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ORIGINAL RESEARCH

Association between abdominal circumference and being at risk of type 2 diabetes mellitus in Peruvian adults

Asociación entre perímetro abdominal y estar en riesgo de diabetes mellitus tipo 2 en adultos peruanos

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Abstract

Introduction: Even though multiple risk factors for the development of type 2 diabetes mellitus (T2DM) have been identified, evidence on the association between abdominal circumference (AC) and being at risk for this disease is scarce.
Objective: To analyze the association between AC and being at risk of developing T2DM in a Peruvian population.
Materials and methods: Cross-sectional analytical study. An analysis of secondary data obtained from the *Encuesta Demográfica y de Salud Familiar peruana 2022 - ENDES* (2022 Peruvian Demographic and Family Health Survey) (16 058 women and 12 349 men) was performed. The risk of T2DM was estimated using the diabetes risk score developed by Bang. Student's t-test was used to evaluate differences in AC between groups (DM2 risk vs. no DM2 risk). Furthermore, to evaluate the association between AC (normal vs. elevated) and being at risk of T2DM, first a bivariate analysis (Chi-square test and crude Odds ratio (OR) calculation) was performed, followed by a multivariate analysis (binary logistic regression). Finally, the correlation between AC and T2DM risk score was assessed using Spearman's correlation coefficient (Rho). Data for men and women are presented separately. Numerical analyses (Student's t and Spearman's Rho) were used to explore general relationships and trends, while categorical analyses (Chi-square and OR) were employed to assess specific associations that translate into practical risk criteria.
Results: The mean age of women and men was 37.32 and 39.26 years, respectively. The mean AC was higher in participants at risk of developing T2DM in both women and men (97.15cm vs. 89.257cm and 97.77cm vs. 85.128cm). In the bivariate analysis, having an elevated AC and being at risk of developing T2DM showed a statistically significant association of low intensity in women (V=0.115) and statistically significant of moderate intensity in men (V=0.519). In the multivariate analysis, it was found that having a high AC showed a 4.56-fold increase in the probability of being at risk of developing T2DM in women (OR=4.56) and a 24.54-fold increase in men (OR=24.54). Finally, the correlation between AC and the T2DM risk score was moderate in women (Rho=0.565) and strong in men (Rho=0.641).
Conclusions: Increased AC is associated with a higher probability of being at risk of developing T2DM in the Peruvian adult population, mainly in men.

Resumen

Introducción. Aunque se han descrito múltiples factores de riesgo para el desarrollo de diabetes *mellitus* tipo 2 (DM2), la evidencia sobre la asociación entre el perímetro abdominal (PA) y estar en riesgo de esta enfermedad es escasa.
Objetivo. Evaluar la asociación entre el PA y estar en riesgo de DM2 en población peruana.
Materiales y métodos. Estudio analítico transversal. Se realizó un análisis de datos secundarios obtenidos a partir de la Encuesta Demográfica y de Salud Familiar peruana (ENDES) 2022 (16 058 mujeres y 12 349 hombres). El riesgo de DM2 se determinó usando el puntaje de riesgo de diabetes desarrollado por Bang. Se usó la prueba t de student para evaluar diferencias en el PA entre grupos (riesgo de DM2 vs. sin riesgo de DM2). Además, para evaluar la asociación entre el PA (normal vs. elevado) y estar en riesgo de DM2 primero se realizó un análisis bivariado (prueba de chi-cuadrado y cálculo de Odds ratio (OR) crudos) y luego, uno multivariado (regresión logística binaria). Finalmente, la correlación entre el PA y el puntaje de riesgo de DM2 se evaluó mediante el coeficiente de correlación de Spearman (Rho). Los datos se presentan para hombres y mujeres por separado. Los análisis numéricos (t de student y Rho de Spearman) se emplearon para explorar relaciones y tendencias generales, mientras que los análisis categóricos (chi-cuadrado y OR), para evaluar asociaciones específicas que se traduzcan en criterios de riesgo práctico.
Resultados. La edad promedio en las mujeres y los hombres fue 37.32 y 39.26 años, respectivamente. El PA promedio fue más alto en los participantes con riesgo de DM2, tanto en mujeres como en hombres (97.15cm vs. 89.257cm y 97.77cm vs. 85.128cm). En el análisis bivariado, tener un PA elevado y estar en riesgo de DM2 mostró una asociación estadísticamente significativa de baja intensidad en las mujeres (V=0.115) y estadísticamente significativa de intensidad moderada en los hombres (V=0.519). En el análisis multivariado se encontró que tener un PA elevado aumentó la probabilidad de estar en riesgo de DM2 4.56 veces en las mujeres (OR=4.56) y 24.54 veces en los hombres (OR=24.54). Finalmente, la correlación entre el PA y la puntuación de riesgo de DM2 fue moderada en las mujeres (Rho=0.565) y fuerte en los hombres (Rho=0.641).
Conclusiones. El PA elevado está asociado con una mayor probabilidad de estar en riesgo de DM2 en población adulta peruana, principalmente en hombres.

Introduction

Diabetes mellitus (DM) is a chronic metabolic disorder characterized by persistent high blood glucose levels. It can be caused by resistance to the peripheral actions of insulin, impaired insulin secretion, or both.[1] Diabetes can be classified into two types: type 1 (DM1), which accounts for 5-10% of cases and is characterized by autoimmune destruction of insulin-producing pancreatic beta cells, and type 2 (DM2), which accounts for about 90% of cases and is characterized by a reduced response to insulin referred to as insulin resistance.[1] Insulin resistance occurs when muscle, liver, and fat tissue cells do not respond adequately to insulin and cannot absorb glucose from the blood easily, causing the pancreas to produce more insulin to help glucose enter the cells.[2]

T2DM is a disease that impairs the function of almost all organs in the long term and is associated with the development of chronic complications, the most common being macroangiopathy (severe cardiac and vascular lesions leading to hypertension, artery narrowing, coronary artery disease, strokes, and erectile dysfunction in men), diabetic retinopathy, neuropathy, and nephropathy, as well as an increased vulnerability to infections, myopathy, osteoporosis, arthropathy, and liver damage.[3]

According to the International Diabetes Federation, nearly 537 million adults (20-79 years) worldwide suffered from diabetes in 2021,[4] and 90% of them had T2DM.[1,5] In Peru, the prevalence of T2DM in the general population varies between 3.9% and 7.0%.[6] Among the most relevant risk factors for the development of T2DM are overweight, obesity, sedentary lifestyle, aging, ethnicity, family history of diabetes, and an unhealthy diet.[7] Accordingly, elevated values of certain anthropometric parameters, such as body mass index (BMI) and abdominal circumference (AC), can be considered as risk factors for T2DM.

AC, also known as waist circumference, is an anthropometric parameter that is not routinely used in clinical practice, although it provides independent and additive information to BMI for predicting morbidity and risk of death.[8] This parameter is especially relevant as it reflects visceral fat accumulation, which has a direct impact on insulin resistance and systemic inflammation,[9] and is a simple and easy method to standardize and use in clinical practice to assess abdominal adiposity.[8] In this regard, it has been reported that, unlike BMI, which fails to determine cardiometabolic risk in isolation because it is an insufficient biomarker of abdominal adiposity, AC is strongly associated with all-cause and cardiovascular mortality, with or without adjustment for BMI. However, the full strength of the association between this parameter and morbidity and mortality is only evident after adjustment for BMI.[8] On the other hand, assessing adiposity is important because adipose tissue, in addition to its role in fat storage and energy production, has significant effects as an endocrine tissue and immune mediator.[10]

T2DM is a multifactorial disease,[11] so it is necessary to know to what extent AC is related to being at risk of T2DM in a population with heterogeneous ethnic and genetic characteristics such as the Peruvian population, given that there are few previous studies and they have been developed in sociodemographically different populations, such as that of the United States[12] and China.[13] Therefore, studies with representative data for Peru are needed to infer the possible role of AC in the development of a T2DM risk profile. To this end, the objective of the present study was to evaluate the association between AC and being at risk of T2DM in the Peruvian population.

Materials and methods

Study design and analyzed data

Analytical retrospective cross-sectional study, in which an analysis of secondary data obtained from the database of the *Encuesta Demográfica y de Salud Familiar peruana - ENDES 2022* (Demographic and Family Health Survey), conducted between January 1 and December 31, 2022, in 35 287 households (out of 36 650) throughout Peru, was carried out. The ENDES is a complex, probabilistic, two-stage and independent population-based survey that evaluates every year the demographic and health dynamics of the Peruvian population depending on their area of residence (urban and rural).[14] It should be noted that the study was conducted following the recommendations of the REporting of studies Conducted using Observational Routinely-collected health Data (RECORD) guidelines.[15]

Sampling was purposive. Respondents of legal age (≥18 years) in whom the measurement of anthropometric data (weight, height, and AC) was reported (N=34 301) were considered as eligible. Subsequently, respondents with incomplete or missing data for the variables of interest for the study and those who reported a diagnosis of diabetes mellitus were excluded, thus obtaining a sample of 28 407 individuals (16 058 women and 12 349 men) (Figure 1).

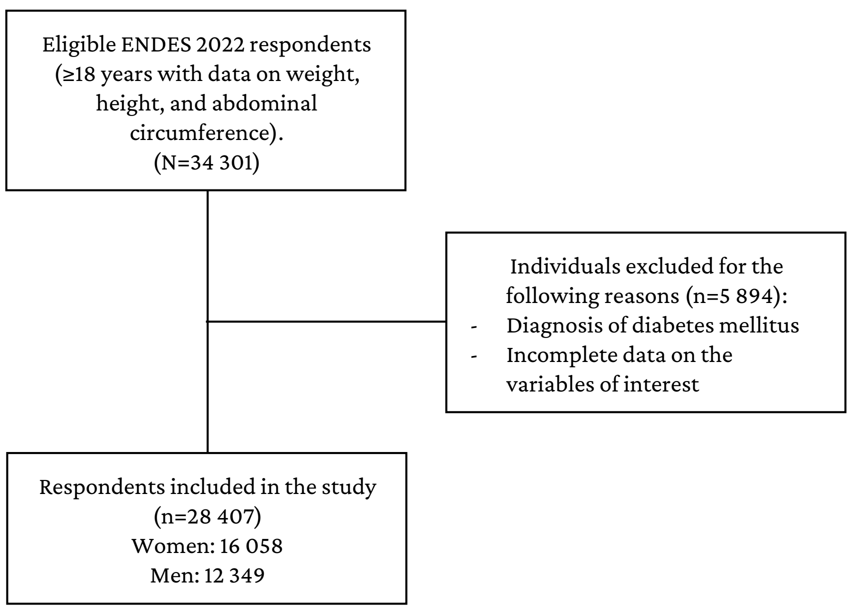

Figure 1. Flowchart for the selection of study participants.

Variables and measurements

Information on the following variables was obtained from the ENDES 2022 database: sex, age, educational attainment (primary, secondary, higher, no education), alcohol consumption (yes/no), BMI, AC, systolic blood pressure (SBP, with values ≥130mmHg considered as hypertension), diastolic blood pressure (DBP, with values ≥80mmHg considered as hypertension), mean arterial pressure (MAP, with values ≥100mmHg considered as hypertension), and basal metabolic rate (BMR).

As reported in the literature,[16] AC was classified as normal (women: <81cm; men: <95cm) or high (abdominal obesity) (women: ≥81cm; men: ≥95cm). The measurement of the other anthropometric parameters was performed by anthropometrists trained in measurement techniques by the *Centro Nacional de Alimentación, Nutrición y Vida Saludable* (National Center for Food, Nutrition and Healthy Living) in a training that lasted about 17 days. AC was measured by placing a measuring tape perpendicular to the longitudinal axis of the body, between the costal ridge and the iliac spine and with the individual standing upright.

Moreover, the risk of T2DM was determined using the diabetes risk score developed and validated by Bang *et al.*[17] This instrument was used instead of the FINDRISK test because the latter includes an item on the frequency of fruit and vegetable consumption, an aspect not surveyed in the ENDES. The instrument developed by Bang *et al.*[17] is a 6-question closed-ended questionnaire on the following aspects: age, sex, family history of diabetes (in parents or siblings), presence of arterial hypertension, presence of overweight or obesity as measured by BMI, and physical activity. The response to each of these questions has an assigned score, and the diabetes risk score is obtained by adding the scores for each question, where a score ≥4 means high risk of undiagnosed diabetes or prediabetes and a score ≥5, high risk of undiagnosed diabetes.[17] Importantly, in the present study, individuals with a score ≥4 were considered to be at risk for T2DM (Table 1).

Table 1. Instrument used to determine the risk of diabetes.

Question	Score	Enter your score (Enter 0 if you don't know)
How old are you?	<40 years old (0 points)	
	40-49 years old (1 point)	
	50-59 years old (2 points)	
	≥60 years old (3 points)	
Are you a woman or man?	Woman (0 points)	
	Man (1 point)	
Do your family members (parent or sibling) have diabetes?	No (0 points)	
	Yes (1 point)	
Do you have high blood pressure or are you on medication for high blood pressure?	No (0 points)	
	Yes (1 point)	
Are you overweight or obese? (see chart below to answer this question more accurately)	Not overweight or obese (0 points)	
	Overweight (1 point)	
	Obese (2 points)	
	Extremely obese (3 points)	
Are you physically active?	No (0 points)	
	Yes (1 point)	
Total score (add points from questions 1–6)		
If your TOTAL SCORE is ≥4, you are at high risk for undiagnosed diabetes or prediabetes. If your TOTAL SCORE is ≥5, you are at high risk for undiagnosed diabetes. See your doctor for a blood test to look for diabetes if your score is high.		
Obesity definitions Extreme obesity: BMI ≥40kg/m² (men and women), or waist circumference ≥50 in (men) or ≥49 in (women) Obesity: BMI ≥30kg/m² but <40kg/m² (men and women), or waist circumference ≥40 in but <50 in (men) or ≥35 in but <49 in (women) Overweight: BMI ≥25kg/m² but <30kg/m² (men and women), or waist circumference ≥37 in but <40 in (men) or ≥31.5 in but <35 in (women)		

Source: Taken from Bang *et al.*[17]

With respect to question 4 (Do you have high blood pressure or are you on medication for high blood pressure?), the presence of hypertension was assessed using the MAP because this parameter, compared to SBP and DBP alone, efficiently measures blood pressure during a complete cardiac cycle, thereby reflecting tissue perfusion better. MAP was calculated with the following formula and using the SBP and DBP data reported in the second blood pressure measurement performed in the context of the ENDES:

$$MAP = \frac{(DBP\ 2) + SBP}{3}$$

Statistical analysis

Prior to analysis, data were cleaned by correcting decimals, spell-checking misspelled variables, and transforming data for the calculation of the diabetes risk score. This cleaning was performed in the same database on the SPSS statistical software. Data are described using absolute frequencies and percentages for qualitative variables and means and standard deviations for quantitative variables. Also, the data are presented separately for men and women.

Regarding inferential analysis, Student's t-test was used to evaluate differences in AC between groups (individuals at risk of T2DM vs. individuals at no risk of T2DM) for men and women. To evaluate the association between AC (normal vs. high) and being at risk of T2DM in both men and women, we first performed a bivariate analysis using the chi-square test and calculated crude odds ratios (OR), and then a multivariate analysis using a binary logistic regression model that included the Wald test and the β-exponential, which represents the adjusted ORs. Furthermore, other variables were included in this model, such as BMR (which was obtained using the Harris-Benedict formula based on BMI and weight), educational attainment, and alcohol consumption, to obtain greater statistical precision and reduce bias due to confounding factors.

It is noteworthy that, even though both AC and the diabetes risk score allow determining the presence of obesity (abdominal obesity and obesity, respectively), it was considered that there was no collinearity in the binary logistic regression model between these two variables, given that the method of measurement is different (the former involves a waist measurement, while the latter uses weight, height, and age). Similarly, multicollinearity, which was assessed by means of the variance inflation factor (VIF), was within acceptable limits (VIF<10).

Finally, Spearman's correlation coefficient (Rho) was used to assess the correlation between AC and T2DM risk score. This test was used due to the non-normality of data distribution (Kolmogorov-Smirnov test). Notably, although this nonparametric test measures monotonic relationships, results should be interpreted with caution when extrapolating to other populations, as potential biases include nonlinear relationship, sample dependence, and extrapolation outside the observed range. Therefore, these results should not be extrapolated directly outside the context of the sample, and we recommend validating these findings in further research.

A significance level of $p<0.05$ and a 95% confidence interval were used in all analyses. The adequacy of the models and assumptions was checked by standard diagnostics, such as deviance residuals, to ensure that the logistic regression model was not misspecified.

Ethical considerations

The study followed the ethical principles for biomedical research involving human subjects established in the Declaration of Helsinki[18] and received authorization for the use of open data from the Peruvian Ministry of Health through the National Institute of Health by means of Minutes No. 001-2023-UDT-OTIC-INS of November 11, 2023. It should be noted that the database used does not include personal data (names, addresses, etc.) that would make it possible to know the identity of the participants (available at: https://www.datosabiertos.gob.pe/dataset/encuesta-demogr%C3%A1fica-y-de-salud-familiar-endes-2022-instituto-nacional-de-estad%C3%ADstica-e).

Results

The mean age, mean AC, and mean T2DM risk score in women and men were 37.32 and 39.26 years, 91.15cm and 91.31cm, and 2.93 and 4.24 points, respectively. With the exception of BMI, men showed higher values for all parameters evaluated (age, BP, SBP, DBP, MAP, BMR, and T2DM risk score) (Table 2).

Table 2. Population characteristics by sex.

Characteristics		Women (n=16 058)		Men (n=12 349)	
Age (years) **Mean, SD**		37.32	15.8	39.26	16.4
Systolic blood pressure (mm/Hg) **Mean, SD**		110.76	16.23	122.23	15.36
Diastolic blood pressure (mm/Hg) **Mean, SD**		72.3	9.82	76.65	10.7
Mean arterial pressure (mm/Hg) **Mean, SD**		85.11	11.01	91.84	11.37
Body mass index (kg/m²) **Mean, SD**		27.5	5.31	26.2	4.71
Abdominal circumference (cm) **Mean, SD**		91.15	11.94	91.312	11.6873
Basal Metabolic Rate (Kcal/day) **Mean, SD**		1238.79	171.2	1377.35	191.33
Type 2 diabetes mellitus risk score (points) **Mean, SD**		2.93	1.36	4.24	1.3
Educational attainment **n, %**	**Elementary**	3 124	19.45	2 631	21.31
	Secondary	7 729	48.13	5 766	46.69
	Higher	4 988	31.06	3 796	30.74
	None	217	1.35	156	1.26
Alcohol use **n, %**	**Yes**	13 995	87.15	11 663	94.44
	No	2 063	12.8	686	5.56

SD: standard deviation.

Of the 28 407 respondents included in the study, 34.23% (n=9 725) were at risk for T2DM, and 61.85% of them were men. Along the same lines, the frequency of T2DM risk was much higher in men than in women (48.71% vs. 23.10%). Moreover, in both men and women, mean AC was significantly higher in subjects at risk of T2DM (97.77cm vs. 85.12cm, p<0.001 and 97.15cm vs. 89.25cm, p<0.001). These data show that, for participants at no risk of T2DM, AC was higher in women than in men (89.25±10.89cm vs. 85.12±8.89cm) (Table 3).

Table 3. Abdominal circumference in Peruvian adult women and men depending on the presence of risk of type 2 diabetes mellitus (n=28 407).

	Women (n=16 058)				Men (n=12 349)			
	n (%)	Mean	SD	*p*-value	n (%)	Mean	SD	*p*-value
At risk of T2DM	3 710 (23.10%)	97.15cm	13.18	<0.001	6 015 (48.70%)	97.77cm	10.81	<0.001
No risk of T2DM	12 348 (76.90%)	89.25cm	10.89		6 334 (51.30%)	85.12cm	8.89	

SD: standard deviation; T2DM: type 2 diabetes mellitus.

The results of the bivariate analysis showed a statistically significant association of low intensity (OR=2.174; p<0.001, V=0.115) between having a high AC and being at risk of T2DM in women, with a greater frequency of high AC being found in the group at risk of T2DM (87.63% vs. 76.51%). In men, the proportion of individuals with high AC was much greater in the group at risk of T2DM (63.59% vs. 13.21%), while having a high AC increased the likelihood of being at risk of T2DM by almost 12-fold (OR=11.471), with this being a statistically significant association of moderate intensity (p<0.001, V=0.519) (Table 4).

Table 4. Association between abdominal circumference and presence of type 2 diabetes mellitus in Peruvian adult women and men. Bivariate analysis.

	Women							Men						
	At risk of T2DM n=3 710	No risk of T2DM n=12 348	Total (n=16 058)	*p*-value	Cramér's V	OR	95%CI	At risk of T2DM n=6 015	No risk of T2DM n=6 334	Total (n=12 349)	*p*-value	Cramér's V	OR	95%CI
Large circumference (≥81cm)	3251 (87.63%)	9448 (76.51%)	12699 (79.08%)	<0.001	0.115	2.174	1.955-2.418	3825 (63.59%)	837 (13.21%)	4662 (37.75%)	<0.001	0.519	11.471	10.486-12.5478
Normal circumference (<81cm)	459 (12.37%)	2900 (23.49%)	3359 (20.92%)					2190 (36.41%)	5497 (86.79%)	7687 (62.25%)				

T2DM: diabetes mellitus type 2; OR: Odds ratio.

In the multivariate analysis (binary logistic regression model), after interaction with the variables included to obtain greater statistical precision (i.e., BMR, educational attainment, and alcohol use), it was found that women with a high AC were 4.56 times more likely to be at risk of T2DM compared to those with normal AC (OR=4.56, 95%CI: 3.963-5.520; p<0.001). For men, having a high AC increased this probability 24.54-fold (OR=24.54, 95%CI: 21.534-27.975) (Table 5).

Table 5. Results of multivariate analysis (binary logistic regression).

	Women						Men					
	B	Standard error	Wald test	*p*-value	Exponential β	95%CI	B	Standard error	Wald test	*p*-value	Exponential β	95%CI
Basal metabolic rate	0.835	0.047	315.965	<0.001	2.304	2.101-2.526	1.192	0.066	323.192	<0.001	3.292	2.891-3.749
Abdominal circumference - high	1.518	0.072	447.008	<0.001	4.561	3.963-5.520	3.200	0.067	2298.862	<0.001	24.545	21.534-27.975
Educational attainment - no education	0.703	0.051	189.593	<0.001	2.020	1.828-2.233	0.296	0.051	33.433	<0.001	1.344	1.216-1.486
Alcohol use - yes	0.453	0.074	37.806	<0.001	1.572	1.361-1.617	1.430	0.123	134.334	<0.001	4.180	3.282-5.324

Finally, AC and T2DM risk score were found to be positively and moderately correlated (Rho=0.565; $p<0.001$) in women, while this correlation was positive and strong in men (Rho=0.641; $p<0.001$) (Table 6).

Table 6. Spearman correlation between abdominal circumference and risk score for type 2 diabetes mellitus in adults included in the study population.

	Rho	*p*-value	n
Women	0.565	<0.001	16 058
Men	0.641	<0.001	12 349

Rho: Spearman's rank correlation coefficient.

Discussion

In the present study, conducted using data from 28 407 Peruvian adults retrieved from the ENDES 2022 database (16 058 women and 12 349 men), 34.23% of participants were at risk of developing T2DM (diabetes risk score ≥4) and 61.85% of these subjects were men, with a much higher proportion of risk of T2DM in men than in women (48.71% vs. 23.10%). While the mean AC was similar in men and women (91.31±11.68cm vs. 91.15±11.94cm), it should be noted that the cutoff points for high circumference are different for each sex (≥95cm and ≥81cm), which in fact was reflected in a much higher frequency of elevated AC in women (79.08% [n=12 699] vs. 37.75% [n=4 662]). Likewise, in both men and women, the mean AC was significantly higher in individuals at risk of T2DM (97.77cm vs. 85.12cm, $p<0.001$, and 97.15cm vs. 89.25cm, $p<0.001$), but this parameter was higher in women who were not at risk of T2DM.

The greater proportion of women with a high AC compared to men could be attributed to sex differences in adipose tissue distribution and body composition, given that women tend to accumulate more body fat than men and men tend to have a more central fat distribution, with these differences becoming more evident after puberty due to changes in sex hormone levels.[19] This finding could also be attributed to differences between sexes related to body constitution and composition, as it has been described that men are generally 7% to 8% taller than women and their weight is usually 15% heavier.[20]

Even though the reason why certain women are susceptible to visceral accumulation is still unknown, it has been reported that sex hormones play an important role in regulating the distribution of adipose tissue. On this point, estrogens are considered to be responsible for the gluteal-femoral distribution of fat that seems to protect women from T2DM. However, there is a shift to an android distribution of body fat after menopause, presumably due to a decrease in estrogen levels.[21] In this regard, the fact that in the present study the frequency of high AC was much higher in women than in men (79.08% vs. 37.75%), whereas the proportion of women with a high AC was similar between individuals at risk and without risk of T2DM (87.63% vs. 76.51%), unlike what was observed in men, for whom this proportion was much higher in the group at risk of T2DM (63.59% vs. 13.21%), suggests that higher AC does not have a significant impact on the risk of T2DM in women, which may be influenced by sex hormonal factors.

According to the results of the bivariate analysis, men with a high AC had a nearly 12-fold increased risk of T2DM (OR=11.471) compared to those with normal AC, with this association being significant and moderate in intensity ($p<0.001$, V=0.519), while this association in women, although significant, was low in intensity (OR=2.174; $p<0.001$, V=0.115). Furthermore, the correlation between T2DM risk score with high AC was positive and strong in men (Rho=0.641; $p<0.001$), but positive and moderate in women (Rho=0.565; $p<0.001$). The foregoing suggests that the impact that AC has on the presence of T2DM risk differs depending on sex. In fact, in the multivariate analysis, the magnitude of this association was twice as strong in the presence of variables such as BMR, educational attainment and alcohol use, as the probability of being at risk of T2DM was more than 24 times higher in men (OR=24.54, 95%CI: 21.534-27.975; $p<0.001$) and over 4 times higher (OR=4.56, 95%CI: 3.963-5.520; $p<0.001$) in women when AC was high.

These findings are in agreement with those reported in the literature. For example, Fan *et al.,*[13] in a prospective study conducted between 2008 and 2012 in 10 419 adults residing in Tianjin (China) to evaluate the associations between baseline adiposity indicators (BMI, waist circumference, and WHtR) and short-term body adiposity changes with the risk of T2DM, found that subjects with the most waist circumference gain had a 1.37-fold greater risk of T2DM. Similarly, Nair *et al.,*[22] in a US study using data from 30 780 young adults to assess the relationship between overweight/obesity during early adulthood and later-life diabetes, found that having an elevated BMI (≥30kg/m^2) and a high waist circumference (women: >88cm; men: >102cm) in early adulthood is associated with an increased risk of T2DM after the age of 40, regardless of later exposures (HR: 1.99 and 2.13, respectively).

Taking into account these findings, various T2DM prevention measures that incorporate high AC could be implemented in Peru, including abdominal obesity awareness programs to sensitize the population on the importance of maintaining a healthy AC, especially in men, who are at higher risk. Also, expanding the monitoring of risk indicators with tools such as the Bang *et al.*[17] instrument would be key to identify at an early stage those individuals most likely to develop T2DM. Likewise, sex-specific interventions should be designed bearing in mind hormonal and body composition differences between men and women, which would allow for a more individualized approach in the prevention and treatment of the disease. Finally, physical activity, especially aerobic exercise, should be encouraged, as it has been shown to reduce visceral fat and contribute to AC control. The implementation of these measures would contribute to reducing the burden of T2DM in the Peruvian population, thus improving public health nationwide.

The limitations of the present study have to do with the failure to randomize sample selection, since the ENDES 2022 data were purposively sampled. However, due to the characteristics of the survey's sampling, which covered the entire Peruvian territory, the results are considered extrapolable to the national population. Another limitation was the inability to include in the binary logistic regression model more variables that could have been confounding factors, such as the presence of dyslipidemias, baseline blood glucose levels, glycosylated hemoglobin, presence of other comorbidities, among others. Moreover, despite a follow-up and data cleaning procedure, misclassification bias in the processing of these data by the survey developers, who may have misclassified cases of suicidal ideation, anthropometric characteristics, or sociodemographic data, could not be ruled out. Finally, as is the case of any cross-sectional study, the research cannot categorically establish direct causality between the variables, and there may be an overrepresentation of long-standing cases with high AC and risk of T2DM or an underrepresentation of normal cases. Also, although patients who reported having been diagnosed with T2DM were excluded, it is possible that there were cases not yet diagnosed or not reported at the time of the survey, which could lead to information bias.

Conclusions

Based on the results reported in the present study, it could be concluded that a high AC in the Peruvian adult population is associated with a greater likelihood of being at risk of developing T2DM, with a strong correlation in men and a moderate correlation in women. Due to the extensive differences relating to the impact of AC in men and women on the risk phenotype of T2DM, it is necessary to conduct research focused on the study, prevention, and treatment of abdominal obesity in adults in the context of the probable physiological, biochemical, and anatomical causal characteristics linked to sex in the Peruvian population. Likewise, the use of test tools such as the Bang *et al.*[17] score is suitable for the detection of populations with anthropometric profiles at risk of developing T2DM in massive epidemiological studies, and its use in future epidemiological studies at the national level is suggested.

Conflicts of interest

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