Journal of Sport and Health Research 2022, 14(3):359-374

Caballero-García, Mª. F.; Albaladejo-Saura, M.; Vaquero-Cristóbal, R.; Esparza-Ros, F. (2022). Utility of the anthropometric variables in the diagnosis and characterization of type 2 diabetes mellitus patiens. *Journal of Sport and Health Research. 14*(3):359-374.

Review

UTILIDAD DE LAS VARIABLES ANTROPOMÉTRICAS EN EL DIAGNÓSTICO Y CARACTERIZACIÓN DE PACIENTES DE DIABETES MELLITUS TIPO 2

UTILITY OF THE ANTHROPOMETRIC VARIABLES IN THE DIAGNOSIS AND CHARACTERIZATION OF TYPE 2 DIABETES MELLITUS PATIENTS

Caballero-García, Mª. F.[1]; Albaladejo-Saura, M.[1]; Vaquero-Cristóbal, R.[1,2*]; Esparza-Ros, F.[1]

[1]*Kinanthropometry International Chair. Universidad Católica San Antonio de Murcia, Murcia, Campus de los Jerónimos, 30107 Guadalupe, Murcia, Spain*

[2]*Sports Faculty. Universidad Católica San Antonio de Murcia, Murcia, Campus de los Jerónimos, 30107 Guadalupe, Murcia, Spain*

Correspondence to:
Vaquero-Cristóbal, Raquel
Kinanthropometry International Chair. Universidad Católica San Antonio de Murcia, Murcia, Campus de los Jerónimos, 30107 Guadalupe, Murcia, Spain.
Tel. +34 968278824
rvaquero@ucam.edu

Edited by: D.A.A. Scientific Section Martos (Spain)

Didactic Association ANDALUCIA

editor@journalshr.com

Received: 15/04/2021
Accepted: 20/07/2021

Journal of Sport and Health Research 2022, 14(3):359-374

RESUMEN

Objetivos; analizar la relación de las variables antropométricas con la predicción y la descripción de pacientes adultos de Diabetes Mellitus Tipo 2 Se realizó una búsqueda en PubMed, Web of Sciences y Scopus hasta diciembre de 2019. Durante el proceso se siguió la declaración PRISMA. Resultados: Se seleccionaron 2622 artículos y se incluyeron 15 en la revisión. La calidad de los estudios incluidos en la revisión se evaluó con la escala STROBE para estudios descriptivos (rango 16-21). El índice de masa corporal (IMC) (10 artículos, 66,6%), el perímetro de la cintura (CC) (10 artículos, 66,6%), la relación cintura-cadera (RCC) (6 artículos, 40%) y la relación cintura-talla (RCT) (3 artículos, 20%) fueron las variables más utilizadas en estos estudios en relación con la DM2-DM22. Conclusiones: Los adultos con factores de riesgo de DM2 o diagnosticados de DM2 tienden a tener un mayor IMC, WC, WHR y WHtR. La antropometría ha demostrado ser una técnica eficaz y fiable para predecir y describir a los pacientes diagnosticados de DM2 cuando se utiliza una combinación de variables

Palabras clave: Antropometría, factores de riesgo, enfermedad crónica, diabetes mellitus tipo 2

ABSTRACT

Objective: to analyze the relationship of anthropometry with the prediction and description of DM2 patients in adults. Method: A search in PubMed, Web of Sciences and Scopus was performed up to December 2019. During the process, the PRISMA statement was followed. Results: A total of 2622 articles were screened and 15 were included in the review. The quality of the studies included in the review was assessed with the STROBE scale for descriptive studies (range 16-21). Body mass index (BMI) (10 articles, 66.6%), waist circumference (WC) (10 articles, 66.6%), waist to hip ratio (WHR) (6 articles, 40%), and waist to height ratio (WHtR) (3 articles, 20%) were the most commonly used variables in these studies in relation to DM2. Conclusions: Adults with DM2 risk factors or diagnosed with DM2 tend to have higher BMI, WC, WHR, and WHtR. Anthropometry has been shown to be an efficient and reliable technique for predicting and describing patients diagnosed with DM2 when a combination of variables is used.

Keywords: Anthropometry, risk factors, chronic disease, diabetes mellitus typo 2

Journal of Sport and Health Research 2022, 14(3):359-374

INTRODUCTION

Previous research has estimated that the incidence of diabetes for all age groups will be 4.4% by 2030 (Wild et al., 2004), with a majority of cases being type-2 diabetes (Bullard et al., 2018). Approximately 90.9% of the diagnosed cases of diabetes mellitus are identified as type-2 diabetes, accounting for an incidence of 8.6% of the total population (Bullard et al., 2018). Diabetes mellitus is characterized by β-cell failure (Cnop et al., 2005), thus, type-2 diabetes (DM2) signifies resistance to insulin due to its relative deficiency (Sanz-Sánchez & Bascones-Martínez, 2009). DM2 is a complex chronic and metabolic disease, associated to irreversible, disabling and fatal conditions (Baynest, 2015).

The DM2 has a combination of several etiologies, requiring the use of different strategies for identifying the disease in order to improve the prevention, treatments and the management of patients (Pearson, 2019). Physical activity, smoking and obesity are considered relevant factors for disease emergence (Al Amiri et al., 2015; Aune et al., 2015). Thus, techniques to determine different health and morphological conditions of these patients must be investigated to elucidate the input and weight of each one for DM2 diagnosis.

Anthropometric techniques are considered important instruments for quantifying health conditions (Khunti et al., 2010; Muñoz et al., 2010), and some institutions have recommended anthropometry measurements as a way to monitor non-transmissible diseases (ACSM, 2014; WHO, 1999). Anthropometry is widely used in health assessment due to the ease of use as a field test, the reliability and validity showed, and the low cost of the equipment needed compared with other methods (Ayvaz & Çimen, 2011; Tellez et al., 2020). In fact, anthropometry-based methods could be utilized as the main technique for determining the morphological aspects of DM2 patients (Duren et al., 2008).

Among the anthropometric variables that have been most commonly used to describe DM2 risk are waist circumference (WC), BMI, and waist-to-hip ratio (WHR), although some controversy can be found as to which of these are most useful. (Awasthi et al., 2017; Bays et al., 2010; Schulze et al., 2006). The use of these variables is justified by the relationship between obesity and visceral fat accumulation and the risk of developing DM2. (Bays et al., 2010). Higher visceral adipose tissue (VAT) has been found to be associated with a higher likelihood of developing DM2, so higher WC and WHR values could be indicators of risk for DM2. (Bays et al., 2010; Schulze et al., 2006). The relationship between the risk of DM2 and BMI value is controversial, being found to be a good predictor and descriptor of patients with DM2 in some articles (Awasthi et al., 2017), while in others lose relevance against other variables (Schulze et al., 2006).

However, in recent years, the age for DM2 diagnosis has decreased, as it has become a disease typical of adults, young people and even children (Amed et al., 2018). This makes the identification of variables related to DM2 in adults and young people important for achieving better prevention, characterization and/or treatment (Jensen & Dabelea, 2018). Along this line, a large variety of scientific reports on DM2 have been published with different sample sizes, sample characteristics, quality levels, techniques, and research procedures, among others factors. Therefore, the aim of this systematic review was to know the relationship between anthropometric variables and the prediction and description of patients with DM2 in adult samples.

METHODS

Study design

The design of the study was a systematic review based on the PRISMA declaration guidelines (Page et al., 2021). All the documents related to the applications of anthropometry for predicting or detecting DM2 were considered for the systematic review. For the correct use of the terminology during the research process, different terms were assigned to each of the parts that comprised the PICO (Patient, Intervention/Comparison, Outcomes/Results) strategy (da Costa Santos et al., 2007).

Search strategy

A search through Pubmed-Medline, Web of Science and Scopus databases was performed. The keywords used were “anthropometry” and “diabetes” in the abstract search field, where the Boolean operator “and” was used to determine documents with both terms in this field combined with the connector “AND”. All the published studies up to December 2019 were screened.

Journal of Sport and Health Research 2022, 14(3):359-374

The specific inclusion criteria were: a) original studies; b) descriptive studies, accepted between 2000 and 2019; c) studies with human samples; d) studies with healthy participants or DM2 patients; e) studies with adult population; f) studies that applied at least one anthropometric technique; g) studies referred to the prediction or patients' description of DM2; h) studies written in English. The exclusion criteria were: a) scientific articles focused on other pathologies aside from DM2; b) systematic, narrative, meta-analysis reviews, RCT studies; c) meeting abstracts; d) articles written in any other languages not specified in the inclusion criteria.

Search profile and risk of bias

Two reviewers (M.F.C.-G. and M.A.-S.) performed the search independently, screened the titles and abstracts of the search results and reviewed the full text selected before the inclusion in the meta-analysis. A third reviewer (R.V.-C.) was consulted to resolve any disagreement regarding inclusion. To determine the inter-rater reliability of the reviewers, Cohen´s Kappa (McHugh, 2012) was calculated, showing a strong level of agreement (Kappa = 0.913). The first search resulted in 2,622 documents; 2,613 articles were selected from the databases following the selection criteria, and another 9 documents were included after searching through the references. After the search for duplicated documents, 1715 articles were excluded. Thus, 907 full texts were finally assessed for eligibility. From these studies, 881 did not meet the inclusion criteria established. Four out of 26 previously-selected studies were excluded due to not showing results related to the application of anthropometry to DM2. A total number of 15 studies were included in the systematic review. The flow diagram of the search process is shown in Figure 1.

Journal of Sport and Health Research 2022, 14(3):359-374

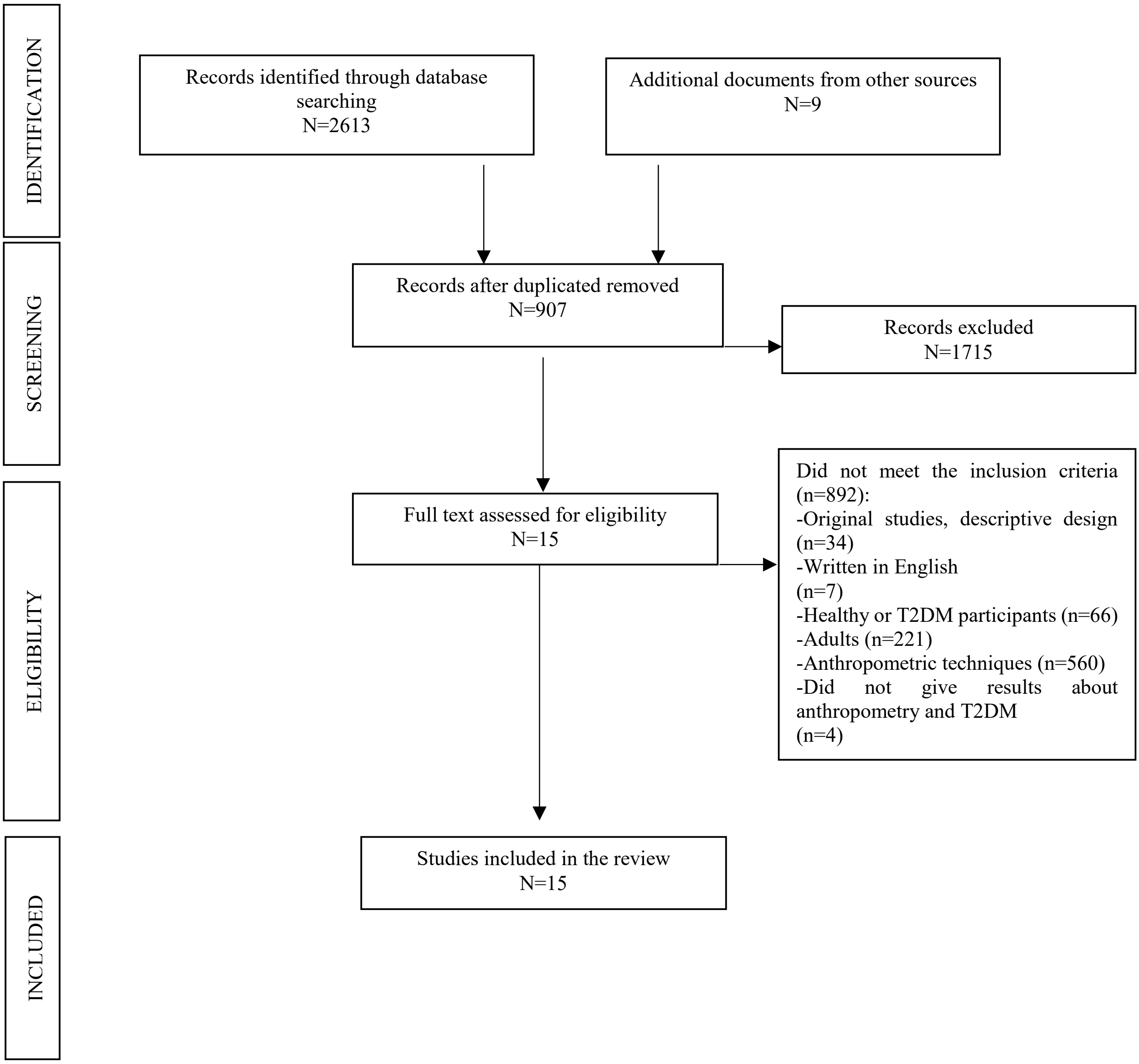

Figure 1. Searching procedure and studies included.

Data extraction and risk of bias

The following information from each document was extracted: year; country; sample size; sample age; sample sex; sample characteristics; design; procedure; aspects studied; training of the researchers in anthropometric techniques; techniques used; measurement methodology and significant results. It was used Strengthening Reporting of Observational Studies in Epidemiology (STROBE) statement (von Elm et al., 2008) to assess the quality of the studies included. Quality assessment was performance by two reviewers (M.F.C.-G. and M.A.-S.). Disagreement was consulted to resolve by a third reviewer (F.E.-R.)

RESULTS

The approach to DM2 allowed for the classification of the documents into two specific areas: prediction and patients' description. From the 15 articles included in the review, 13 (86.6%) were focused on the identification of predictive variables of DM2, and 2 (13.4%) aimed to describe anthropometric characteristics of DM2 patients. The results related to location, sample size, sex and age are shown in Table 1. Most studies included both sexes (Anjana et al., 2004; Ben Ali et al., 2019; Gracey et al., 2007;

Journal of Sport and Health Research 2022, 14(3):359-374

Guerrero-Romero & Rodríguez-Morán, 2003; Lee & Kim, 2016; Moy & Rahman, 2002; Padaki et al., 2011; Qureshi et al., 2019; Sargeant et al., 2002; Ting et al., 2018; Zaman et al., 2011) . There was heterogeneity in the sample size (n=64-30,915 participants) and in the presence or absence of DM2 in the samples (Diabetic patients: n=1, 6.67%; Non-diabetic: n=9, 60%; Diabetic and non-diabetic: n=5, 33.33%).

The objective, design, procedures, kinanthropometric variables used and main results can be observed in Table 2. The majority of the prediction-related articles utilized across-sectional design (n=14; 93.33%) (Anjana et al., 2004; Ben Ali et al., 2019; Brenner et al., 2017; Gracey et al., 2007; Guerrero-Romero & Rodríguez-Morán, 2003; Lee & Kim, 2016; Lutsey et al., 2010; Moy & Rahman, 2002; Padaki et al., 2011; Qureshi et al., 2019; Sargeant et al., 2002; Sánchez-Jiménez et al., 2019; Wang et al., 2005; Zaman et al., 2011). BMI (n=12, 80.00%) (Anjana et al., 2004; Brenner et al., 2017; Gracey et al., 2007; Lee & Kim, 2016; Moy & Rahman, 2002; Padaki et al., 2011; Qureshi et al., 2019; Sargeant et al., 2002; Sánchez-Jiménez et al., 2019; Ting et al., 2018; Wang et al., 2005; Zaman et al., 2011), WC (n=11, 73.33%) (Ben Ali et al., 2019; Brenner et al., 2017; Gracey et al., 2007; Lee & Kim, 2016; Lutsey et al., 2010; Padaki et al., 2011; Sargeant et al., 2002; Sánchez-Jiménez et al., 2019; Ting et al., 2018; Wang et al., 2005; Zaman et al., 2011), WHR (n=7, 46.67%) (Brenner et al., 2017; Lee & Kim, 2016; Padaki et al., 2011; Qureshi et al., 2019; Sargeant et al., 2002; Sánchez-Jiménez et al., 2019; Wang et al., 2005), and WHtR (n=3, 20%) (Gracey et al., 2007; Padaki et al., 2011; Sargeant et al., 2002)were the most commonly calculated variables in these studies, although hip circumference (HC) (Ting et al., 2018), rib-to-hip-ratio (RHR) (Lee & Kim, 2016), antero-posterior diameter (APD) (Anjana et al., 2004), abdominal volume index (AVI) (Guerrero-Romero & Rodríguez-Morán, 2003), neck circumference (NC) (Lee & Kim, 2016; Ting et al., 2018), thorax circumference (TC) (Lee & Kim, 2016), and waist width (WW) (Ting et al., 2018) were also used. According to the articles included, an increase in waist circumference (WC) (Ben Ali et al., 2019; Gracey et al., 2007; Sargeant et al., 2002; Wang et al., 2005; Zaman et al., 2011), Body mass index (BMI) (Brenner et al., 2017; Moy & Rahman, 2002; Qureshi et al., 2019; Sargeant et al., 2002; Wang et al., 2005), waist-to-hip ratio (WHR) (Lee & Kim, 2016; Qureshi et al., 2019; Sargeant et al., 2002)and waist-to-height ratio (WHtR) (Gracey et al., 2007; Sargeant et al., 2002)was related to the appearance of DM2 or disease indicators. In four articles (26.7%), the aim was to describe anthropometric differences of DM2 patients with respect to the non-diabetic population (n=3, 20%), and impaired glucose tolerance (IGT) with respect to the non-diabetic population (n=1, 6.6%). One article (6.6%) described anthropometric differences between individuals with a diabetes family history (DH) and a healthy population. The results of these articles showed that patients with DM2 or DH had a higher WC, BMI and WHR as compared to the healthy population.

The quality of the selected studies, assessed with STROBE scale can be observed in Table 3. All the studies followed a descriptive design (STROBE scale range 16-21).

Journal of Sport and Health Research 2022, 14(3):359-374

Table 1. Authors, location and sample characteristics.

Authors	Country	Sample size	Age (years)
Anjana et al. (2004)	India	82 D and 82 ND: 88 W; 76 M	45±9
Ben Ali et al. (2019)	Comoros	902 ND: 540 W; 362 M	39,5±11,63
Brenner et al. (2017)	Canada	30;915 ND: 12;062 M; 18;853 W	35-69
Gracey et al. (2007)	Australia	401 ND: 228 W; 173 M	Adults: Not specified
Guerrero-Romero & Rodríguez-Morán (2003)	Mexico	746 ND: 546 W; 200 M	40,7±11,2
Lee & Kim (2016)	Korea	9;952 ND: 6;103 W; 3;849 M; 1;985 D: 928 W; 1;057 M	54,39±11,34 W and ND; 61,49±10,36 W and D; 55,81±11,05 M and ND; 58,49±9,79 M and D
Lutsey et al. (2010)	USA	5;446 ND	61,6
Padaki et al. (2011)	India	32 DH: 15 W; 17 M; 32 ND: 14 W; 18 M	18,56±1,6 DH; 18,8±1,9 ND
Qureshi et al. (2019)	Pakistan	804 D: 598 W; 206 M; 396 ND: 295 W; 100 M	48,7±11;40 D; 37,85±14,36 ND
Sánchez-Jiménez et al. (2019)	Mexico	155 ND and W	44±8,45
Sargeant et al. (2002)	Jamaica	728 ND: 438 W; 290 M	45,9±13,1 W; 49,2±14,9 M
Ting et al. (2018)	Taiwan	8;450 ND: 4;019 W; 4431 M	51,1±11,9
Wang et al. (2005)	USA	27270 ND and M	40-75
Ming & Rahman (2002)	Malaysia	230 D: 127 W; 103 M	54,8±8,2
Zaman et al. (2011)	India	994 ND: 441 W; 503 M; 165 (IGT): 93 W; 72 M; 261 D: 151 W; 110 M	Adults: Not specified

D: Diabetic participants; ND: Non-diabetic participants; CVD: Cardiovascular Disease risk; DH: Diabetes family history; IGT: Impaired Glucose Tolerance; W: women; M: men

Journal of Sport and Health Research 2022, 14(3):359-374

Table 2. Main outcome of the selected studies.

Authors	Objective	Design	Kinanthropometric procedures	Variables	Results
Anjana et al. (2004)	Prediction	Cross-sectional	Protocol not specified	BMI, APD, TC, WC, WHR	Visceral and central abdominal fat showed a strong association with DM2DM22. Both measurements correlate well with each other and with WC and APD in DM2 patients and non-diabetics patients
Ben Ali et al. (2019)	Prediction	Cross-sectional	Protocol not specified	WC	Positive correlation between WC excess and DM2 risk
Brenner et al. (2017)	Prediction	Cross-sectional	Self-reported by participants	BMI, WC, WHR	Overweightness, obesity and WC correlate with family history of DM2
Gracey et al. (2007)	Prediction	Cross-sectional	National Health and Medical Research Council Guidelines (Australia)	BMI, WC, WHtR	WC or WHtR seem to be more useful than BMI to predict DM2
Guerrero-Romero & Rodríguez-Morán (2003)	Prediction	Cross-sectional	Protocol not specified	AVI	The AVI is a reliable and easy measurement and anthropometric tool for the modification of the total abdominal volume that is strongly related to DM2
Lee & Kim (2016)	Prediction	Cross-sectional	Standardized protocols. Not specified	BMI, HC, NC, RHR, TC, W, WC, WHR	Best predictors of DM2 were WHR together with triglycerides for men and the RHR together with triglycerides for women
Lutsey et al. (2010)	Prediction	Cross-sectional	Protocol not specified	WC	Increased WC has a significant association with DM2
Padaki et al. (2011)	Prediction	Cross-sectional	Protocol not specified	BMI, HC, US/LS, WC, WHR, WHtR, WTR	BMI, WHR and upper segment are higher in participants with a family history of DM2 than the control group
Qureshi et al. (2019)	Prediction	Cross-sectional	World Health Organization protocol	BMI, DXA, WHR	89.2% of DM2 patients are obese or overweight (BMI). 97.9% of DM2 patients have a high WHR
Sánchez-Jiménez et al. (2019)	Prediction	Cross-sectional	World Health Organization protocol	BMI, WC, WHR	Positive correlation between DM2 risk and BMI, WC and WHR
Sargeant et al. (2002)	Prediction	Cross-sectional	Protocol not specified	BMI, WC, WHR, WHtR	BMI, WC, WHR, and WHtR predicted DM2 incidents. WC is easiest to interpret and could be useful for promoting health as an alternative to BMI
Ting et al. (2018)	Prediction	Longitudinal	3D scanner	Ht, W, BMI, HdC, HdSA, HdV, NC, CC, WC, CW, WW, CSA, WSA, TSA, TV, AL, AC, FC, ASA, AV, HC, HW, HSA, LL, ThC, CalfC, LSA, LV	A combination of NC and WW corrected by TC could be useful measurements for predicting an individual's future risk of developing DM2
Wang et al. (2005)	Prediction	Cross-sectional	Self-reported by participants	BMI, WC, WHR	WC and BMI were similar and were better than WHR for predicting DM2
Ming & Rahman (2002)	Patients description	Cross-sectional	Protocol not specified	BMI	From all the DM2 patients 66.8% are overweight and 15.8% are obese
Zaman et al. (2011)	Patients description	Cross-sectional	Protocol not specified	BMI, WC	WC is significantly higher in DM2 patients than non-DM2 participants. An increase in WC has a significant association with DM2.

AC: Arm circumference; AL: Arm length; ASA: Arm surface area; AV: Arm volume; AVI: Abdominal volume index; BMI: Body mass index; CalfC: Calf circumference; CC: Chest circumference; CSA: Chest sectional area; CW: Chest width; DXA: Dual-energy X-ray absorptiometry; FC: Forearm circumference; FM: Fat mass; HC: Hip circumference; HdC: Head circumference; HdSA: Head surface area; HdV: Head volume; HSA: Hip sectional area; Ht: Height; HW: Hip width; LL: Leg length; LSA: Leg surface area; LV: Leg volume; NC: Neck circumference; RHR: Rib/hip ratio; TC: Thorax circumference; ThC: Thigh circumference; TSA: Trunk sectional area; TV: Trunk volume; US/LS: Upper segment/low segment ratio; VF: Visceral fat; WC: Waist circumference; WHR: Waist/hip ratio; WHtR: Waist/height ratio; WSA: Waist sectional area; WTR: Waist/tight ratio; WW: Waist width.

Table 3. Results of the STROBE statement scale.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	100%	Score (N=22)
Anjana et al. (2004)	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	86	19
Ben Ali et al. (2019)	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	86	19
Brenner et al. (2017)	1	1	0	0	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	82	18
Gracey et al. (2007)	1	1	1	1	1	0	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	0	82	18
Guerrero-Romero & Rodríguez-Morán (2003)	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	91	20
Lee & Kim (2016)	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	91	20
Lutsey et al. (2010)	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	95	21
Padaki et al. (2011)	1	1	1	1	0	0	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	0	77	17
Qureshi et al. (2019)	1	1	1	0	0	1	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	1	82	18
Sánchez-Jiménez et al. (2019)	1	1	1	0	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1	1	1	0	82	18
Sargeant et al. (2002)	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	91	20
Ting et al. (2018)	1	1	0	0	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	82	18
Wang et al. (2005)	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	91	20
Ming & Rahman (2002)	1	1	1	0	0	0	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	0	72	16
Zaman et al. (2011)	1	1	0	1	0	1	1	1	0	1	1	1	1	1	1	0	1	1	0	1	1	0	72	16

Journal of Sport and Health Research 2022, 14(3):359-374

DISCUSSION

The objective of this systematic review was to analyze the relationship of anthropometry with the prediction and description of adult DM2 patients. The influence of fat mass and its distribution on DM has been widely demonstrated both in the prediction of DM2 and in the characterization of patients (Boyko et al., 2000; Fox et al., 2007; Liu et al., 2010) . Previous works have described how abdominal obesity, or the accumulation of fat mass in the visceral and abdominal areas, is a risk factor for developing type-2 diabetes and other diseases related to metabolic syndrome (Després & Lemieux, 2006; Ritchie & Connell, 2007; Wang et al., 2005) . Due to the increase in obesity and sedentary lifestyles, DM2 increasingly affects the younger adult population, and is even being detected in children and adolescents (Koopman et al., 2005). Therefore, it is important to have tools available that could help identify DM2 to be able to carry out interventions to reduce the risk of suffering the disease.

According to the information provided in the articles included in the review, the anthropometric variables that were most often used for the prediction and characterization of patients were BMI and WC in first place (10 articles, 66.67%, respectively), followed by WHR (6 articles, 40%), and WHtR (3 articles, 20%). In this review, it was found that BMI was a predictor variable for DM2, with a positive correlation with the diagnosis of the disease and with some factors of risk of disease such as insulin resistance and a family history of DM2 (Brenner et al., 2017; Fox et al., 2007; Padaki et al., 2011; Qureshi et al., 2019; Sargeant et al., 2002; Sánchez-Jiménez et al., 2019; Wang et al., 2005). BMI relates total weight to individual height, without distinguishing the components of weight, and has traditionally been used as a variable to assess overweightness and obesity as related to overall health (Kruschitz et al., 2013; Oviedo et al., 2007). It has been observed that among the many factors that influence the increase in fat percentage, is an increased BMI, including overweightness and obesity (Shuster et al., 2012). However, this variable has the limitation that the distribution of this fat mass depends on the ethnicity or age of the population studied, finding that different population groups have a higher or lower risk even when they have the same BMI (Després & Lemieux, 2006; Lutsey et al., 2010). It is possible that this was the reason why some studies determined that BMI alone was less effective in predicting DM2 than other anthropometric techniques such as WC, WHR, WHtR, and NC (Ben Ali et al., 2019; Gracey et al., 2007; Lee & Kim, 2016; Lutsey et al., 2010; Sargeant et al., 2002; Ting et al., 2018; Zaman et al., 2011).

Of the variables mentioned above, both WC and WHR were widely used in the articles included in the review, observing a higher WC and WHR in patients diagnosed with DM2 or in subjects with risk factors related to the disease (Anjana et al., 2004; Ben Ali et al., 2019; Brenner et al., 2017; Gracey et al., 2007; Lutsey et al., 2010; Sargeant et al., 2002; Sánchez-Jiménez et al., 2019; Ting et al., 2018; Wang et al., 2005; Zaman et al., 2011). WC has been related to all types of metabolic and cardiac diseases, being strongly associated with all-cause mortality in both men and women (Bigaard et al., 2005; Khunti et al., 2010). WC has a high correlation with visceral adipose tissue (VAT) (Shuster et al., 2012), and this high correlation, along with the involvement of this fat mass distribution with DM2, may explain the use of this variable as a predictor or descriptor of DM2 patients. HC is considered as an estimation variable of subcutaneous adipose tissue (SAT) (Ashwell et al., 1985; Shuster et al., 2012). The relationship between WC and HC (WHR) is closely related to the VAT-to-SAT ratio, and can be a reliable indicator of the proportion of intra-abdominal fat (Shuster et al., 2012). The WHtR, a variable that relativizes the WC with the individual's height, has also been highlighted as an easy test to use, and it has a high correlation with the previous ones (Gracey et al., 2007; Sargeant et al., 2002). Despite being less used, NC has also been shown to be an effective predictive variable for metabolic syndrome (Laohabut et al., 2020). When NC was combined with WW and the thoracic circumference, it was considered a useful predictor of risk factors related to DM2 (Ting et al., 2018).

However, despite the proven practical applications of these variables, there are some limitations to consider. Firstly, these are variables based on double indirect methods (Ayvaz & Çimen, 2011). In these cases, the protocol followed, the material used and the training of the researcher play crucial roles in the reliability and validity of the measurement, with possible errors of 4% due to the calibration of the material (Khalil et al., 2014) and between 3 and 11% due to the researcher. Only three articles followed a standardized method (Gracey et al., 2007; Qureshi et al., 2019; Sánchez-

Jiménez et al., 2019). Moreover, some of the articles used patients self-reported measurements (Brenner et al., 2017; Wang et al., 2005), what could be leading to errors in the interpretation of the results obtained . Secondly, the reliability of these variables is based on correlations with indirect methods, with computed tomography (CT) being the most widely used (Ashwell et al., 1985; Kvist et al., 1988). While CT offers a clear view of subcutaneous and visceral fat, BMI, WC, WHR and WHtR do not measure adiposity either in a total or relative manner, and cannot be used to analyze its distribution (Ode et al., 2007; Shuster et al., 2012) . Due to this, if the use of the gold standard (CT) is not possible, it may be a better option to use these variables together with the skinfolds sums (Ayvaz & Çimen, 2011; Vaquero-Cristóbal et al., 2020). In this way, this combination could help provide information about the fat distribution present in a subject, helping to prevent or diagnose DM2. More research would be necessary to clarify the role of this variable and the relevance of the information provided in the diagnosis and characterization of DM2 patients.

Given the importance of fat mass and its distribution, and overweightness and obesity as risk factors for suffering from DM2, several authors agreed that changes in lifestyle could be a useful method for reducing the risk of suffering from the disease (Ben Ali et al., 2019; Brenner et al., 2017; Lee & Kim, 2016; Lutsey et al., 2010; Sargeant et al., 2002) . It has been observed that subjects with a family history of diabetes or diagnosed DM2 have worse dietary habits and worse physical fitness than the control group of healthy subjects (Padaki et al., 2011; Sánchez-Jiménez et al., 2019) . However, there is strong evidence of the positive effects of physical activity and a healthy diet on risk factors associated with DM2 (Sánchez-Jiménez et al., 2019). Regular practice of physical exercise, both strength and resistance training, has been shown to have a positive effect on insulin sensitivity, showing better effects when both are performed in combination (Bird & Hawley, 2016). Likewise, performing physical exercise favors weight loss, preventing weight regain in the long-term (Swift et al., 2018). Also, it has been observed how a balanced diet aimed at weight loss, based on a moderate caloric deficit, has positive effects on reducing total fat mass in obese subjects (Fisher et al., 2011). In patients with DM2, insulin resistance or impaired glucose tolerance, as precursors of the disease, it has been observed that the improvements in exercise and eating habits can reduce the risk of developing the disease or help delay the effects of DM2, and can also help control blood glucose in diagnosed patients (Sanz et al., 2010; Sigal et al., 2006) .

Despite the well-known effects of an intervention based on lifestyle changes, most of the articles analyzed followed a cross-sectional design, with the exception of Ting et al. (Ting et al., 2018), who carried out a longitudinal design.. Other limitations found were related to the samples included. Only five of the included articles compared diabetic patients with healthy population (Anjana et al., 2004; Lee & Kim, 2016; Padaki et al., 2011; Qureshi et al., 2019) , and only one analyzed diabetic population (Moy & Rahman, 2002). Moreover, the studies showed heterogeneity in the punctuations of STROBE statement scale when the risk of bias was assessed (von Elm et al., 2008).

Therefore, it could be necessary to carry out more studies with controlled clinical trial designs and standardized protocols focused on observing the effects of the interventions on the anthropometric variables used for the diagnosis and monitoring of DM2.

CONCLUSIONS

This literature review on the matter shows that anthropometry is an effective and reliable technique to evaluate the description of the morphotype of patients with DM2, assessing the variables related to the prediction of risk factors in adults diagnosed with DM2, facilitating its prevention, with the anthropometric measurement of the following indices: BMI, WC, WHR and WHtR, as they are higher than in the healthy population, as well as the use of a combination of them.

REFERENCES

1. ACSM. (2014). *Health-Related physical fitness assessement manual*. Wolters Kluwer. Lippincott Wiliams & Wilkins.
2. Al Amiri, E., Abdullatif, M., Abdulle, A., Al Bitar, N., Afandi, E. Z., Parish, M., & Darwiche, G. (2015). The prevalence, risk factors, and screening measure for prediabetes

and diabetes among Emirati overweight/obese children and adolescents. *BMC Public Health*, *15*, 1298. https://doi.org/10.1186/s12889-015-2649-6

3. Amed, S., Islam, N., Sutherland, J., & Reimer, K. (2018). Incidence and prevalence trends of youth-onset type 2 diabetes in a cohort of Canadian youth: 2002-2013. *Pediatric Diabetes*, *19*(4), 630-636. https://doi.org/10.1111/pedi.12631

4. Anjana, M., Sandeep, S., Deepa, R., Vimaleswaran, K. S., Farooq, S., & Mohan, V. (2004). Visceral and central abdominal fat and anthropometry in relation to diabetes in Asian Indians. *Diabetes Care*, *27*(12), 2948-2953. https://doi.org/10.2337/diacare.27.12.2948

5. Ashwell, M., Cole, T. J., & Dixon, A. K. (1985). Obesity: new insight into the anthropometric classification of fat distribution shown by computed tomography. *British Medicine Journal (Clinical Research Edition)*, *290*(6483), 1692-1694. https://doi.org/10.1136/bmj.290.6483.1692

6. Aune, D., Norat, T., Leitzmann, M., Tonstad, S., & Vatten, L. J. (2015). Physical activity and the risk of type 2 diabetes: a systematic review and dose-response meta-analysis. *Europena Journal of Epidemiology*, *30*(7), 529-542. https://doi.org/10.1007/s10654-015-0056-z

7. Awasthi, A., Rao, C. R., Hegde, D. S., & Rao N, K. (2017). Association between type 2 diabetes mellitus and anthropometric measurements - a case control study in South India. *Journal of Preventive Medicine & Hygiene*, *58*(1), E56-E62.

8. Ayvaz, G., & Çimen, A. R. (2011). Methods dor body composition analysis in adults. *The Open Obesity Journal*, *3*, 62-69.

9. Baynest, H. W. (2015). Classification, pathophysiology, diagnosis and management of diabetes mellitus. *Journal of Diabetes & Metabolism*, *6*(5).

10. Bays, H. E., Fox, K. M., Grandy, S., & Group, S. S. (2010). Anthropometric measurements and diabetes mellitus: clues to the "pathogenic" and "protective" potential of adipose tissue. *Metabolic Syndrome Related Disorders*, *8*(4), 307-315. https://doi.org/10.1089/met.2009.0089

11. Ben Ali, R. A., Hannoun, Z., Harraqui, K., Zeghari, L., Aboussaleh, Y., Mohamed, S., Anssoufouddine, M., & Bour, A. (2019). Profile of diabetes and cardiovascular risk factors in adults Anjouan Island (Comoros). *Pan African Medical Journal*, *33*(140).

12. Bigaard, J., Frederiksen, K., Tjønneland, A., Thomsen, B. L., Overvad, K., Heitmann, B. L., & Sørensen, T. I. (2005). Waist circumference and body composition in relation to all-cause mortality in middle-aged men and women. *International Journal of Obesity (London)*, *29*(7), 778-784. https://doi.org/10.1038/sj.ijo.0802976

13. Bird, S. R., & Hawley, J. A. (2016). Update on the effects of physical activity on insulin sensitivity in humans. *BMJ Open Sport & Exercise Medicine*, *2*(1), e000143. https://doi.org/10.1136/bmjsem-2016-000143

14. Boyko, E. J., Fujimoto, W. Y., Leonetti, D. L., & Newell-Morris, L. (2000). Visceral adiposity and risk of type 2 diabetes: a prospective study among Japanese Americans. *Diabetes Care*, *23*(4), 465-471. https://doi.org/10.2337/diacare.23.4.465

15. Brenner, D. R., Poirier, A. E., Haig, T. R., Akawung, A., Friedenreich, C. M., & Robson, P. J. (2017). Measures of excess body weight and anthropometry among adult Albertans: cross-sectional results from Alberta's tomorrow project cohort. *BMC Public Health*, *17*(1), 899. https://doi.org/10.1186/s12889-017-4887-2

16. Bullard, K. M., Cowie, C. C., Lessem, S. E., Saydah, S. H., Menke, A., Geiss, L. S., Orchard, T. J., Rolka, D. B., & Imperatore, G. (2018). Prevalence of Diagnosed Diabetes in Adults by Diabetes Type - United States, 2016. *Morbility & Mortality Weekly Report*, *67*(12), 359-361. https://doi.org/10.15585/mmwr.mm6712a2

17. Cnop, M., Welsh, N., Jonas, J. C., Jörns, A., Lenzen, S., & Eizirik, D. L. (2005). Mechanisms of pancreatic beta-cell death in type 1 and type 2 diabetes: many differences, few similarities. *Diabetes*, *54 Suppl 2*, S97-107. https://doi.org/10.2337/diabetes.54.suppl_2.s97

18. da Costa Santos, C. M., de Mattos Pimenta, C. A., & Nobre, M. R. (2007). The PICO strategy for the research question construction and evidence search. *Revista Latino-Americana de Enfermagem*, *15*(3), 508-511. https://doi.org/10.1590/s0104-11692007000300023

19. Després, J. P., & Lemieux, I. (2006). Abdominal obesity and metabolic syndrome. *Nature*, *444*(7121), 881-887. https://doi.org/10.1038/nature05488

20. Duren, D. L., Sherwood, R. J., Czerwinski, S. A., Lee, M., Choh, A. C., Siervogel, R. M., & Cameron Chumlea, W. (2008). Body composition methods: comparisons and interpretation. *Journal of Diabetes Science & Technology*, *2*(6), 1139-1146. https://doi.org/10.1177/193229680800200623

21. Fisher, G., Hyatt, T. C., Hunter, G. R., Oster, R. A., Desmond, R. A., & Gower, B. A. (2011). Effect of diet with and without exercise training on markers of inflammation and fat distribution in overweight women. *Obesity (Silver Spring)*, *19*(6), 1131-1136. https://doi.org/10.1038/oby.2010.310

22. Fox, C. S., Massaro, J. M., Hoffmann, U., Pou, K. M., Maurovich-Horvat, P., Liu, C. Y., Vasan, R. S., Murabito, J. M., Meigs, J. B., Cupples, L. A., D'Agostino, R. B., & O'Donnell, C. J. (2007). Abdominal visceral and subcutaneous adipose tissue compartments: association with metabolic risk factors in the Framingham Heart Study. *Circulation*, *116*(1), 39-48. https://doi.org/10.1161/CIRCULATIONAHA.106.675355

23. Gracey, M., Burke, V., Martin, D. D., Johnston, R. J., Jones, T., & Davis, E. A. (2007). Assessment of risks of "lifestyle" diseases including cardiovascular disease and type 2 diabetes by anthropometry in remote Australian Aborigines. *Asia Pacific Journal of Clinical Nutrition*, *16*(4), 688-697.

24. Guerrero-Romero, F., & Rodríguez-Morán, M. (2003). Abdominal volume index. An anthropometry-based index for estimation of obesity is strongly related to impaired glucose tolerance and type 2 diabetes mellitus. *Archives Medical Research*, *34*(5), 428-432. https://doi.org/10.1016/S0188-4409(03)00073-0

25. Jensen, E. T., & Dabelea, D. (2018). Type 2 Diabetes in Youth: New Lessons from the SEARCH Study. *Current Diabetes Reports*, *18*(6), 36. https://doi.org/10.1007/s11892-018-0997-1

26. Khalil, S. F., Mohktar, M. S., & Ibrahim, F. (2014). The theory and fundamentals of bioimpedance analysis in clinical status monitoring and diagnosis of diseases. *Sensors (Basel)*, *14*(6), 10895-10928. https://doi.org/10.3390/s140610895

27. Khunti, K., Taub, N., Tringham, J., Jarvis, J., Farooqi, A., Skinner, T. C., & Davies, M. J. (2010). Screening for the metabolic syndrome using simple anthropometric measurements in south Asian and white Europeans: a population-based screening study. The Leicester Ethnic Atherosclerosis and Diabetes Risk (LEADER) Study. *Primary Care Diabetes*, *4*(1), 25-32. https://doi.org/10.1016/j.pcd.2010.01.002

28. Koopman, R. J., Mainous, A. G., Diaz, V. A., & Geesey, M. E. (2005). Changes in age at diagnosis of type 2 diabetes mellitus in the United States, 1988 to 2000. *Annals of Family Medicine*, *3*(1), 60-63. https://doi.org/10.1370/afm.214

29. Kruschitz, R., Wallner-Liebmann, S. J., Hamlin, M. J., Moser, M., Ludvik, B., Schnedl, W. J., & Tafeit, E. (2013). Detecting body fat-A weighty problem BMI versus subcutaneous fat patterns in athletes and non-athletes. *PLoS One*, *8*(8), e72002. https://doi.org/10.1371/journal.pone.0072002

30. Kvist, H., Chowdhury, B., Grangård, U., Tylén, U., & Sjöström, L. (1988). Total and visceral adipose-tissue volumes derived from measurements with computed tomography in adult men and women: predictive equations. *American Journal of Clinical Nutrition*, *48*(6), 1351-1361. https://doi.org/10.1093/ajcn/48.6.1351

31. Laohabut, I., Udol, K., Phisalprapa, P., Srivanichakorn, W., Chaisathaphol, T., Washirasaksiri, C., Sitasuwan, T., Chouriyagune, C., & Auesomwang, C. (2020). Neck circumference as a predictor of metabolic syndrome: A cross-sectional study. *Primary Care Diabetes*, *14*(3), 265-273. https://doi.org/10.1016/j.pcd.2019.08.007

32. Lee, B. J., & Kim, J. Y. (2016). Identification of Type 2 Diabetes Risk Factors Using Phenotypes Consisting of Anthropometry and Triglycerides based on Machine Learning. *IEEE Journal of Biomedical & Health Informatics*, *20*(1), 39-46. https://doi.org/10.1109/JBHI.2015.2396520

33. Liu, J., Fox, C. S., Hickson, D. A., May, W. D., Hairston, K. G., Carr, J. J., & Taylor, H. A. (2010). Impact of abdominal visceral and subcutaneous adipose tissue on cardiometabolic risk factors: the Jackson Heart Study. *Journal of Clinical Endocrinology & Metabolism*, *95*(12), 5419-5426. https://doi.org/10.1210/jc.2010-1378

34. Lutsey, P. L., Pereira, M. A., Bertoni, A. G., Kandula, N. R., & Jacobs, D. R. (2010). Interactions between race/ethnicity and anthropometry in risk of incident diabetes: the multi-ethnic study of atherosclerosis. *American Journal of Epidemiology*, *172*(2), 197-204. https://doi.org/10.1093/aje/kwq100

35. McHugh, M. L. (2012). Interrater reliability: the kappa statistic. *Biochemistry Medicine (Zagreb)*, *22*(3), 276-282.

36. Moy, F., & Rahman, S. (2002). Anthropometry and dietary intake of type 2 diabetes patients attending an outpatient clinic. *Malaysian Journal of Nutrition*, *8*(1), 63-73.

37. Muñoz, A. M., Falque-Madrid, L., Zambrano, R. C. h., & Maestre, G. E. (2010). Basic anthropometry and health status of elderly: findings of the Maracaibo Aging Study. *Journal of Aging & Health*, *22*(2), 242-261. https://doi.org/10.1177/0898264309357444

38. Ode, J. J., Pivarnik, J. M., Reeves, M. J., & Knous, J. L. (2007). Body mass index as a predictor of percent fat in college athletes and nonathletes. *Medicine & Science in Sports & Exercise*, *39*(3), 403-409. https://doi.org/10.1249/01.mss.0000247008.19127.3e

39. Oviedo, G., Marcano, M., Morón de Salim, A., & Solano, L. (2007). Exceso de peso y patologías en mujeres adultas. *Nutrición Hospitalaria*, *22*(3), 358-362.

40. Padaki, S., Vijayakrishna, K., Dambal, A., Ankad, R., Manjula, R., Surekharani, C., Herur, A., & Patil, S. (2011). Anthropometry and physical fitness in individuals with family history of type-2 diabetes mellitus: A comparative study. *Indian Journal of Endocrinology & Metabolism*, *15*(4), 327-330. https://doi.org/10.4103/2230-8210.85595

41. Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., McGuinness, L. A., Stewart, L. A., Thomas, J., Tricco, A. C., Welch, V. A., Whiting, P., & Moher, D. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*, *372*, n71. https://doi.org/10.1136/bmj.n71

42. Pearson, E. R. (2019). Type 2 diabetes: a multifaceted disease. *Diabetologia*, *62*(7), 1107-1112. https://doi.org/10.1007/s00125-019-4909-y

43. Qureshi, S. S., Amer, W., Kaleem, M., & Beg, B. M. (2019). Adult anthropometry in Type 2 diabetic population: A case-control study. *Pakistan Journal of Medical Sciences*, *35*(5),

Journal of Sport and Health Research 2022, 14(3):359-374

1284-1289. https://doi.org/10.12669/pjms.35.5.759

44. Ritchie, S. A., & Connell, J. M. (2007). The link between abdominal obesity, metabolic syndrome and cardiovascular disease. *Nutrition, Metabolism & Cardiovascular Diseases*, *17*(4), 319-326. https://doi.org/10.1016/j.numecd.2006.07.005

45. Sanz, C., Gautier, J. F., & Hanaire, H. (2010). Physical exercise for the prevention and treatment of type 2 diabetes. *Diabetes Metabolism*, *36*(5), 346-351. https://doi.org/10.1016/j.diabet.2010.06.001

46. Sanz-Sánchez, I., & Bascones-Martínez, A. (2009). Diabetes mellitus: Su implicación en la patología oral y periodontal. *Avances en Odontoestomatología*, *25*(5), 249-263.

47. Sargeant, L. A., Bennett, F. I., Forrester, T. E., Cooper, R. S., & Wilks, R. J. (2002). Predicting incident diabetes in Jamaica: the role of anthropometry. *Obesity Research*, *10*(8), 792-798. https://doi.org/10.1038/oby.2002.107

48. Schulze, M. B., Heidemann, C., Schienkiewitz, A., Bergmann, M. M., Hoffmann, K., & Boeing, H. (2006). Comparison of anthropometric characteristics in predicting the incidence of type 2 diabetes in the EPIC-Potsdam study. *Diabetes Care*, *29*(8), 1921-1923. https://doi.org/10.2337/dc06-0895

49. Shuster, A., Patlas, M., Pinthus, J. H., & Mourtzakis, M. (2012). The clinical importance of visceral adiposity: a critical review of methods for visceral adipose tissue analysis. *British Journal of Radiology*, *85*(1009), 1-10. https://doi.org/10.1259/bjr/38447238

50. Sigal, R. J., Kenny, G. P., Wasserman, D. H., Castaneda-Sceppa, C., & White, R. D. (2006). Physical activity/exercise and type 2 diabetes: a consensus statement from the American Diabetes Association. *Diabetes Care*, *29*(6), 1433-1438. https://doi.org/10.2337/dc06-9910

51. Swift, D. L., McGee, J. E., Earnest, C. P., Carlisle, E., Nygard, M., & Johannsen, N. M. (2018). The Effects of Exercise and Physical Activity on Weight Loss and Maintenance. *Progress in Cardiovascular Diseases*, *61*(2), 206-213. https://doi.org/10.1016/j.pcad.2018.07.014

52. Sánchez-Jiménez, B., Chico-Barba, G., Rodríguez-Ventura, A. L., Sámano, R., Veruete-Bedolla, D., & Morales-Hernández, R. M. (2019). Detection of risk for type 2 diabetes and its relationship with metabolic alterations in nurses. *Revista Latino-Americana de Enfermagem*, *27*, e3161. https://doi.org/10.1590/1518-8345.3002.3161

53. Tellez, M. J. A., Silva, A. M., Ruiz, J. R., Martins, S. S., Palmeira, A. L., Branco, T. L., Minderico, C. S., Rocha, P. M., Themudo-Barata, J., Teixeira, P. J., & Sardinha, L. B. (2020). Neck circumference is associated with adipose tissue content in thigh skeletal muscle in overweight and obese premenopausal women. *Scientific Reports*, *10*(1), 8324. https://doi.org/10.1038/s41598-020-65204-9

54. Ting, M. K., Liao, P. J., Wu, I. W., Chen, S. W., Yang, N. I., Lin, T. Y., & Hsu, K. H. (2018). Predicting Type 2 Diabetes Mellitus Occurrence Using Three-Dimensional Anthropometric Body Surface Scanning Measurements: A Prospective Cohort Study. *Journal of Diabetes Research*, *2018*, 6742384. https://doi.org/10.1155/2018/6742384

55. Vaquero-Cristóbal, R., Albaladejo-Saura, M., Luna-Badachi, A. E., & Esparza-Ros, F. (2020). Differences in fat mass estimation formulas in physically active adult population and relationship with sums of skinfolds. *International Journal of Environmental Research & Public Health*, *17*, 7777.

56. von Elm, E., Altman, D. G., Egger, M., Pocock, S. J., Gotzsche, P. C., & Vandenbroucke, J. P. (2008). Declaración de la Iniciativa STROBE (Strengthening the Reporting of Observational studies in Epidemiology): directrices para la comunicación de estudios observacionales. *Gaceta Sanitaria*, *22*(2), 144-150.

57. Wang, Y., Rimm, E. B., Stampfer, M. J., Willett, W. C., & Hu, F. B. (2005). Comparison of abdominal adiposity and overall obesity in predicting risk of type 2 diabetes among men. *American Journal of Clinical Nutrition*, *81*(3), 555-563. https://doi.org/10.1093/ajcn/81.3.555

58. Wild, S., Roglic, G., Green, A., Sicree, R., & King, H. (2004). Global prevalence of diabetes: Estimates for the year 2000 and projections for 2030. *Diabetes Care*, *27*(5), 1047-1053.

59. World Health Organization. (1999). *Obesity: preventing & managing the global epidemic* (W. H. Organization, Ed.)

60. Zaman, F. A., Pal, R., Zaman, G. S., Swati, I. A., & Kayyum, A. (2011). Glucose indices, frank and undetected diabetes in relation to hypertension and anthropometry in a South Indian rural population. *Indian Journal of Public Health*, *55*(1), 34-37. https://doi.org/10.4103/0019-557X.82545