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Anthropometric Measurements for Assessing the Diabetes mellitus Risk Status in the Filipino Cohort Population

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Abstract
The measurement of anthropometric indices can be used to promote early prevention of Diabetes mellitus (DM) in the Filipino population. This study aims to compare the recommended anthropometric measurements namely body mass index (BMI), waist circumference, waist-to-height ratio (WHR), skin fold thickness, and mid-upper arm circumference (MUAC) of two groups, those with diabetes and those without (control), to predict the health risk status of the Filipino adult population. The results suggest that the parameters such as BMI, waist circumference, and WHR in females proved to be the most accurate to predict the diabetes risk among Filipino females. On the other hand, using the logistic regression model, the BMI, MUAC, and waist circumference indices collectively were found to have significant bearings with regard to the risk of acquiring DM. The Asian cut-off values of 18.5-24.9 kg/m2 for BMI, and < 90cm and < 80cm for waist circumference of male and female respectively, as recommended according to Taiwanese standards, are also said to apply to the Filipino population. This study is perhaps the first study in the Philippines that has relied on actual data gathering instead of using meta-analysis as done in earlier studies. In the wake of higher mortality in the diabetic COVID 19 positive patients, the gathering of baseline data of potential DM patients will help the government/stakeholders to efficiently strategize public health policies related to future preparedness for such pandemics.

Keywords: Diabetes mellitus; body mass index (BMI); waist circumference (WC); waist-to-hip ratio (WHR); skin fold thickness; mid-upper arm circumference (MUAC)

1. INTRODUCTION

Diabetes mellitus (DM) is a chronic cardio metabolic disease that affects many of the global population, which is related to obesity and overweight condition.[1] Globally in the past 30 years, the number of Diabetic patients has increased alarmingly from 108 million to 422 million.[2] In the Philippines, DM happens to be in the realm of public health as it is said to be the 6th leading cause of death among Filipinos.[3] and accounts for 6% of total deaths in the Philippines.[4] According to the data available, over 5 million Filipinos have been diagnosed with DM.[5] These numbers are said to increase to 20% by 2045.[5] Since overweight/obesity is linked to DM, it is alarming to notice that the prevalence of overweight/obesity among the Filipino population has also increased from 16.6% in 1993 to 31% in 2015.[6] The chronic disease like DM puts a lot of strain on the public health system of any country that has further been evident by the current data related to COVID -19 pandemic.[7]

The data across the globe so far suggests higher mortality among the patients with underlying health conditions such as hypertension, diabetes, and cardiovascular diseases.[8,9] Hence it is very important for all the countries including the Philippines to gather baseline data about the projected proportion of the population that can suffer from diseases like DM, hypertension, etc for future planning in their health care systems.

The anthropometric indices such as Body Mass Index (BMI), waist circumference, weight height ratio, etc are often used to predict the risk of individuals developing chronic diseases such as DM as they give information on the physiological characteristics of the human body. However the accuracy of using these indices for the prognosis of chronic diseases for early intervention and health management is being continuously evaluated.[10,11]

The difference in the muscle and skeletal mass and overall adiposity distribution has led to misleading prognosis while using the standard values of anthropometric parameters (BMI) as recommended by WHO and NIH.[12,13] The value of 30 kg/m^2 by American standards is considered obese, while the value of 24.9 kg/m^2 is considered obese by Asian standards.[14] Similarly, regarding the use of Waist-hip ratio (WHR), Waist circumference (WC) or Waist – Height ratio (WHtR), as anthropometric indices, the verdict is still not out on the suitability of using these parameters for DM risk assessment due to inconsistent results.[15,16] Some of the Meta-analysis studies conclude that WC, WHtR and WHR are superior indices than BMI in predicting cardiovascular disease as well as DM risks.[17,18] However, some other studies do not support the reliance on these indices for DM risk assessment.[19,20] Therefore, the continuous assessment of the DM risk to the population using reliable indicators such as anthropometric parameters is needed.

Thus, this research paper aimed to use five anthropometric measurements namely, mid-upper arm circumference (MUAC), skin fold thickness, waist circumference (WC), waist-to-hip ratio (WHR), and BMI to assess the risk of Filipino population developing DM in the future. Further, the researchers intended to determine which of the five anthropometric measurements can or most accurately predict one's chances of acquiring DM in the future. In most of the studies so far, the Meta-analysis approach was used to make predictions but in this study for the first time in the Philippines, the actual measurements of the anthropometric parameters in the sample population have been done to generate the baseline data.

2. METHODOLOGY

2.1 Study Design/Study population

The researchers attended and partnered with selected organizations such as Westlake Medical Center and Philippine Diabetes Society to conduct the cross-sectional study to gather the data of the confirmed DM patients. Information on medical history and lifestyle was obtained using a well-structured and validated questionnaire.

Table I. The proportion of respondents in percentage in obese category based on the calculated Body Mass Index and body weight across the studied population at ages 18-34 and 35-55 years.

Age(Years)	*Underweight	**Normal	¶Overweight	¶¶Obese
18-34	15%	60%	20%	4%
35-55	5%	69%	17%	8%

* Underweight: BMI is less than 18.5
**Normal weight: BMI is 18.5 to 24.9
¶Overweight: BMI is 25 to 29.9
¶¶ Obese: BMI is 30 or more

2.2 Recruitment and selection of study participants

The research survey acquired data from a cohort population of Filipinos (n=500, 250 Females, and 250 Males) with two equal groups for those with DM and those without (Control). The sample population only included the adult population with two age groups namely 18-34 years and 35-70 years for both groups. For the control group, a random population with people from all walks of life was taken for an unbiased sample composition. The recommended procedures were followed after obtaining the ethics clearance from the De La Salle University Research ethics committee.

2.3 Data collection/gathering

The anthropometric measurements were acquired from all sample groups. Using a measuring tape their mid-upper arm circumference (MUAC), waist, and hip circumference were recorded whereas the skin fold thickness was measured by using the Vernier Caliper. After measuring the height, the BMI was calculated as well as the waist-to-hip ratio (WHR) was computed.

Fig I. The research group acquiring measurements in Westlake Medical Center, Laguna

2.4 Data Analysis

The data were subjected to a t-test to compare each anthropometric parameter between the DM patients and the control population of both age groups. Using MS Excel, a chi-square test was used to assess the association of the recommended universal cut-off to the measurements gathered for waist circumference and BMI. Additionally, the Asian cut-off was used for the chi-square test of the MUAC and the WHR. To come up with the best model for selecting the best combination of anthropometric indices for predicting DM risk, one predictor (intercept) was first used. After this, one variable (anthropometric parameter) was added in the subsequent models until all variables were considered. Logistic regression (using Eq 1 as given below) was also performed to select the best anthropometric indices that can be used simultaneously to predict the DM risk of the Filipino population.

Eq 1. Formulated model for predicting DM
$\ln(\hat{p}/1-\hat{p})$
$= -9.55517 + 0.09854\ (Waist)$
$= -\ 0.25217(Mid\ Upper\ Arm\ Circumference)$
$=+\ 0.33738\ (BMI)$

Table II. International standard values for Anthropometric indices and their source for healthy males and females

Anthropometric Parameter	**Standard value for Normal Male (M)**	**Standard value for Normal Female (F)**	**Source**
MUAC	<29.90 cm	<29.90cm	Van Tonder 2018[21]
Waist circumference	<90.0 cm	<80.0	International Diabetes Federation 2009
BMI	18.50-24.90 kg/m^2	18.50-24.90 kg/m^2	Hwang et al. (2017)
WHR (Taiwanese Standard)	0.89	0.82	Cheng et al. (2010)
Skin fold Thickness	No Data Available	No Data Available	

Legend: MUAC - Mid Upper Arm Circumference, WHR - Waist to Hip Ratio, BMI - Body Mass Index

3. RESULTS

The sample population consisted of a control population (those who were healthy and did not suffer or [illegible]nosed with Diabetes) and DM patients with equal numbers of males and females selected for each category.

3.1 Comparison of the Anthropometric Parameters between the Control and DM groups

In the control group (without any diagnosed DM patient), the average overall BMI value for (males + females) was found to be 23.51 kg/m^2, which is within the range of recommended healthy BMI (18.5-24.9 kg/m^2) (Table III). Overall, there was an increase in BMI with the progressive increase in the age of 18-34 yrs to 35 to 55 yrs control groups in both genders. The Waist Circumference (WC) was found to increase with age in both genders with males showing overall higher WC as compared to the females (Table III). With respect to WHR, the male group had larger measurements than the females (Table III). The age-dependent increase in the BMI and WC observed is consistent with other findings.[22] In the DM group (patient with a confirmed diagnosis of DM), the average BMI was found to be 27.41 kg/m^2, which is considered as obese in the BMI cut-offs (Table II).[23] Similar to the control group, the mean values for the WHR and waist circumference of males were larger than those of the females (Table IV). Moreover, there was a trend present in the data set wherein the means of all the anthropometric measurements of the DM group were larger than those of the non-diabetic group (Table IV). With age obesity increases as evident by the data obtained in the present study where 17 % were found to be overweight with obese category almost double at 8% in the age group of 35-55 years as compared to the 18-34 years age group (Table I). Our results are similar to the one reported by WHO.[24] These numbers can be used to predict the percentage of overweight and obesity applied to the overall population of the Philippines.

The means for BMI, waist circumference and WHR (females) of both the control and experimental groups were significantly different as the p-values for these were less than 0.05 (Table V). In contrast, there was no significant difference between the control and DM groups with respect to skin fold thickness, and WHR (males) and MUAC leveling out at p=0.05 (Table V). In the WHR anthropometric measurement, only the females were shown to have a significant difference in both groups (Table V).

Table III. The Mean and standard deviation of the Anthropometric parameter of respondents (without diabetes) in age groups (18-34 and 35-55) and overall average (with both males and females)

Anthropometric Parameter	Mean + SD
Waist Circumference: Male 18-34 Yrs	78.50 + 2.01
Waist Circumference: Male 35-55 Yrs	80.97 + 3.27
Waist Circumference: Male only (overall)	79.73 + 2.64
Waist Circumference: Female18-34 yrs	71.52 + 2.78
Waist Circumference: Female 35-55 yrs	75.68 + 3.51
Waist Circumference: Female only (overall)	73.60 + 3.15
Waist Circumference: 18-34 yrs both males + females)	75.01 + 2.40
Waist Circumference: 35-55 yrs (both males + females)	78.32+ 3.39
BMI: Male 18-34 yrs	23.61 + 2.42
BMI: Male 35-55 yrs	24.57+2.92
BMI: Male only (average of both age groups)	24.09+2.92
BMI: Female 18-34 yrs	21.95 + 1.91
BMI: Female 35-55 yrs	23.95 +2.28
BMI: Female (average of both age groups)	22.95 +2.09
BMI: 18-34 yrs	22.78 + 2.19
BMI: 35-55 yrs	24.26+2.90
MUAC (cm) (Males +Females)	29.10 ± 3.35
Skin fold thickness (cm) (Males + Females)	2.83 ± 2.31
WHR of Males (both age groups)	0.90 ± 0.06
WHR of Females (both age groups)	0.85 +/-0.04
Waist Circumference (Overall males and females both age groups)	76.67 + 2.90
BMI (Overall) (Male + Female)	23.52 + 2.52

Legend: MUAC - Mid Upper Arm Circumference, WHR - waist to hip ratio, BMI - body mass index, SD – Standard Deviation

Table IV. The Mean and standard deviation of anthropometric parameter for male and female with Diabetes

Anthropometric Parameter	Mean+/-SD
MUAC (cm)	30.37 ± 3.14
Waist circumference of Males (cm)	92.87 ± 6.16
Waist circumference of Females (cm)	90.25 ± 11.4
Skinfold thickness (cm)	3.37 ± 0.94
WHR of Males	0.92 ± 0.05
WHR of Females	0.88 ± 0.06
BMI (kg/m^2)	27.41 ± 3.84

Legend: MUAC - Mid Upper Arm Circumference, WHR - waist to hip ratio, BMI - body mass index, SD – Standard Deviation, DM – Diabetes Mellitus

Table V. Comparison of anthropometric parameters between Control (no diabetes) and group with diabetes with the probability values of each measured anthropometric parameter (p-values < 0.05 are with *)

Anthropometric Parameter	p Value

MUAC	5.38×10^{-2}
Waist circumference Males (35-55 years)	*9.69×10^{-5}
Waist circumference Females (35-55 yrs)	*4.29×10^{-4}
Skin fold thickness	0.13
WHR (M)	0.25
WHR (F)	*4.26×10^{-2}
BMI Females (35-55years)	*3.47×10^{-7}
BMI Males (35-55years)	0.05

Legend: MUAC - Mid Upper Arm Circumference, WHR - waist to hip ratio, BMI - body mass index, SD – Standard Deviation

3.2 Comparison of Anthropometric Parameters Measured in this Study with the Standard Cut-off Values

Table VI shows that the BMI and waist circumference data are significantly associated with their corresponding cut-off values based on the p-values from the chi-squared test. The cut-offs are said to be < 25kg/m^2 for the BMI, < 90cm for the waist circumference for males and <80cm for the waist circumference for females.[25] Using recommended standardized BMI values as criteria, almost 20 % of the sample population in the 18-34 years age group was found to be overweight with 4% in the obese category. Compared to that in the 35-55 years, 17 % were found to be overweight but the obese category was found to be almost double at 8% as compared to the 18-34 years age group (Table I).

Table VI. Comparison of anthropometric parameters calculated for the population in the present study to that of the International standard cut-off values (p-values < 0.05 are represented as p*)

Anthropometric Parameter	p-value	Standard cut-off
MUAC	0.32	< 29.90cm
Waist circumference (M)	0.02*	< 90.00cm
Waist circumference (F)	0.02*	< 80.00cm
WHR (M)	0.36	<= 0.89
WHR (F)	0.72	<=0.82
BMI	1.06×10^{-4} *	< 25.00kg/m2

Legend: MUAC - Mid Upper Arm Circumference, WHR - waist to hip ratio, BMI - body mass index

3.4 Predictive Model for DM using Logistic Regression

To select the best combination of anthropometric indices, for the prediction of the DM risk, the model having all significant variables and the lowest Akaike Information Criterion (AIC) was selected to estimate the out of sample prediction error. As seen in the coefficients table (Table VII), all the variables, namely the MUAC, waist circumference, and BMI, were considered to be significant with a p<0.05. Moreover, the calculated AIC of this equation was 108.18, which was lower than the AIC of other parameters.

Overall, five models were considered in this study. Model 1 included only the constant intercept and garnered an AIC of 140.63. Model 2 included only the BMI and garnered an AIC of 115.66. Model 3 included the BMI and waist circumference and garnered an AIC of 112.15. Model 4, which was the model chosen, included the BMI, waist circumference, and MUAC and garnered an AIC of 108.18. Model 5 included the BMI, waist circumference, MUAC, and WHR and garnered an AIC of 107.68. However, in model 5, the WHR received a p-value of 0.114, which makes the WHR insignificant.

Table VII. Comparison of the p-values of selected parameters, which showed significant results at p<0.05 (p-values < 0.05 is represented with a *) Anthropometric parameters' standard error and z value are shown along with the p-values.

Anthropometric Parameters with significant results	Estimate	Std Error	Z	p-value
Intercept	-9.56	3.07	-3.11	1.85x10^{-3} *
Waist Circumference	0.10	0.04	2.46	1.402x10^{-2} *
MUAC	-0.25	0.11	-2.33	1.99x10^{-2} *
BMI	0.34	0.12	2.93	3.40x10^{-3} *

Legend: MUAC - Mid Upper Arm Circumference, BMI - body mass index

Aside from this, when calculated using the coefficients, the model depicted that the odds of acquiring DM in the future was 1.10x100.09854 times higher for those having a waist circumference over the cut-off (<90cm for male, <80cm for female) whereas these odds were 0.78 times higher for those having a MUAC above the cut-off (Table VII). Additionally, the odds also were 1.40 times higher for those having a BMI exceeding the cut-off.

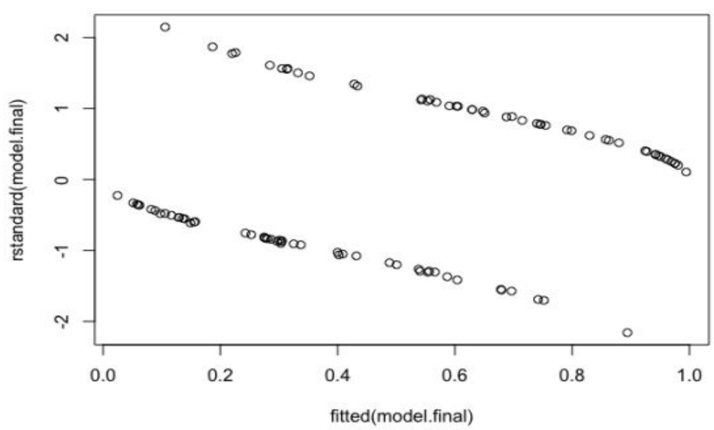

Fig II. The logistic regression model that considers BMI, waist circumference, and MUAC as variables

4. DISCUSSION

4.1 Comparison of the Anthropometric Parameters between the Control and DM groups

Our results clearly show that BMI can be used to predict DM risk. The results presented in this research are similar to some other studies where it was reported that having a high BMI may increase the probability of having a problem in insulin response.[26] This may be because obesity and being overweight are associated with the presence of DM in the human body as excess nutrition can desensitize insulin receptors.[27] Waist circumference can be used as a parameter in determining the risk of having DM because visceral fats and abdominal obesity can be linked to the secretion of serum retinol-binding protein 4 by visceral fats leading to the resistance to insulin in an individual.[28,29] The BMI value of 27.42 kg/m^2 observed is most certainly cause of concern for the Filipino population as there are reports that Filipino American women exhibited a significant increase in the cardiovascular disease (CVD) risk factors such as hypertension, reduced HDL-C levels, elevated triglycerides and high –sensitivity C –reactive protein and diabetes mellitus with an increase in the BMI values within the range of 23 to 24.9 Kg/m$^{2.}$.[30]

4.2 Comparison of Anthropometric Parameters Measured in this Study with the Standard Cut-off Values

Table VI shows that the BMI and waist circumference data are significantly associated with their corresponding cut-off values based on the p-values from the chi-squared test. The cut-offs are said to be < 25kg/m^2 for the BMI, < 90cm for the waist circumference for males and < 80cm for the waist circumference for females.[25] However it is important to point out those high levels of CVD risks among Asians at BMI cut-offs even lower than the WHO obesity standard values have been reported.[31] The incidence of DM was found to be higher in the Filipino–American at a lower BMI (23-24.9 kg/m$^{2)}$ when compared to non-Hispanic Whites[32] or other Asian races.[33] The studies carried out in the adult populations of China and Taiwan have revealed that the prevalence of high fasting sugar was 3 times higher in the group with the BMI>28kg/m^2 as compared to the group with BMI<20 kg/m^2.[34] Countries like Malaysia and China have come up with the recommended BMI cutoffs of 23 and 24.0 kg/m^2 for men and women respectively.[35,36] Interestingly, the findings suggest that the association between BMI and mortality seems to be stronger at younger ages than at older age.[37] Another observation that is noteworthy is that almost 15% of the population was found to be underweight in the 18-34 years age group (Table I). Future studies are needed to investigate the incidence of underweight and malnutrition in the Filipino population as lower BMI is associated with increased mortality risk with respect to mental, behavioral, and neurological factors.[37]

According to WHO NCD Progress Monitor Index, Philippines does not have clear guidelines/policies for the levels of salt/sodium and saturated fatty acids/ trans –fats in the food products (one of the few factors related to cardiovascular diseases) as well as no restrictions on the marketing of processed foods.[38] Therefore, at the policy level, proper guidelines need to be laid down to address this public health concern. The current COVID 19 pandemic trends have shown higher mortality (20.3%) in the DM patients due to complications both in the Italian and Wuhan cohort populations.[39,40]. With the reported higher mortality rate among the diabetic COVID 19 positive patients, the gathering of baseline data of potential DM patients is crucial for the government/stakeholders to efficiently strategize public health policies related to future preparedness for such pandemics. Hence it is of utmost importance to find if the Filipino population can use the current cut off values of BMI for the overall Asian population or they need to have lower BMI cutoffs due to ethnicity, lifestyle, and other epigenetic factors.

Type 2 diabetes in females with a WHR of <0.80 is low, but the risk is moderate and high in women with a WHR of 0.81-0.85 and > 0.86.[41] In general, it is desirable to maintain WHR values of < 1.00 for men and < 0.85 for women.[42] However, a study focusing on the determination of new anthropometric cut-off values for Indonesian adults suggested a WHR cut-off of 0.86 and 0.77 for males and females respectively.[43] Regarding using MUAC as a reliable anthropometric parameter, a statistically insignificant marginal p-value (0.054) was obtained in our data. While focusing on the prevalence of obesity in South Africa, a MUAC cut-off value of 23cm for underweight, and a value of >=33cm for those who were obese was proposed.[44] Perhaps a larger sample size is needed to verify the suitability of using MUAC for predicting health risks due to DM.

4.3 Predictive Model for DM using Logistic Regression

Using the predictive model with all significant variables and the lowest Akaike Information Criterion MUAC was found to be a relatively more reliable tool for DM risk assessment. So our study also corroborates some of the other findings where MUAC is found to be a relatively more reliable tool for health screening of population groups.[45,46] The use of multi-component indices such as BMI, WHR, skin fold thickness involves carrying and transporting weighing scales, weight height boards, skinfold caliper, etc which is logistically challenging especially when large population sample sizes are required, compared to that a MUAC tool is a simple measuring tape, which is cheap and easy to carry.

Since the healthcare services of the country need to include tools that can be used for regular screening for obesity-related conditions and treatments for obesity, MUAC in addition to BMI could be included as an anthropometric parameter for monitoring the health status of individuals. This will help to get more accurate early-warning assessments for potential diabetes patients.

5. CONCLUSIONS

This study concludes that the combination of BMI, and the waist circumference along with WHR specifically for females, can be considered for a more accurate prediction of the preliminary DM health risk of the Filipino population though they have their own limitations. As for the cross-checking of the given standard cut-off values to the acquired data results, this study concludes that the cut-offs specified for the BMI and waist circumference can be used for comparison sake for the Filipino population. This is because there is a significant association between the aforementioned anthropometric measurements and their associated cut-off values. Based on the logistic regression analysis, the study also concludes that when used in conjunction with each other, the BMI, waist circumference, and MUAC can be relatively more accurate in predicting DM. Moreover, the odds of acquiring DM is 1.10 times higher for those having a waist circumference above the given cut-off (< 90cm for males and < 80cm for females), 0.78 times higher for those having a MUAC above the cut-off (<= 29.9cm), and 1.40 times higher for those having a BMI above the cut-off (<= 23kg/m2). Since the current studies have shown the link between the higher mortality associated with COVID 19 infection in the cohort populations around the world, it is crucial to predict the prevalence of DM and predict the future occurrence based on the anthropometric parameters. Our results clearly suggest that regular monitoring of the anthropometric parameters by the health care providers can prevent the onset of DM.

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