-height ratio, the majority (89.12%, 67.18% and 54.58%, respectively) of the participants were within acceptable limits. Furthermore, most (83.87%) of the participants demonstrated normal levels of FBS (Table 3).

Association of Anthropometric Parameters with Elevated Fasting Blood Sugar among Adults in HUCs of the Philippines

Seven out of 10 adults with normal FBS had a healthy weight, while five out of 10 adults with elevated FBS were overweight/obese. The majority of participants (90.11%) with non-elevated FBS tend to have low waist circumference, compared to 77.59% individuals with elevated FBS. Among the study participants with normal FBS, six out of 10 have a low waist-hip ratio. Whereas about half of the individuals

Table 2. Demographic Characteristics, Fasting Blood Sugar Status, Blood Pressure Status, and Nutritional Status of Filipino Adults from Highly Urbanized Cities of Philippines, 2018–2019, 2021, n=14,655

Demographic characteristics	n	%
Age (years)		
18–40	6,481	44.22
41–60	5,525	37.70
>60	2,649	18.08
Sex		
Male	6,538	44.61
Female	8,117	55.39
Ethnicity		
Belongs to an indigenous group	404	2.76
Does not belong to any indigenous group	14,030	95.74
Unknown	221	1.51
Household wealth index		
Poorest	2,954	20.16
Poor	3,924	26.78
Middle	3,238	22.09
Rich	2,425	16.55
Richest	2,114	14.43
Smoking		
Never	9,567	65.28
Current	2,513	17.15
Former	2,172	14.82
Unknown	403	2.75
Binge drinking/ Alcohol intake		
Abstainer	4,030	27.50
Current	7,087	48.36
Former	3,135	21.39
Unknown	403	2.75
General Physical Activity		
High	8,692	59.31
Low	5,635	38.45
Unknown	328	2.24

Table 3. Proportion Estimates of Filipino Adults from HUCs of Philippines according to Blood Pressure Status, Nutritional Status, Fasting Blood Sugar Level Status, and Anthropometric Parameters, 2018-2019, 2021

Status	Proportion (95% CI)
Blood pressure status (mm Hg)	
Optimal (<140/90)	92.26 (91.42–93.02)
Elevated (≥140/90)	7.73 (6.98–8.58)
BMI status	
Healthy weight	67.00 (65.55–68.42)
Overweight/Obese	33.00 (31.58–34.45)
Waist circumference (cm)	
Low	89.12 (88.22–89.96)
High	10.88 (10.04–11.78)
Waist-hip ratio	
Low	67.18 (65.77–68.56)
High	32.82 (31.44–34.23)
Waist-to-height ratio	
Low	54.58 (53.03–56.12)
High	45.42 (43.88–46.70)
Fasting blood sugar status (mg/dL)	
<110	83.87 (82.70–84.97)
≥110	16.13 (15.03–17.30)

Table 4. Association of Anthropometric Parameters with Elevated Fasting Blood Sugar Status among Filipino Adults from HUCs of Philippines, 2018-2019, 2021

Covariates	Fasting blood sugar status, n (%)	
	Normal	Elevated
BMI status		
Healthy weight	8,388 (70.10)	1,234 (50.18)
Overweight/Obese	3,578 (29.90)	1,225 (49.82)
Waist circumference (cm)		
Low	10,783 (90.11)	1,908 (77.59)
High	1,183 (9.89)	551 (22.41)
Waist-hip ratio		
Low	7,958 (66.51)	1,226 (49.86)
High	4,007 (33.49)	1,233 (50.14)
Waist-to-height ratio		
Low	6,666 (55.75)	733 (29.81)
High	5,291 (44.25)	1,726 (70.19)

with elevated FBS have either low or high waist-hip ratio. Moreover, more than half (55.75%) of the adults with normal FBS indicate a low waist-to-height ratio, while seven out of 10 adults with elevated FBS have a high ratio (Table 4).

Crude Association of Socio-demographic, Lifestyle Factors, and Anthropometric Parameters with Elevated Fasting Blood Sugar of Filipino Adults from HUCs

Table 5 summarizes the crude association of selected a priori variables which are known to contribute to elevated FBS, such as certain socio-economic, lifestyle factors, alongside anthropometric parameters with FBS among the study participants. In terms of age, the odds of having elevated FBS was at least three times higher among participants who were 41–60 years of age compared to those who were less than 41 years old (OR=3.27; p<0.01). Moreover, the odds also increased if the participants were older than 60 years old (OR=3.83; p<0.01).

Considering the household wealth quintile, there was no sufficient evidence suggesting that having an elevated FBS was associated with an individual belonging in the poor quintile compared to their poorest quintile counterpart. In relation to wealth quintiles, being a recipient of 4Ps could decrease the likelihood of having elevated FBS by 37% (OR=0.63; p<0.01) compared to those who were not beneficiaries. However, the odds of having elevated FBS increased by 132% (OR=1.32; p=0.03), 178% (OR=1.78; p<0.01), and 164% (OR=1.64; p<0.01), respectively, among Filipino adults belonging in the middle, rich, and richest quintile compared to those who belong to their poorest counterpart.

In terms of different anthropometric parameters, the odds of having elevated FBS was 2.7 times higher among overweight/obese adults (OR=2.73; p<0.01) while it was 2.6 times higher among those with above normal waist circumference (OR=2.64; p<0.01) compared to those with normal BMI and waist circumference. Moreover, the odds

Table 5. Crude Association of Socio-economic and Lifestyle Factors with Fasting Blood Sugar among Filipino adults from HUCs of Philippines, 2018-2019, 2021

Predictors	Blood sugar status	
	OR (95% CI)	*p*-value
Age (years)		
<41	Ref	Ref
41–60	3.27 (2.65–4.04)	<0.01
>60	3.83 (3.04–4.81)	<0.01
Sex		
Male	Ref	Ref
Female	0.857 (0.73–1.01)	0.07
Ethnicity		
Non-member	Ref	Ref
Member	0.86 (0.62–1.19)	0.36
Recipient of 4Ps		
No	Ref	Ref
Yes	0.63 (0.52–0.77)	<0.01
Household wealth index		
Poorest	Ref	Ref
Poor	1.04 (0.83–1.30)	0.73
Middle	1.32 (1.03–1.69)	0.03
Rich	1.78 (1.38–2.29)	<0.01
Richest	1.64 (1.28–2.11)	<0.01
BMI status		
Normal	Ref	Ref
Above normal	2.73 (2.30–3.24)	<0.01
Waist circumference (cm)		
Normal	Ref	Ref
Above normal	2.64 (2.17–3.23)	<0.01
Waist-hip ratio		
Normal	Ref	Ref
Above normal	2.15 (1.82–2.55)	<0.01
Waist-to-height ratio		
Normal	Ref	Ref
Above normal	3.34 (2.77–4.04)	<0.01
Blood pressure status		
Optimal	Ref	Ref
High	2.87 (2.25–3.65)	<0.01
Physical activity		
High	Ref	Ref
Low	1.13 (0.95–1.34)	0.16
Smoking status		
Non-smoker	Ref	Ref
Current	0.88 (0.70–1.12)	0.30
Former	1.42 (1.14–1.78)	<0.01
Alcohol intake status		
Never	Ref	Ref
Current	0.85 (0.71–1.03)	0.09
Former	0.77 (0.62–0.96)	0.02

of having elevated FBS increased by 2.2 times (OR=2.15; p<0.01) and 3.3 times (OR=3.34; p<0.01), respectively, if the waist-hip and waist-to-height ratios were above normal compared to those with normal ratios.

In relation to anthropometric parameters, those with an elevated BP were almost thrice as likely to have an elevated FBS compared to those with optimal BP (OR=2.87; p<0.01). However, former smokers were 142% more likely

Table 6. Adjusted Association of Different Exposure Variables to Elevated Fasting Blood Sugar among Filipino Adults in HUC according to Different Anthropometric Parameters

Predictors	Anthropometric Parameters							
	Body Mass Index		Waist Circumference		Waist-Hip Ratio		Waist-to-Height Ratio	
	aOR (95% CI)	*p*-value	aOR (95% CI)	*p*-value	aOR (95% CI)	*p*-value	aOR (95% CI)	*p*-value
Anthropometric parameter used*								
Normal	Ref		Ref		Ref		Ref	
Above normal	2.33 (1.88–2.89)	<0.01	2.25 (1.73–2.93)	<0.01	3.11 (2.30–4.22)	<0.01	2.58 (2.07–3.22)	<0.01
Age (years)								
<41	Ref		Ref		Ref		Ref	
41–60	2.84 (2.25–3.59)	<0.01	2.85 (2.25–3.61)	<0.01	2.67 (2.10–3.40)	<0.01	2.55 (2.02–3.22)	<0.01
>60	3.65 (2.80–4.75)	<0.01	3.23 (2.48–4.21)	<0.01	3.08 (2.35–4.05)	<0.01	3.06 (2.34–4.00)	<0.01
Sex								
Male	Ref		Ref		Ref		Ref	
Female	0.71 (0.54–0.92)	0.01	0.63 (0.48–0.82)	<0.01	0.37 (0.27–0.51)	<0.01	0.63 (0.49–0.82)	<0.01
Blood pressure status								
Optimal	Ref		Ref		Ref		Ref	
High	1.46 (1.09–1.95)	0.01	1.58 (1.18–2.10)	0.01	1.54 (1.16–2.05)	<0.01	1.46 (1.11–1.92)	0.01
Physical activity								
High	Ref		Ref		Ref		Ref	
Low	1.15 (0.94–1.42)	0.17	1.21 (0.98–1.49)	0.07	1.21 (0.99–1.49)	0.07	1.18 (0.96–1.45)	0.12
Smoking status								
Never	Ref		Ref		Ref		Ref	
Current	0.91 (0.65–1.29)	0.60	0.87 (0.61–1.22)	0.41	0.86 (0.61–1.21)	0.40	0.91 (0.64–1.30)	0.61
Former	1.12 (0.81–1.53)	0.50	1.14 (0.84–1.57)	0.40	1.09 (0.80–1.50)	0.58	1.08 (0.79–1.49)	0.63
Alcohol intake								
Abstainer	Ref		Ref		Ref		Ref	
Current	0.87 (0.69–1.10)	0.26	0.89 (0.70–1.13)	0.36	0.90 (0.71–1.14)	0.37	0.87 (0.69–1.10)	0.25
Former	0.77 (0.58–1.01)	0.06	0.79 (0.60–1.03)	0.08	0.78 (0.59–1.02)	0.07	0.78 (0.60–1.02)	0.07
Recipient of 4Ps								
No	Ref		Ref		Ref		Ref	
Yes	0.69 (0.56–0.86)	<0.01	0.65 (0.52–0.80)	<0.01	0.67 (0.54–0.83)	<0.01	0.70 (0.56–0.87)	<0.01

to have elevated FBS compared to those who never smoked (OR=1.42; p<0.01). A similar interpretation can be noted regarding alcohol intake status where former alcohol drinkers were 23% less likely to have elevated FBS compared to those who never drank alcohol (OR=0.77; p<0.02).

Adjusted Models on the Association of Different Anthropometric Parameters to Elevated Fasting Blood Sugar among Filipino Adults in HUC

All the predictors discussed above were considered to ensure that their effects on the association of each elevated anthropometric parameter status and FBS status can be controlled. However, certain factors that were discussed, such as being a member of an ethnic group and household quintile did not make it to the final multiple models.

BMI Model

After controlling for other predictors, the odds of elevated FBS were two times higher among adults who were overweight/obese compared to their counterparts with normal nutritional status based on their BMI (aOR=2.33; p<0.01). Those who were aged 41–60 years and over 60 years were 2.8 and 3.7 times, respectively, more likely to have elevated FBS compared to those who were younger than 41 years old (aOR=2.84; p<0.01; aOR=3.65; p<0.01). The odds of having elevated FBS was 29% less among females compared to males (aOR=0.71; p=0.01). It can also be noted that the odds of having elevated FBS were 146% more among those with high BP compared to those with optimal BP (aOR=1.46; p=0.01). Lastly, compared to their counterparts, 4Ps recipients were 31% less likely to have elevated FBS (aOR=0.69; p<0.01) (Table 6).

Waist Circumference Model

After controlling for other predictors, the odds of elevated FBS were two times higher among adults who have above normal waist circumference compared to those who have normal waist circumference measurement (aOR=2.25; p<0.01). It can be noted that those who were aged 41–60 years and over 60 years were 2.9 and 3.2 times, respectively, more likely to have elevated FBS compared to those who were younger than 41 years old (aOR=2.85; p<0.01; aOR=3.23; p<0.01). Additionally, the odds of having elevated FBS was 37% less among females compared to males (aOR=0.63; p<0.01). Furthermore, the odds of having elevated FBS were 158% more among those with high BP compared to those with optimal BP (aOR=1.58; p=0.01), compared to their counterparts. It can also be noted that those who are 4Ps recipients were 35% less likely to have elevated FBS (aOR=0.65; p<0.01). Details are shown in Table 6.

Waist-hip Ratio Model

After holding the other variables constant, adults who have normal waist-hip ratio were three times more likely to have elevated FBS compared to those who have normal ratio (aOR=3.11; p<0.01). It can be noted that the odds of having elevated FBS among those who were aged 41–60 years and over 60 years were 2.7 and 3.1 times, respectively, higher compared to those who were younger than 41 years old (aOR=2.67; p<0.01; aOR=3.08; p<0.01). In terms of sex, the odds of having elevated FBS was 63% less among adult females compared to adult males (aOR=0.37; p<0.01). It can also be noted that adults with high BP were 154% more likely to have elevated FBS compared to those with optimal BP (aOR=1.54; p<0.01). Additionally, those who are 4Ps recipients were 33% less likely to have elevated FBS (aOR=0.67; p<0.01) (Table 6).

Waist-to-Height Ratio Model

After controlling for other predictors, the likelihood of elevated FBS was about three times higher among adults who have above normal waist-to-height ratio compared to their counterparts with normal ratio (aOR=2.58; p<0.01). Additionally, those who were aged 41–60 years and over 60 years were 2.6 and 3.1 times, respectively, more likely to have elevated FBS compared to those who were younger than 41 years old (aOR=2.55; p<0.01; aOR=3.06; p<0.01). It can also be noted that the odds of having elevated FBS was 37% less among females compared to males (aOR=0.63; p<0.01). In terms of BP status, the odds of having elevated FBS were 146% higher among those with high BP compared to those with optimal BP (aOR=1.46; p=0.01). Furthermore, adults who are 4Ps recipients were 30% less likely to have elevated FBS (aOR=0.70; p<0.01). Details are shown in Table 6.

Across the Four Anthropometric Parameter Models

Controlling for the presence of notable predictors, the data showed that an elevated waist-hip ratio among adults posed the highest likelihood of having elevated FBS (Table 6). Consistent across the four anthropometric parameters, an increase in age was associated with a higher likelihood of elevated FBS. It was noted that there was also a consistent significant reduction of the likelihood of elevated FBS among females compared to males across the four models. However, the reduction was greatest (63% lower) for the waist-hip model. Across the models, another consistent reduction in the likelihood of elevated FBS was observed in recipients of 4Ps compared to their counterparts. Furthermore, it was noted that having elevated BP is associated with higher likelihood of elevated FBS regardless of the anthropometric parameters used.

In terms of model metrics, although all the models had significant p-values, the model with the highest value of the goodness-of-fit statistic (F: 29.56 p<0.001) was the waist-hip ratio model. However, among the four models, only the waist circumference model has the highest and an acceptable correct classification rate of detecting elevated FBS (78.57%). The BMI and waist-hip ratio models have rates higher than 60% at 66.64% and 63.72%, respectively, while the waist-to-height ratio model had a correct classification rate of 58.21%.

DISCUSSION

Prevalence of Select Outcomes among Adults in HUCs

Despite the data suggesting most study participants are healthy, the persistent public health challenge of T2DM highlights the need for continuous monitoring, particularly as diabetes-related complications become increasingly prevalent, even in seemingly low-risk populations. In a comparable study by Mirzaei and Khajeh,[22] both men and women with diabetes had higher average values for BMI, waist circumference, waist-hip ratio, and waist-to-height ratio compared to non-diabetics. Meanwhile, as per Zhang et al.,[23] diabetes trends differed by sex, age, region, and other factors, and identified obesity, age, family history, and education as significant risk factors.

Elevated FBS and obesity predispose adult individuals to develop T2DM.[24] According to Chandrasekaran and Weiskirchen,[25] central obesity is a better predictor of T2DM than BMI in Asians. The majority of individuals with T2DM are obese, often characterized by a higher percentage of body fat or abnormal fat distribution. Adipose tissue contributes to insulin resistance by releasing increased levels of free fatty acids. Dysfunction in the pathways governing precursor cell differentiation and adipocyte proliferation impairs adipogenesis, limiting the body's ability to effectively store excess lipids, and resulting in insulin resistance exacerbated by ectopic fat accumulation.[26]

Statistics have shown that there has been a notable twofold increase in the trends of overweight and obesity from 1993 to 2018-2019, 2021 in the Philippines.[6] Chopra et al.[27] stated that Indian women were found to have a significantly higher prevalence compared to men due to poor dietary intake and sedentary lifestyles. Overweight and obesity were also observed in urban areas and among individuals in the wealthiest quintile, compared to those in rural areas and the poorest quintile.[28] Asian-Indian and Japanese women exhibit a higher prevalence of android obesity, indicated by greater waist and hip circumferences than men, compared to Caucasians.[29] Asians tend to exhibit greater adiposity than whites due to factors such as lower birth weight, smaller body size, and shorter leg-to-trunk ratio, indicating a body composition with less skeletal and muscle mass, and more body and trunk fat for individuals with similar BMI.[30]

According to DOST-FNRI, the true prevalence of high blood pressure is slightly higher than figures derived from single visits.[6] This discrepancy may be due to the inclusion of individuals with a history of hypertension and those taking anti-hypertensive medications. Furthermore, the prevalence of elevated FBS has a notable increase as well from 2008 to 2018-2019, 2021.

T2DM can develop even in individuals who currently have favorable health indicators, as some may have normal FBS but still be at risk due to undiagnosed insulin resistance or other metabolic dysfunctions.[31] Such subclinical conditions may not be detected through standard measurements but can significantly increase the risk overtime. This demonstrates that while the current data fall within acceptable limits, it does not fully account for all potential risks.

Between 2007 and 2017, there has been a concerning increase in the prevalence of diabetes, emerging as one of the leading causes of disability in the country.[32] The rise in the trends is largely linked to dietary issues, with inadequate access to nutrient-dense foods at work cited as a major challenge to maintaining a balanced diet. Given that six out of 10 Filipino adults are part of the workforce, addressing workers' nutritional needs and promoting healthier lifestyle choices are vital.[33] Recent data also revealed an increasing prevalence of diabetes in the Philippines, exacerbated by rapid urbanization, increased screen time in gadgets, and sedentary lifestyle.[21]

Association of Anthropometric Parameters with Elevated Fasting Blood Sugar among Adults in HUCs of the Philippines

In this present study, lower BMI was found to be associated with normal FBS levels, albeit inconsistent across all age groups and individuals. This can be explained by several factors such as genetic predisposition or variations in insulin sensitivity, allowing individuals with healthy weight who developed T2DM to metabolize glucose differently from those who are overweight with T2DM. It was also noted that non-obese individuals with T2DM exhibit a more significant β-cell dysfunction, a primary pathogenic mechanism of the disease.[34,35]

Moreover, it was also observed that some individuals classified as obese might appear metabolically healthy, but this does not imply overall health, as they may still develop health issues over time.[36] The result of this study is consistent with existing literature indicating that BMI of an individual is linked with metabolic health.[37] However, it is vital to recognize that excess body fat, particularly visceral fat, is a critical contributor to insulin resistance and impaired glucose metabolism.[38]

Further analysis reveals that a significant majority of participants with normal FBS levels have lower ratios of waist circumference, waist-hip ratio, and waist-to-height ratio, compared to those with elevated FBS, wherein most adults tend to have a higher waist-to-height ratio. This supports the concept that central obesity is a crucial factor and a stronger predictor of insulin resistance and T2DM risk than BMI alone, as it contributes to metabolic disturbances that elevates blood sugar levels.[39-41] Garnett, Baur and Cowell[42] also noted that waist-to-height ratio offers advantages by eliminating the need for sex- and ethnicity-specific cutoffs, thereby reducing confusion and potentially useful in public health settings. These findings suggest that a more comprehensive evaluation of T2DM should incorporate multiple anthropometric parameters than relying solely on a single parameter.

It was also noted that across the four anthropometric parameters, the waist circumference performs the best in screening out most of the participants who have normal FBS. On the other hand, waist-to-height ratio works best in screening individuals who have elevated FBS (Table 4). The finding highlights the differential effectiveness of anthropometric parameters in assessing FBS levels. This suggests that waist circumference is a reliable marker for confirming normal glucose levels and could be particularly useful in routine health screenings for metabolic health.[43] Meanwhile, the waist-to-height ratio is more adept at identifying individuals with elevated FBS, indicating that the parameter may be more sensitive to changes in glucose regulation.[44] Utilizing both parameters can provide a more comprehensive approach to monitoring and managing metabolic health, enabling more accurate risk assessments and targeted interventions.[45]

Crude Association of Socio-demographic, Lifestyle Factors, and Anthropometric Parameters with Elevated Fasting Blood Sugar of Filipino Adults from HUCs

The present study highlighted that several factors were associated with elevated FBS including age, wealth quintile, anthropometric parameters, blood pressure levels, drinking habits, and history of smoking, while sex, ethnicity, current smoking status, and physical activity level did not show significant association.

In this present study, participants aged 41–60 years have at least three times higher odds of having elevated FBS compared to those below 41 years old. This risk increases even further than those older than 60 years. These findings are consistent with established research showing that aging is associated with decreased insulin sensitivity and increased risk of T2DM.[46] As individuals age, metabolic processes tend to slow, and glucose tolerance deteriorates progressively. Hence, β-cells may become less responsive to incretin hormones, reducing their ability to manage insulin resistance.[47]

In terms of wealth quintiles, the study found no significant difference in elevated FBS odds between the poor and poorest quintiles. However, higher wealth quintiles (middle, rich, and richest quintiles, respectively) showed increased odds of elevated FBS. The findings contradict the common belief that higher socio-economic status correlates with better health outcomes, as poverty often negatively impacts health by limiting access to nutritious foods and healthcare.[48] The increase in results may reflect their lifestyle factors such as frequent consumption of calorie-dense and processed foods, and lower physical activity.[49] The impact of socio-economic interventions is highlighted by the 4Ps, which was associated with a reduction in the likelihood of elevated FBS. Organo[50] reported that recipients of the 4Ps experienced a notable decrease in both the frequency and severity of illnesses. This can be explained by the beneficial impact of conditional cash transfer to the nutritional well-being of an individual, including increased meal frequency, improved BMI, and access to essential vitamins. Furthermore, the 4Ps initiative was found to positively influence the overall lifestyle of beneficiaries, improving aspects such as health, nutrition, education, household finances, and income.[50] This suggests that targeted social programs can have a beneficial effect on health outcomes, similar to findings from other countries where social assistance and high quality healthcare have improved health metrics and reduced the prevalence of chronic diseases.[51,52]

The analysis of anthropometric parameters shows a significant association between overweight/obesity and elevated FBS, with an odds ratio of 2.73. Also, individuals with high waist circumference, waist-hip ratio, and waist-to-height ratio exhibit higher odds of elevated FBS, reinforcing the role of body composition in glucose metabolism.[53] This is consistent with global research demonstrating that central obesity is a major risk factor of T2DM.[54] Watts[55] explains that abdominal fat triggers fat cells to release 'pro-inflammatory' chemicals. These substances reduce the body's sensitivity to its own insulin by interfering with the function of insulin-responsive cells and their ability to properly respond to insulin.

Individuals with high BP are associated with a nearly threefold increased likelihood of elevated FBS. This supports the link between hypertension and T2DM, as hypertension often accompanies insulin resistance and metabolic syndrome through mechanisms involving endothelial impairment, inflammation, and oxidative stress.[56]

Former smokers have a higher likelihood of elevated FBS, while former alcohol drinkers are 23% less likely to have elevated FBS compared to those who never engaged in these behaviors. These results are consistent with existing literature suggesting that smoking exacerbates insulin resistance and T2DM. Evidence shows that glucose metabolism continues to deteriorate after smoking cessation compared to long-term smokers, as these changes may be linked to or contribute to the weight gain often observed after quitting smoking.[57] On the other hand, former alcohol drinkers show an improvement on their liver function, reducing oxidative stress and inflammation, which enhances insulin sensitivity and glucose metabolism regulation.[58]

Moreover, sex, ethnicity, current smoking status, and levels of physical activity did not show significant associations with elevated FBS. This contradicts other studies that have found sex differences in T2DM prevalence[59] and highlighted the importance of physical activity in managing blood sugar levels.[60] The lack of significant results could be due to specific characteristics of the study population or limitations in how these variables were measured.

Differences between regions can be attributed to the diversity in healthcare systems, lifestyle influences, and cultural norms. These varying factors play a crucial role in shaping associations with significant predictors of T2DM.[61]

Adjusted Models on the Association of Different Anthropometric Parameters to Elevated Fasting Blood Sugar among Filipino Adults in HUC

Based on the findings, the study challenges traditional assumptions regarding the impact of lifestyle factors such as physical activity, smoking, and alcohol consumption on metabolic health, particularly in relation to elevated FBS levels. Contrary to common beliefs, the data indicate that these factors do not exhibit strong associations with an increased likelihood of elevated FBS. This challenges the simplistic view that lifestyle choices alone dictate metabolic health outcomes.[62] Instead, the findings imply that factors beyond these behaviors, such as genetic predispositions or environmental influences specific to urban settings, may significantly contribute to variations in metabolic health markers like FBS.[63]

The discussion underscores the significant role of regional differences in shaping health outcomes. Individuals from HUCs often lead busy lifestyles, characterized by demanding work schedules and limited time for exercise.[64,65] Urbanization further compounds this issue by limiting access to recreational spaces, thereby constraining opportunities for regular physical activity.[19] Despite these factors potentially suggesting lower physical activity levels, the study did not find a pronounced correlation between reduced physical activity and elevated FBS levels among urban residents (Table 5). This finding is supported by the study of Braver et al.[66] which explained that physical activity and elevated FBS levels have no significant correlation due to limited data from inconsistencies in self-reported measures. Moreover, while smoking and alcohol consumption are prevalent in these urban settings, particularly during social gatherings, their direct association with increased FBS levels appears to be less pronounced than previously assumed (Table 5).[67,68]

According to Liu et al.,[69] socio-economic status and diabetes risk have negative associations. This may be attributed to the difficulties in maintaining healthy dietary habits, whereas urban residents tend to have unhealthy dietary choices.[70] Based on findings, wealth quintiles may be less effective at identifying individuals at risk for elevated FBS compared to being a recipient of 4Ps (Table 5). The 4Ps program, designed to assist families in poverty with conditional cash transfers, appears to exert a more significant influence on health outcomes, potentially due to improved access to healthcare services, nutritional support, or other resources critical for managing health conditions.[71] This highlights the pivotal role of targeted social welfare programs in addressing health disparities among economically disadvantaged populations, surpassing the predictive power of wealth quintiles alone.[72,73]

The study's exploration of ethnicity further complicates the narrative around health determinants. While ethnicity is influenced by genetic predisposition and cultural practices crucial for overall health, it appears not to be as useful in predicting the risk of having elevated FBS. This finding is echoed in the independent works of Tanamas et al. and Rosella et al. where the incorporation of ethnicity-related variables in their prediction models for the risk of T2DM did not improve their models' performance in terms of discrimination and accuracy.[74,75]

The findings attribute the effectiveness of these predictive models to a confluence of various factors integrated within them. For instance, the waist circumference model demonstrates a high classification rate, indicative of its strong predictive ability in identifying specific health conditions, as it is often used to measure visceral adiposity, which is closely linked to metabolic disorders like insulin resistance, T2DM, and cardiovascular disease.[76] A strong classification rate suggests that individuals with larger waist circumferences are more likely to have certain health conditions.[77,78] This could be explained by the complex interplay of biochemical factors and clinical variables that affect waist measurements. These variables create a competitive environment within the model, influencing its predictive accuracy.[79]

The observation of a relationship between sex and blood sugar levels highlights the need for models that are sensitive to sex-specific variations in health outcomes. For example, hormonal shifts in menopausal women, such as decrease in estrogen levels, reducing insulin responsiveness, potentially increasing the risk of conditions like elevated FBS and obesity.[80] Hence, models like the waist-hip ratio demonstrate the best goodness of fit for this group.[81] This underscores the importance of tailoring predictive models to account sex-specific variations, enhancing precision and applicability in clinical settings.

Limitations of the Study

Secondary data analysis often encounters inherent limitations, as the data were not collected to address specific research questions or hypotheses, and key variables might be missing. Moreover, researchers analyzing data often differ from those who collected it, thus unaware about specific details that could affect the interpretation of specific variables. For instance, the original study did not include information on participants' medical conditions, a significant limitation given that such data was not part of the initial dataset. To address these concerns, a thorough review of all relevant sources are vital.[82]

The exposure and outcome variables were measured simultaneously; hence, the study cannot identify causal relationships between the predictors and elevated FBS. The researchers could only conclude whether the different factors, including socio-economic variables and lifestyle factors, are associated with the FBS status of the adults residing in the selected highly urbanized cities in the Philippines. Additionally, the dataset was extracted from a nationwide nutrition survey. The method of data collection was based on the standard protocol developed for the said survey; hence, researchers have no control over the selection criteria set in the protocol. For example, blood samples for FBS determination were obtained only from adults aged 20 years and above. Furthermore, the cut-off values used for classifying the different predictor variables were not specific for Filipinos due to unavailability of such data; hence, the study utilized the values set from relevant WHO guidelines. There was also missing information on socio-demographic status, lifestyle variables, and some anthropometric parameters. However, no imputations were done to avoid further introduction of possible biases.

Moreover, other confounding variables might not be accounted for in this study as this goes beyond the scope of the study. This includes non-inclusion of diet-related variables and relevant disease-related conditions, hence, their effects in the model were not analyzed. Another limitation is that the study did not check on the possible interaction between BP and FBS, as an elevation in FBS is usually associated with elevated BP.[83]

Also, the authors noted significant differences in the proportions observed in the current study population, i.e., adults in HUCs, compared with the original study population as published in previous reports.[6] Data validation and multivariate analysis were performed to mitigate these discrepancies that may have occurred from sampling variation, subgroup effects, the possibility of selection bias, or uncontrolled confounders. Hence, the findings must be cautiously interpreted to ensure that both statistical and clinical implications are considered.

CONCLUSIONS AND RECOMMENDATIONS

This secondary analysis of the ENNS data reveals that elevated FBS was noted in 16% of the adults residing in HUCs. Overweight/obese and high waist circumference, waist-hip ratio, and waist-to-height ratio were affecting 33%, 11%, 33%, and 45% of these adults, respectively.

The above normal status of each anthropometric parameter, in the models for BMI, weight circumference, weight-hip ratio, waist-to-height ratio, was associated with increased likelihood for elevated FBS. Age, sex, blood pressure status, and being a 4Ps recipient were all significantly associated with elevated FBS across the four adjusted final models. The waist-hip ratio model can better predict elevated FBS probably due to the model being a sex-sensitive anthropometric parameter, while the waist circumference model has the highest acceptable correct classification rate of detecting elevated FBS. This reveals the potential use of waist circumference and waist-hip ratio to be an indicator for elevated FBS in a situation where the evaluation of the actual FBS of the individuals is not feasible.

Disparity in the values were observed from the findings of this study and the data from the countrywide report. Hence, the associations described in this paper may be affected by unaccounted variables and other variations. Future research is then recommended to explore the possible interaction of BP and FBS, to see the effects of diet quality and adequacy, and to examine the role of diet in the likelihood of having elevated FBS. The effectiveness of having multiple anthropometric parameters in one model may also be further explored. Furthermore, a comparison of the strength of the associations may be explored between HUCs and non-HUCs.

Nonetheless, this study still underscores the need for adults in HUCs to sustain a healthy weight and to seek central adiposity-losing clinical intervention to maintain and/or control the individual's blood sugar levels.

Statement of Authorship

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