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Identification of Anthropometric Indices That Best Correlate With Insulin Sensitivity and Insulin Resistance from Subjects from Central Mexico

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Abstract

Background: Insulin Sensitivity (IS) and Insulin Resistance (IR) mark the development of Type 2 Diabetes. Many reports have demonstrated that anthropometric indices can detect IS and IR, however ethnic variations can influence the optimal cutoff value. Therefore, the aim of this study was to determine the optimal cutoff value for Waist Circumference (WC), Body-Mass Index (BMI), Waist-To-Hip Ratio (WHR), Waist-To-Height Ratio (WHtR), and percent Body Fat (BF %) to determine IS and IR from subjects from central Mexico.

Methods: WC, BMI, WHR, WHtR, BF%, fasting plasma glucose, and insulin were determined in 569 subjects (male=286 & females=283; ages: 18-84). IR and IS were determined by the Homeostatic Model Assessment online calculator and Quantitative Insulin Sensitivity Check Index, respectively. The area under the Receiver Operating Characteristic curve (AUC) and Youden´s index for each anthropometric index was calculated to determine its cutoff value. Cutoff value´s efficiency was measured by determining the test´s accuracy.

Results: WC, BMI, WHtR and BF% negatively correlated IS and positively correlated to IR (p<0.0001). WHR did not correlate with IS nor IR. AUC analysis showed that WC, BMI, WHtR and BF% were acceptable test to determine IS and IR (IS: males: AUC=0.736-0.770 and females: AUC=0.648-0.666; IR: males: AUC=0.740-0.760 and females: AUC=0.681-0.709, p<0.001). Comparison of AUC demonstrated that WC, BMI, WHtR and BF% had similar efficiency to determine IS and IR. However, after determining the optimal cutoff value and using highest test accuracy, we determined the better indicators for IS was WHtR (cutoff=0.540, accuracy=76.8%) and BF% (cutoff=31.5%, accuracy=68.0%) and for IR was WC (cutoff=99.5 cm, accuracy=71.0%) and BMI (cutoff=31.6 kg/m^2, accuracy=79.9%) for males and females, respectively.

Conclusion: When comparing multiple anthropometric indices, we determined that WHtR and WC for males and BF% and BMI for females were better indicators for determining IS and IR, respectively.

Keywords: Insulin resistance; Insulin sensitivity; Waist circumference; Body-mass index, Waist-to-height ratio; Percent body fat; Receiver-operating characteristic curve

Abbreviations: IS: Insulin Sensitivity; IR: Insulin Resistance; WC: Waist Circumference; BMI: Body-Mass Index; WHR: Waist-to-Hip Ratio; Whtr: Waist-to-Height Ratio; BF%: Percent Body Fat; T2D: Type 2 Diabetes; FPG: Fasting Plasma Glucose; HOMA2-IR: Homeostatic Model Assessment for Insulin Resistance; QUICKI: Quantitative Insulin Sensitivity Check Index; SPSS: Statistical Package for the Social Sciences; Receiver-Operating Characteristic (ROC) Curve; AUC: Area Under the ROC Curve; PPV: Positive Predictive Value; NPV: Negative Predictive Value

Introduction

The prevalence of Type 2 Diabetes (T2D) is a major health concern in Mexico, as well as the rest of the world [1-3]. According to Mexican Ministry of Health, current estimates suggest that, by 2030, the cases of T2D will increase to 37.8% of the total population, with a 23.9% morbidity rate [4]. T2D is a metabolic disease characterized by a poor response to insulin secretion or resistance to insulin action, or both, due in part to β-cell dysfunction, decreased Insulin Sensitivity (IS), Increased Insulin Resistance (IR), and hyperglycemia. Moreover, IS and IR can be present five years before the development of pre-diabetes, a stage preceding T2D characterized by impaired glucose function [5].

Obesity and increased central adiposity are two risk factors associated with T2D [6-8]. The current methods to measure these characteristics are to determine the Body-Mass Index (BMI) or measuring Waist Circumference (WC) [9,10]. Many reports have shown WC to be a superior predictor than BMI to determine T2D [8,11], but their ability to determine IS and IR in Mexican population remains inconclusive [12,13]. Other anthropometric measures, such as Waist-To-Hip Ratio (WHR), Waist-To-Height (WHtR), and body fat percent (BF %), have been correlated with T2D, but their predictive value for IS and IR remains to be fully understood with Mexican subjects [14,15]. The aim of this study was to determine the predictive capabilities of WC, BMI, WHR, WHtR, and BF% indices to determine IS and IR for males and females from central Mexico.

Material and Methods

Subjects and settings

We designed a cross-sectional study, which included 569 subjects

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from central Mexico (males=286 and non-pregnant females=283) that were from 18 to 84 years old. All subjects were recruited from IMSS Clinic 2, located in the city of Puebla, Mexico, between March 2012 to February 2014. Healthy subjects and without a T2D diagnosis were asked to participate. Subjects were excluded from the study, if it was suspected they had an acute or chronic illness that would interfere with the analysis. The protocol was approved by the Scientific Research Committee of the Mexican Social Security Institute. All participants provided informed consent to participate in the study protocols, conducted in accordance with the Declaration of Helsinki.

Clinical characterization

Subjects were clinically evaluated according to a standardized protocol including personal and family medical history. WC was measured at the midpoint between the highest point of the iliac crest and the lowest point of the costal margin at the mid-axillary line using a non-stretching anthropometric measuring tape. Hip circumference was measured at the widest part of the buttocks. Measurements were performed at the end of a normal inhalation using minimal pressure with the tape to avoid compression of the skin. With the subjects in fasting conditions, wearing light clothing and without shoes, their height (m), weight (kg), and BF% were measured using the body composition analyzer (TBF-215, Tanita, Tokyo, Japan). BMI was calculated as weight/height^2 (Kg/m^2) [13]. The WC measurement was used to calculate WHR and WHtR by dividing it by hip circumference and height, respectively.

Biochemical assays

Whole blood samples were collected from the antecubital vein following a 10-12h overnight fast. The samples were kept at room temperature for 2h to allow clotting. The serum fraction was recovered and frozen at -20˚C until use. Samples were used for the following endpoints: Fasting plasma glucose and insulin. Fasting plasma glucose was determined using the enzymatic method/spectrophotometric glucose oxidation (Beckman Instruments, Brea, CA). Insulin levels were determined by automated immunoassay (Access, Beckman).

Calculation of HOMA2-IR and QUICKI

IR was assessed by the homeostatic model assessment online calculator (HOMA2-IR) downloaded from http://www.dtu.ox.ac.uk/homacalculator/index.php on (April 2014). Subjects were classified as IR (+) with a HOMA2-IR score ≥ 1.8 [16] and IR (-) with a score <1.8. IS was calculated from the Quantitative Insulin Sensitivity Check Index (QUICKI) by the following formula: QUICKI=1/(log [Insulin]+log[Glucose]). Subjects were classified as low IS with a QUICKI score ≤ 0.357 or normal IS with a QUICKI score>0.357 [17].

Statistical analysis

Statistical analyses were performed using Statistical Package for the Social Sciences program for Windows, version 19 (SPSS, Chicago, IL) or Medcalc Statistical Software version 13.3.3 (Medcalc, Ostend, Belgium). Due to the sample size for both genders, the differences between groups were evaluated by Student´s T Test (SPSS). The normality of the data was assessed by the Shapiro-Wilk Test (SPSS) and determined that only BF% was normally distributed. Since the data for HOMA-IR and QUICKI were non-normally distributed, correlation analysis was done by calculating the Spearman´s correlation coefficient (ρ) [18,19]. P-values<0.05 were considered statistically significant. Results were expressed as mean ± standard error. Receiver Operating Characteristic (ROC) curve was used to determine the sensitivity and specificity of each anthropometric index. The area under the ROC curve (AUC) was calculated using the method described by Hanley and McNeil [18] (Medcalc). Comparisons between ROC curves were also determined using the Hanley and McNeil method (Medcalc). Using the sensitivity

		Insulin Sensitivity		**Insulin Resistance**	
	Total	**Normal IS**	**Low IS**	**IR (-)**	**IR (+)**
Males					
Sample	286	77	209	222	64
Age	41.8 ± 0.9	37.1 ± 1.5	43.5 ± 1.0*	42.1 ± 1.0	40.5 ± 1.8
WC	96.1 ± 0.7	88.6 ± 1.0	98.9 ± 0.8*	93.8 ± 0.7	104.2 ± 1.6**
BMI	27.9 ± 0.5	24.9 ± 0.4	29.1 ± 0.7*	27.1 ± 0.6	30.9 ± 0.7**
WHR	0.955 ± 0.004	0.931 ± 0.006	0.964 ± 0.005*	0.951 ± 0.004	0.970 ± 0.009**
WHtR	0.572 ± 0.004	0.528 ± 0.006	0.589 ± 0.005*	0.559 ± 0.004	0.620 ± 0.010**
BF%	26.2 ± 0.4	21.2 ± 0.7	28.1 ± 0.5*	24.7 ± 0.5	31.4 ± 0.8**
FPG	106.9 ± 2.4	88.8 ± 1.3	113.6 ± 3.1*	102.2 ± 2.6	113.0 ± 5.7
Insulin	10.1 ± 0.4	4.9 ± 0.2	12.0 ± 0.4*	7.5 ± 0.2	19.0 ± 0.8**
HOMA2-IR	1.34 ± 0.05	0.64 ± 0.02	1.61 ± 0.05*	1.01 ± 0.02	2.51 ± 0.09**
QUICKI	0.342 ± 0.002	0.384 ± 0.003	0.327 ± 0.001*	0.354 ± 0.002	0.305 ± 0.002**
Females					
Sample	283	91	192	216	67
Age	41.9 ± 0.8	40.8 ± 1.4	42.4 ± 1.0	42.0 ± 0.9	41.4 ± 1.6
WC	91.0 ± 0.8	85.8 ± 1.2	93.5 ± 1.0*	88.6 ± 0.9	98.7 ± 1.7**
BMI	27.3 ± 0.3	25.3 ± 0.4	28.2 ± 0.4*	26.1 ± 0.3	31.0 ± 0.8**
WHR	0.888 ± 0.006	0.861 ± 0.008	0.901 ± 0.007*	0.884 ± 0.007	0.902 ± 0.008
WHtR	0.590 ± 0.006	0.554 ± 0.008	0.606 ± 0.007*	0.575 ± 0.006	0.638 ± 0.001**
BF%	34.3 ± 0.5	31.2 ± 0.8	35.8 ± 0.5*	33.1 ± 0.5	38.4 ± 0.9**
FPG	93.7 ± 0.7	88.0 ± 1.0	96.4 ± 0.9*	91.9 ± 0.8	99.3 ± 1.3**
Insulin	10.7 ± 0.4	5.3 ± 0.1	13.3 ± 0.5*	7.8 ± 0.2	20.2 ± 1.0**
HOMA2-IR	1.39 ± 0.05	0.68 ± 0.02	1.72 ± 0.07*	1.01 ± 0.02	2.61 ± 0.13**
QUICKI	0.344 ± 0.002	0.378 ± 0.002	0.328 ± 0.001*	0.356 ± 0.002	0.306 ± 0.002**

Values are mean ± standard error. Significance was determined by Student T Test. *p<0.05 vs. normal IS.**p<0.05 vs. IR(-) . Abbreviations: WC: Waist Circumference; BMI: Body-Mass Index; WHR: Waist-to-Hip Ratio; WHtR: Waist-to-Height ratio; BF%: Body Fat percent; FPG: Fasting Plasma Glucose; HOMA2-IR: Homeostatic Model Assessment for insulin resistance; and QUICKI: Quantitative Insulin Sensitivity Check Index.

Table 1: Clinical and Metabolic characteristics of subjects from central Mexico.

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and specificity, the Youden´s index (sensitivity+specificity−1) was determined for each anthropometric index (Medcalc). The highest Youden´s index score was considered the optimal cutoff value to predict IS or IR. Using the optimal cutoff values, male and female subjects were re-evaluated and the positive predictive value [PPV=true positive/ (true positive+false positive)], negative predictive value [NPV=true negative/ (true negative + false negative)], and test accuracy [accuracy=(true positive+true negative)/total sample] were determined.

Results

Anthropometric indices correlate with insulin sensitivity and insulin resistance

Subjects from central Mexico were classified as either as normal IS or low IS. More females were determined to have low IS than males (32.1 and 26.9 %, respectively, Table 1). Low IS males and females had WC, BMI, WHR, WHtR, and BF% scores that were significantly higher than their normal IS counterparts (p<0.05). Next, we determined the association between the anthropometric indices and IS by calculating the Spearman correlation coefficients. For males, WC, BMI, WHtR, and BF% had a moderate negative correlation with IS (p<0.0001), whereas the females had a weak negative correlation (p<0.0001, Table 2). There was no correlation between IS and WHR in males or females.

When the subjects were separated by IR, similar percentages of IR (+) were determined for males and females (22.4 and 23.7 %, respectively, Table 1). WC, BMI, WHtR, and BF% were all significantly higher in IR (+) males and females (p<0.05). However, only in IR (+) males, WHR was significantly higher (p<0.05). WC, BMI, WHtR, and BF% had a moderate positive correlation with IR in males (p<0.0001), and females had a weak positive correlation (p<0.0001, Table 2). There was no correlation between WHR and IR in males or females. These data suggest that WC, BMI, WHtR and BF% could be used to assess IS and IR.

Determination of the best anthropometric index to predict IS and IR in males and females

To determine the best anthropometric index for evaluating IS, we calculated the AUC for WC, BMI, WHtR, and BF%. For males, the AUC was 0.764 (95% CI: 0.710-0.812, p<0.001) for WC, 0.736 (95% CI: 0.681-0.786, p<0.005) for BMI, 0.761 (95% CI: 0.707-0.809, p<0.001) for WHtR, and 0.770 (95% CI: 0.717-0.817, p<0.0001) for BF% (Figure 1A). For females, the AUC was 0.661 (95% CI: 0.591-0.731, p<0.0001) for WC, 0.648 (95% CI: 0.578-0.717, p<0.0001) for BMI, 0.649 (95% CI: 0.580-0.718, p<0.0001) for WHtR, and 0.666 (95% CI: 0.597-0.735, p<0.0001) for BF% (Figure 1C). For IR, in males, the AUC was 0.743 (95% CI: 0.689-0.793, p<0.0001) for WC, 0.761 (95% CI: 0.708-0.810, p<0.0001) for BMI, 0.740 (95% CI: 0.686-0.790, p<0.0001) for WHtR, and 0.760 (95% CI: 0.706-0.808, p<0.0001) for BF% (Figure 1B). For females, the AUC was 0.705 (95% CI: 0.631-0.780, p<0.0001) for WC, 0.709 (95% CI: 0.732-0.786, p<0.0001) for BMI, 0.681 (95% CI: 0.603-0.759, p<0.0001) for WHtR, and 0.694 (95% CI: 0.620-0.767, p<0.0001) for BF% (Figure 1D). Comparing AUCs between anthropometric indices, we determine which test was more efficient at predicting IS or IR. In males and females, all tests demonstrated similar efficiencies (Table 3). Thus, these data suggest that WC, BMI, WHtR and BF% are equally sufficient test to determine IS and IR.

Determination of optimal anthropometric index cutoff value to predict IS and IR in males and females

To determine the optimal cutoff value for WC, BMI, WHtR, and

	Males		Females	
	ρ	p-value	ρ	p-value
QUICKI vs. WC	-0.499	<0.0001	-0.402	<0.0001
BMI	-0.481	<0.0001	-0.398	<0.0001
WHR	-0.273	<0.0001	-0.227	<0.0005
WHtR	-0.488	<0.0001	-0.377	<0.0001
BF%	-0.486	<0.0001	-0.382	<0.0001
HOMA2-IR vs. WC	0.496	<0.0001	0.378	<0.0001
BMI	0.486	<0.0001	0.386	<0.0001
WHR	0.217	<0.0005	0.216	<0.0005
WHtR	0.476	<0.0001	0.345	<0.0001
BF%	0.496	<0.0001	0.357	<0.0001

Abbreviations: WC: Waist Circumference; BMI: Body-Mass Index; WHR: Waist-to-Hip Ratio; WHtR: Waist-to-Height ratio; BF%: Body Fat percent; HOMA2-IR: Homeostatic Model Assessment for insulin resistance; and QUICKI: Quantitative Insulin Sensitivity Check Index.

Table 2: Spearman Correlation of QUICKI and HOMA2-IR Indices to Anthropometric Characteristics.

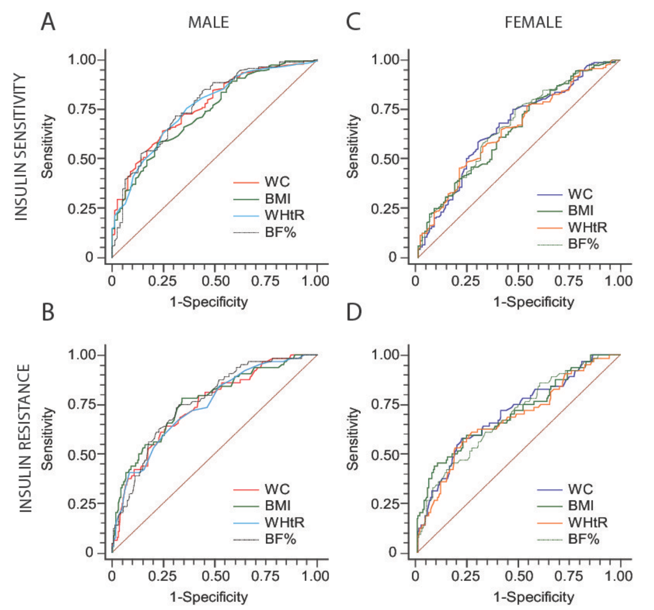

Figure 1: Receiver Operating Characteristic curve for Anthropometric indices in males (A, B) and females (C, D) for detecting insulin sensitivity (A, C) and insulin resistance (B, D). Waist Circumference (WC), Body-Mass Index (BMI), Waist-To-Height Ratio (WHtR), and percent Body Fat (BF%) indices were assessed.

		Males			Females		
IS		WC	BMI	WHtR	WC	BMI	WHtR
	BMI	p = 0.1578			p = 0.5106		
	WHtR	p = 0.8183	p = 0.2082		p = 0.3206	p = 0.9497	
	BF%	p = 0.8022	p = 0.1568	p = 0.6752	p = 0.8567	p = 0.5086	p = 0.6034
IR							
	BMI	p = 0.3814			p = 0.8531		
	WHtR	p = 0.8376	p = 0.3154		p = 0.0816	p = 0.2145	
	BF%	p = 0.5573	p = 0.9578	p = 0.4701	p = 0.7373	p = 0.6235	p = 0.7258

p-values was calculated using Hanley and McNeil Method (Medcalc software v13.3.3). Abbreviations: IS: Insulin Sensitivity; IR: Insulin Resistance; WC: Waist Circumference; BMI: Body-Mass Index; WHtR: Waist-to-Height ratio; BF%: Body Fat percent.

Table 3: Pairwise Comparison of ROC curves for Subjects from Central Mexico Separated by IS and IR.

	Cutoff	Sensitivity	Specificity	PPV (%)	NPV (%)	Accuracy (%)
IS						
WC (cm)	94.0	0.641	0.753	86.6	43.4	67.1
BMI (kg/m^2)	26.8	0.579	0.779	86.6	40.3	63.3
WHtR	0.540	0.756	0.637	83.3	61.0	76.8
BF%	24.0	0.718	0.688	85.2	46.4	70.3
IR						
WC (cm)	99.5	0.641	0.734	40.6	87.6	71.0
BMI (kg/m^2)	27.3	0.781	0.658	39.4	91.2	68.2
WHtR	0.580	0.672	0.676	34.8	88.3	63.6
BF%	27.0	0.734	0.685	39.5	89.8	68.9

Cutoff-values were calculated using the Younden Index = Sensitivity + Specificity -1. Abbreviations: PPV: Positive Predictive Value; NPV: Negative Predictive Value; IS: Insulin Sensitivity; IR: Insulin Resistance; WC: Waist Circumference; BMI: Body-Mass Index; WHtR: Waist-to-Height ratio; BF%: Body Fat percent.

Table 4: Proposed Cutoff values for Anthropometric Indices to determine IS & IR in Males From Central Mexico.

	Cutoff	Sensitivity	Specificity	PPV (%)	NPV (%)	Accuracy (%)
IS						
WC (cm)	89.2	0.589	0.713	81.0	45.4	63.3
BMI (kg/m^2)	24.2	0.776	0.462	75.4	50.0	67.8
WHtR	0.539	0.766	0.484	75.3	49.4	67.5
BF%	31.5	0.751	0.517	76.6	50.0	68.0
IR						
WC (cm)	96.3	0.582	0.778	44.3	85.6	72.8
BMI (kg/m^2)	31.6	0.448	0.903	64.5	84.0	79.9
WHtR	0.613	0.333	0.794	42.0	86.3	70.7
BF%	40.3	0.422	0.856	45.0	82.5	74.3

Cutoff-values were calculated using the Younden Index = Sensitivity + Specificity -1. Abbreviations: PPV: Positive Predictive Value; NPV: Negative Predictive Value; IS: Insulin Sensitivity; IR: Insulin Resistance; WC: Waist Circumference; BMI: Body-Mass Index; WHtR: Waist-to-Height ratio; BF%: Body Fat percent.

Table 5: Proposed Cutoff values for Anthropometric Indices to determine IS & IR in Females from Central Mexico.

BF%, Medcalc software was used to calculate the Youden´s Index. Afterwards, the optimal cutoff values were used to re-evaluate the cohort and determine the test´s PPV, NPV, and accuracy. The test with highest accuracy was considered the better test. The optimal cutoff value for each indices and their test performance for males and females are shown in Table 4 and Table 5, respectively. The optimal cutoff value for IS were always below the optimal cutoff value for IR. For males, we determine the better test for IS was WHtR and for IR was WC. For females, the better test for IS was BF% and for IR was BMI. Overall, due to the similarities in AUC between WC, BMI, WHtR, and BF%, any these anthropometric tests and their corresponding cutoffs are acceptable for determining IS and IR.

Discussion

IS and IR are present in the initiating stages of many diseases, such as T2D [5]. Anthropometric indices are easy, rapid, and inexpensive measures that are utilized in rural and financially burden areas of Mexico and other parts of the world that can identify IS and IR. Therefore, establishing optimal cutoffs values for WC, BMI, WHR, WHtR, and BF% for IS and IR remains an incomplete challenge, especially for Mexico. In this study, we elucidated which anthropometric indices were best to indicate IS and IR for Central Mexico.

Here, using the Spearman correlation and AUC analyses, we demonstrated that WC, BMI, WHtR, and BF% were equally efficient in determining IS and IR in males and females. In agreement with others, we determined that WHR was not an acceptable test [20,21]. However, focusing mainly on the test accuracies of the indices, we posit that WHtR and BF% are better tests for IS in males and females, respectively. Many reports have shown that BMI affectively correlates with IS in children and adults [6,22-24]. Unfortunately, these reports did not compare to alternative measures of obesity. In a study that focused on Brazilians from Sao Paulo, which examined BMI, WC, and WHtR, it found that WHtR was an acceptable method to determine IS; however, their results were based on a gender-mixed sample and did not include BF% in their comparison [21]. Another study that focused on an Inuit population from Nunavut, Canada, which did compare BF%, BMI, and WC, determined that BF% was a better test followed by BMI and WC in females, which is similar to our results [25]. To date and to best of our knowledge, there are no reports that examine anthropometric indices and IS in Mexican subjects.

We also posit that WC and BMI are better tests for IR in males and females, respectively. For males, our results are similar to reports on Pakistani and Iranian populations. Although these studies demonstrated a WC cutoff of 94.4 cm for Pakistani males and 90 cm for Iranian males, our value was 99.5 cm [20,26]. In addition, Gomez-Garcia et al. [27] demonstrated WC was an optimal test to determine IR in Mexicans from Michoacan. However, according to Monero-Estrada et al. [28], subjects from Michoacan (western Mexico) and our cohort (central Mexico) have different genetic backgrounds. The optimal WC cutoff for Mexicans from Michoacan was determined to be 76.5 cm, which is lower than our study [27]. These data confirms that WC is acceptable test to determine IR in males and different ethnic groups have different cutoff values. However, the Inuit study also demonstrated that BMI and BF% were better tests than WC in males, which is different from our data [25]. Their data does support that BMI is a superior test to determine IR in females followed by BF% and WC, which is similar to our results. In Pakistani females, WHtR and WC indices were better indicators than BMI for IR [20]. Overall, this does support the notion that in different regions of the world, different anthropometric indices are more efficient than others in determining IR.

Using the same population, we determined the cutoff values for IS and IR. For each anthropometric indices, the IS cutoff value was lower than the IR cutoff value. This would suggest that IS precedes IR. We, as well as others, have demonstrated that IS does develop before IR [29,30]. Since IS precedes IR, it would be beneficial for general practitioners to start examining patients for IS to prevent the development of IR and pre-diabetes.

We determined a few limitations for this study. First, the study is a cross-sectional study and cannot determine any causal effects between the anthropometric indices and IS or IR. Second, the optimal cutoff values were based on the highest Youden´s Index. Upon further examination, selection of different cutoff values resulted in higher test accuracies while altering the PPVs and NPVs (Data not shown). These suggest that Youden index, even though gives the highest sensitivity and specificity pair, may not predict the optimal cutoff value. Further analyses are required. Third, our cohorts contain a mixture of subject with and without a family history of T2D. Many subjects did not indicate or know if there was a family history of T2D. A family history increases the risk of T2D and its associated complications [31]. Arsalanian et al. [30] showed that subjects with normal glucose function and with a family history of T2D had a more pronounced decrease IS than subjects without a family history. It is possible that the optimal cutoff values are different between subjects with family history of T2D and those without.

Conclusion

In conclusion, we identified optimal cutoff values for WC, BMI, WHtR, and BF% indices to determine IS and IR in males and females from Central Mexico. To identify insulin sensitivity, WHtR in males and BF% in females are better indicators. To identify Insulin Resistance, WC in males and BMI in females are better indicators. However, the efficiency differences between WC, BMI, WHtR, and BF% indices were minimal. These cutoff values will aid clinicians in the diagnosis of IS and IR and help design treatments to mitigate the development of T2D.

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