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Review

Performance of the waist-to-height ratio in identifying obesity and predicting non-communicable diseases in the elderly population: A systematic literature review

Márcia Mara Corrêa[a,*], Elaine Thumé[b], Elizabete Regina Araújo De Oliveira[c], Elaine Tomasi[a]

[a] Postgraduate Program in Epidemiology, Federal University of Pelotas, Brazil
[b] Postgraduate Program of Nursing, Federal University of Pelotas, Brazil
[c] Postgraduate Program of Public Health, Federal University of Espírito Santo, Brazil

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ABSTRACT

A systematic review was carried out aiming to collect evidence on the use of the waist-to-height ratio (WHtR) on the elderly population, focusing on validity measures to identify the best anthropometric indicator in assessing obesity associated with non-communicable diseases. The review consisted in a search of papers published on the databases Pubmed, Web of Science, and Lilacs, with no restriction regarding period of publication, using the following combinations: *abdominal fat* ***or*** *overweight* ***or*** *obesity* ***and*** *waist-to-height ratio* ***or*** *waist height* ***or*** *waist ht* ***or*** *WHtR* ***or*** *waist to stature ratio* ***or*** *wst stature* ***or*** *WSR* ***or*** *stature and girth*. Sixteen papers were selected, most of which with high methodological quality. The receiver-operating characteristic (ROC) curves was the validity measure explored in 13 papers, followed by sensitivity and specificity measures. In all studies, the body mass index (BMI) and waist circumference (WC) received special attention for analysis along with WHtR. Five manuscripts showed evidence of WHtR being the best anthropometric index when used alone, four showed that both WHtR and WC had the best discriminatory power in predicting cardiovascular risk factors compared to the other indices, and two ranked WHtR at the same performance level as waist-to-hip ratio (WHR) and BMI. An association was shown of the obesity assessed by WHtR in predicting risk factors for cardiovascular diseases, metabolic syndrome, and diabetes compared to other anthropometric parameters.
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Contents

1. Introduction

Considered a worldwide epidemic (James, Leach, Kalamara, & Shayeghi, 2001; World Health Organization, 2000), obesity is a relevant risk factor for the development (Guh et al., 2009; Strazzullo et al., 2010) and complication onset of non-communicable diseases (Canoy, 2008; Després et al., 2008; Taylor et al., 2010). Of multifactorial etiology (World Health Organization, 2000), it has stood out with high prevalence in all age groups

* Corresponding author at: Postgraduate Program in Epidemiology, Federal University of Pelotas, Marechal Deodoro 1160 – third floor, 96020-220 Pelotas, RS, Brazil.
E-mail addresses: marciamara@uol.com.br, profmarcia.correa@gmail.com (M.M. Corrêa).

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(Ng et al., 2014), which require international and national public policies to monitor and control obesity, as well as the disorders it causes (World Health Organization, 2012; Brasil, 2011).

Several anthropometric indicators have been proposed to assess obesity and, among the most acknowledged, the body mass index (BMI), waist circumference (WC), and waist-to-hip ratio (WHR) stand out (Leitzmann et al., 2011; de Koning, Merchant, Pogue, & Anand, 2007; Satoh, Kishi, & Tsutsui, 2010). More recently, the waist-to-height ratio (WHtR) has been receiving attention in the worldwide scientific literature for being strongly associated with several chronic diseases (Ashwell, Mayhew, Richardson, & Rickayzen, 2014; Odagiri et al., 2014; Silva, Lemos, Torres, & Bregman, 2014; Xu, Qi, Dahl, & Xu, 2013). It is considered more advantageous compared to the others since its adjustment for height allows a single threshold to be defined which is applicable to the overall population regardless of sex, age, or ethnic group (Browning, Hsieh, & Ashwell, 2010).

Anthropometric indices that use WC to assess obesity, mainly in elderly persons, are more accurate in predicting metabolic diseases and mortality (Dey, Rothenberg, Sundh, Bosaeus, & Steen, 2002; Picon et al., 2007) since these individuals physiologically accumulate more fat in the abdomen (Kanehisa, Miyatani, Azuma, Kuno, & Fukunaga, 2004; Scafoglieri, Provyn, Bautmans, Van Roy, & Clarys, 2011). In addition, the decrease in height due to thoracic kyphosis, scoliosis, osteoporosis, and intervertebral disk compression (Chumlea, Baumgartner, & Vellas, 1991) favor correcting this indicator through height.

Recent studies that used WHtR as an anthropometric indicator have found a strong association with altered blood pressure (Moges, Amare, Fantahun, & Kassu, 2014), cardiovascular events and mortality (Ashwell et al., 2014; Hsieh & Muto, 2005), type-2 diabetes (Xu et al., 2013), and metabolic syndrome (Fu et al., 2014), which makes it the best anthropometric marker to assess such disorders (Ashwell, Gunn, & Gibson, 2012).

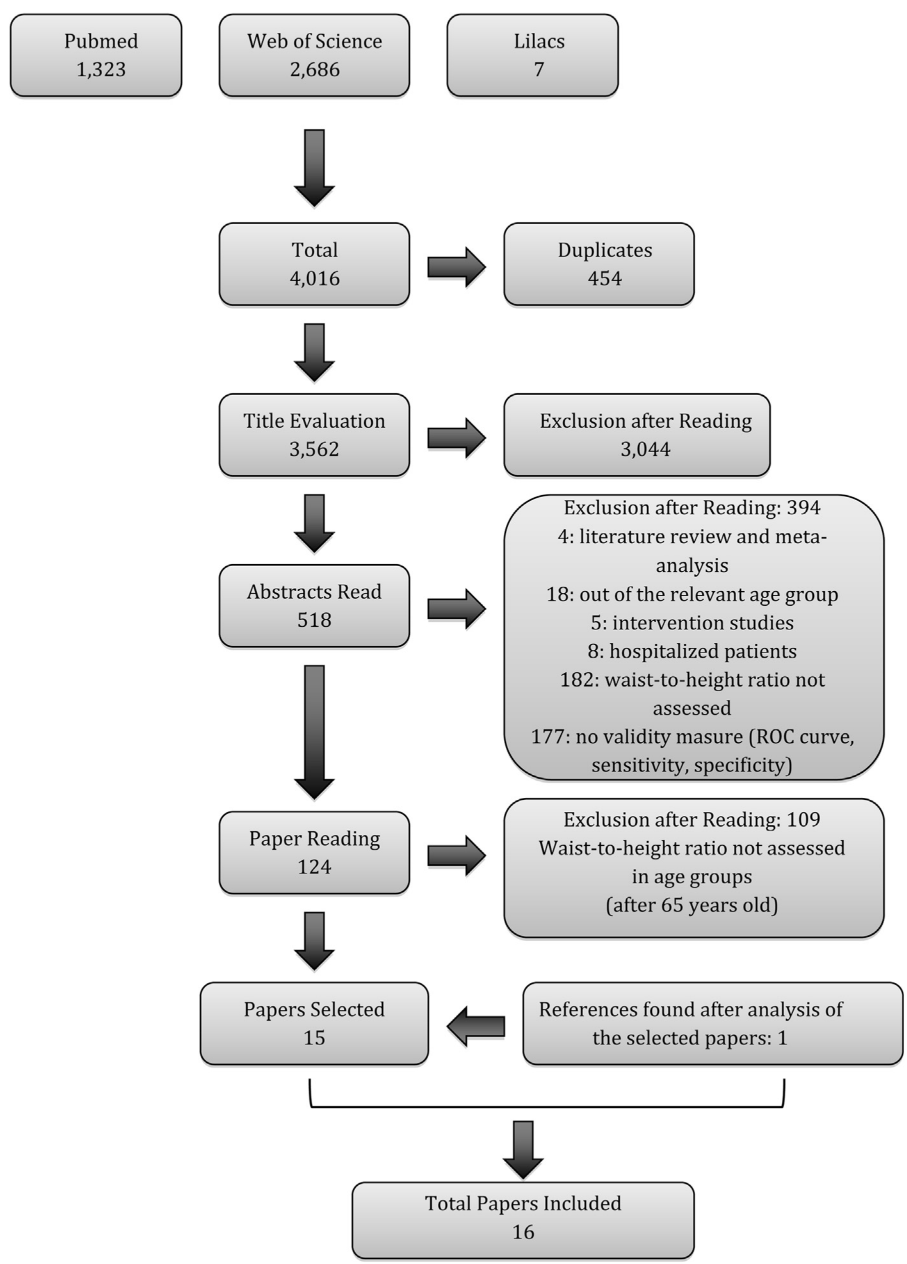

Fig. 1. Flowchart of the papers selected for review.

Elderly persons are at a higher risk of developing chronic diseases and of suffering from more severe forms that lead to incapacitation, thus obesity must be identified early so as to provide better quality of life to this group (Banks, Marmot, Oldfield, & Smith, 2006; Chatterji et al., 2008; Christensen, Doblhammer, Rau, & Vaupel, 2009). In this sense, WHtR has stood out for its strong association with several chronic disorders both in children (Arnaiz et al., 2014) and in adults (Savva, Lamnisos, & Kafatos, 2013) of both sexes and from different ethnic groups (Del Brutto & Mera, 2014; Hsieh, Yoshinaga, & Muto, 2003; Meseri, Ucku, & Unal, 2014), which confirms this anthropometric index as one of the best alternatives to predict chronic diseases (Ashwell et al., 2012).

The effects of demographic transition, allied to the high prevalence of non-communicable diseases, has pushed governmental organs around the world to adopt public policies that target the healthy aging of the population. Hence, the need for more sensitive anthropometric instruments that better comprehend the dynamics involving physiological alterations in the aging process is reinforced in order to enhance obesity diagnosis and prevent morbidities associated with it.

The present review paper aimed to collect evidence on the use of WHtR as a valid anthropometric index to diagnose adiposity among the elderly and to study its association with non-communicable diseases. Since no study was found that aggregated such evidence specifically for the elderly population, this publication is relevant for filling this gap.

2. Methodology

A systematic review was carried out on original scientific publications that assessed obesity in individuals aged 65 years or more through WHtR and its association with chronic diseases. To that end, papers were searched for in indexed journals on the databases Pubmed, Web of Science, and Lilacs with no restriction regarding the period of publication.

The following combinations of terms and descriptors were used: *abdominal fat* **or** *overweight* **or** *obesity* **and** *waist-to-height ratio* **or** *waist height* **or** *waist ht* **or** *WHtR* **or** *waist to stature ratio* **or** *wst stature* **or** *WSR* **or** *stature and girth*.

Papers that met the following criteria were eligible for review: studies with primary data carried out on humans with prospective or cross-sectional design. The population studied had to include elderly persons and the data analysis had to be done by age group while disclosing measures for the category aged 65 years or more of any ethnic group, race, or skin color. The samples could be male, female, or a mix of both. WHtR had to be assessed at least once associated with other anthropometric indicators such as BMI, WC, or WHR. The analyses had to use some validity measure (sensitivity, specificity, positive and/or negative predictive value, or receiver-operating characteristic (ROC) curves). The outcomes associated with WHtR had to be chronic diseases (Duncan, Schimidt, Victora, & Barbara, 2013), namely: cardiovascular diseases – systemic arterial hypertension (SAH); cerebrovascular diseases; ischemic disease, infarction, type-2 diabetes; cancer; respiratory system diseases – chronic obstructive pulmonary disease (COPD) and asthma; metabolic syndrome; and neuropsychiatric diseases. The languages chosen for the analysis of the papers were English, Portuguese, and Spanish.

Studies with children, adolescents, and adults up to 64 years old were excluded, as were literature reviews, intervention studies, annals abstracts, and editorials.

The following aspects were observed for the analysis of the studies selected: sample size and age group, outcomes associated with WHtR, and main findings. Regarding the validity measures of WHtR, special focus was given to identifying the evidence of the best anthropometric indicator to assess obesity associated with non-communicable diseases.

The criteria proposed by Downs and Black (1998) were used to assess paper quality, using a version made up of 27 items, from which 19 elements were selected for the analysis—those pertaining to experimental studies were excluded. The maximum score was 19 points and this process was carried out independently by two reviewers. In case of disagreements, the paper was reviewed by a third member of the team to identify the discrepancies and define the score, which happened with five papers.

The recommendations proposed in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (Liberati et al., 2009) guide regarding review papers were applied to the manuscripts.

3. Results

The flowchart in Fig. 1 shows the selection strategies for the papers included in the present review. An initial analysis identified 4016 references indexed on the three databases used in the systematic search, while 454 duplicates were excluded. A total of 3562 studies were selected to have their titles read and 518 abstracts were chosen that met the inclusion criteria. After this step, 124 manuscripts were read in full, from which 16 papers were identified as meeting all criteria for the review.

Table 1 shows the main methodological aspects, results, and quality scores – according to Downs and Black (1998) – of the studies on the use of WHtR to assess adiposity among the elderly and its association with non-communicable diseases. Only one study (Tatsumi et al., 2013) used a prospective cohort design in which cardiovascular disease was the outcome assessed. Fifteen studies used a cross-sectional design, of which eleven (Aekplakorn, Kosulwat, & Suriyawongpaisal, 2006; Cai, Liu, Zhang, & Wang, 2013; Esmaillzadeh, Mirmiran, & Azizi, 2004; Esmaillzadeh, Mirmiran, & Azizi, 2006; Guasch-Ferre et al., 2012; Haghighatdoost et al., 2014; Jayawardana, Ranasinghe, Sheriff, Matthews, & Katulanda, 2013; Mirmiran, Esmaillzadeh, & Azizi, 2004; Schneider et al., 2007; Wang et al., 2009; Zeng et al., 2014) assessed cardiovascular risk factors as the outcome, particularly hypertension, dyslipidemia, and altered glycemia. Two studies (Hsu et al., 2014; Hori et al., 2014) considered the aggregation of three or more risk factors for the development of cardiovascular disease (metabolic syndrome), one study (Zhao et al., 2012) researched diabetes as the chronic disease, and another study (Santos, Christofaro, Gomes, Santos, & Freitas Júnior, 2013) considered abdominal obesity as the outcome.

Only two studies (Hsu et al., 2014; Santos et al., 2013) were designed for a sample above 65 years old. Most studies were carried out in Asia (Aekplakorn et al., 2006; Cai et al., 2013; Esmaillzadeh et al., 2004, 2006; Haghighatdoost et al., 2014; Hsu et al., 2014; Lohman, Roche, & Martorell, 1988; Jayawardana et al., 2013; Mirmiran et al., 2004; Wang et al., 2009; Zeng et al., 2014; Zhao et al., 2012), three studies (Guasch-Ferre et al., 2012; Tatsumi et al., 2013; Schneider et al., 2007) took place in Europe, and one (Santos et al., 2013), in South America. The papers included in this review were published between 2004 and 2014 with samples that ranged from 125 to 221,270 subjects. Only one study (Santos et al., 2013) had a sample with fewer than 3000 subjects. Most studies included men and women, two (Aekplakorn et al., 2006; Hsu et al., 2014) were carried out only with males, and one (Esmaillzadeh et al., 2006), only with females.

All studies assessed BMI and WC along with WHtR. However, WHR (Aekplakorn et al., 2006; Esmaillzadeh et al., 2004, 2006; Jayawardana et al., 2013; Mirmiran et al., 2004; Santos et al., 2013; Schneider et al., 2007; Wang et al., 2009; Zhao et al., 2012), hip circumference (Schneider et al., 2007), body fat percentage

Table 1
Methodological aspects, main results, and quality scores, according to Downs & Black, of the studies on the use of WHtR to assess adiposity among the elderly and its association with non-communicable diseases.

Identification (Author/ Publication date/ Place)	Design	Sample/ Sex/Age group/ Elderly sample	Anthropometric measures	WC measurement method	Validity measure	Outcome analyzed	Main results	Downs & Black score (maximum score: 19 points)
(Tatsumi et al., 2013) Mediterranean	Prospective (13 years)	5488 Mixed 30–83 1763	BMI/WC	WC was measured at the umbilical scar with the subject standing straight.	AUROC[a] Thresholds Sensitivity Specificity	Cardiovascular disease	WHtR best predicted cardiovascular disease compared to BMI and WC. The association between WHtR differed among age groups and was considered the best predictor for middle-aged men.	17 points
(Schneider et al., 2007) Germany	Cross-sectional	4585 Mixed 20–79 1342	BMI/WC/WHR/ Hip circumference	WC was measured at the mean point between the iliac crest and the last rib on a horizontal plane.	AUROC Thresholds Sensitivity Specificity	Cardiovascular risk factors	WHtR and WC had the best result in diagnosing cardiovascular risk compared to BMI and WHR.	14 points
(Wang et al., 2009) China	Cross-sectional	10,096 Mixed 18–85 2995	BMI/WC/WHR	WC was measured at the umbilical scar with the subject standing straight.	AUROC Thresholds Sensitivity Specificity	Cardiovascular risk factors	After adjusting for age, WC had the best result in diagnosing cardiometabolic risk factors.	17 points
(Guasch-Ferre et al., 2012) Mediterranean	Cross-sectional	7447 Mixed 55–80 Not specified	BMI/WC	WC was measured at the mean point between the iliac crest and the last rib on a horizontal plane.	AUROC	Cardiovascular risk factors	The anthropometric measures for abdominal obesity (WHtR and WC) had the best discriminatory power to predict cardiovascular risk compared to BMI.	17 points
(Aekplakorn et al., 2006) Thailand	Cross-sectional	10,096 Mixed ≥35 1089	BMI/WC/WHR	WC was measured 1 cm above the navel with the subject standing straight with the abdomen relaxed, arms along the body, and feet together.	AUROC Thresholds	Cardiovascular risk factors	Evidence of severity of cardiovascular risk factors and prevalence of morbidity the higher the anthropometric measures assessed. WHR and WHtR, besides WC, best correlated to cardiovascular risk factors compared to BMI at ≥ 65 years old.	15 points
(Cai et al., 2013) Beijing	Cross-sectional	5720 Mixed 18–79 Not specified	BMI/WC	WC was measured at the end of normal exhaling at the mean point between the iliac crest and the last rib.	Thresholds Sensitivity Specificity	Cardiovascular risk factors	WHtR had the best performance compared to BMI and WC for association with SAH and Diabetes Mellitus. The area under the ROC curve for all anthropometric measures decreased with age for all risk factors analyzed, i.e., lower discriminatory power for older groups.	17 points
(Esmaillzadeh et al., 2004) Tehran	Cross-sectional	4449 Men 18–74 1090	BMI/WC/WHR	WC was measured at the narrowest point of the waist.	Sensitivity Specificity Accuracy	Cardiovascular risk factors	WHR was the best anthropometric predictor in identifying individuals at cardiovascular risk.	15 points
(Esmaillzadeh et al., 2006) Tehran	Cross-sectional	5073 Women 18–74 2339	BMI/WC/WHR	WC was measured at the narrowest point of the waist.	Sensitivity Specificity	Cardiovascular risk factors	WC had the best sensitivity and specificity for AH and hyperglycemia, however, BMI and WHR best diagnosed dyslipidemia.	15 points

Table 1 (*Continued*)

Identification (Author/ Publication date/ Place)	Design	Sample/ Sex/Age group/ Elderly sample	Anthropometric measures	WC measurement method	Validity measure	Outcome analyzed	Main results	Downs & Black score (maximum score: 19 points)
(Haghighatdoost et al., 2014) Iran	Cross-sectional	9555 Mixed 18–74 Not specified	BMI/Body adiposity estimator/A body shape index (ABSI)	WC was measured at the narrowest point of the waist.	AUROC	Cardiovascular risk factors	ABSI was strongly associated with cardiovascular risk factors.	16 points
(Jayawardana et al., 2013) Sri Lanka	Cross-sectional	5000 Mixed 18–70 Not specified	BMI/WC/WHR	WC was measured at the end of normal exhaling at the mean point between the iliac crest and the last rib.	AUROC	Cardiovascular risk factors	A strong association was found between WHtR as a measure of adiposity and cardiometabolic risk factors. A higher correlation was found for males than for females.	17 points
(Mirmiran et al., 2004) Tehran	Cross-sectional	10,522 Mixed 18–74 Not specified	BMI/WC/WHR	WC was measured at the narrowest point of the waist.	AUROC	Cardiovascular risk factors	WHtR had the largest area below the ROC curve for most cardiovascular risk factors.	13 points
(Zeng et al., 2014) China	Cross-sectional	221,270 Mixed 20–79 35,556	BMI/WC	WC was measured at the mean point between the iliac crest and the last rib on a horizontal plane.	AUROC Thresholds	Cardiovascular risk factors	WHtR and WC were the best predictors for cardiovascular risk compared to BMI.	14 points
(Hsu et al., 2014) Taiwan	Cross-sectional	3004 Men ≥65 years old 3004	BMI/WC/Body fat%	WC was measured at the mean point between the iliac crest and the last rib on a horizontal plane.	AUROC	Metabolic syndrome	WHtR was not associated with metabolic syndrome while BMI and WC were significantly associated. BMI + WC did not improve the accuracy for diagnosing the outcome, but WC is the measure that best predicts metabolic syndrome.	12 points
(Hori et al., 2014) Japan	Cross-sectional	53,710 Mixed 18–84 3047	BMI/WC	WC was measured at the umbilical scar with the subject standing straight.	AUROC Sensitivity Specificity	Metabolic syndrome	No difference found between WHtR and BMI to detect the aggregation of cardiovascular risk factors. Thresholds for each obesity index rises as age advances.	15 points
(Zhao et al., 2012) Rural China	Cross-sectional	1031 Mixed ≥30 199	BMI/WC/WHR	WC was measured at the mean point between the iliac crest and the last rib at the end of normal exhaling.	AUROC	Diabetes	WHtR had the largest area below the ROC curve for men, however, WHR had a better result for women compared to BMI.	14 points
(Santos et al., 2013) Brazil	Cross-sectional	125 Mixed ≥80 125	BMI/WC/WHR/ DXA	WC was measured in mm at the mean point between the iliac crest and the last rib using a metallic anthropometric measuring tape.	AUROC Sensitivity Specificity	Abdominal obesity	BMI and WC had the largest areas below the ROC curve and were the most appropriate to identify the presence or absence of abdominal obesity.	13 points

[a] AUROC: area under the ROC.

Table 2
Distribution of the papers analyzed according to the analysis outcomes and the performance of the anthropometric indices in assessing adiposity and predicting diseases either alone or associated with other indices/anthropometric measures.

	WHtR		BMI		WC		WHR		Other Measures	
	Alone	Associated	Alone	Associated	Alone	Associated	Alone	Associated	Alone	Associated
Cardiovascular risk factors	(Cai et al., 2013)	(Schneider et al., 2007)		(Esmaillzadeh et al., 2006)	(Wang et al., 2009)	(Schneider et al., 2007)	(Esmaillzadeh et al., 2004)	(Aekplakorn et al., 2006)	(Haghighatdoost et al., 2014)	
11/16	(Jayawardana et al., 2013) (Mirmiran et al., 2004)	(Guasch-Ferre et al., 2012) (Aekplakorn et al., 2006) (Zeng et al., 2014)				(Guasch-Ferre et al., 2012) (Aekplakorn et al., 2006) (Esmaillzadeh et al., 2006) (Zeng et al., 2014)		(Esmaillzadeh et al., 2006)		
Metabolic syndrome 2/16		(Hori et al., 2014)		(Hsu et al., 2014) (Hori et al., 2014)				(Hsu et al., 2014)		
Cardiovascular disease 1/16	(Tatsumi et al., 2013)									
Diabetes 1/16	(Zhao et al., 2012) Males						(Zhao et al., 2012) Females			
Abdominal obesity 1/16				(Santos et al., 2013)		(Santos et al., 2013)				

(Hsu et al., 2014), body adiposity estimator and the a body shape index (Haghighatdoost et al., 2014), besides dual-energy X-ray absorptiometry (DXA) (Santos et al., 2013) were also assessed along with WHtR in some studies.

The ROC curve was the validity measure explored in 13 studies, followed by sensitivity and specificity measures to assess the anthropometric parameter that best diagnosed adiposity and that was effective in predicting non-communicable diseases. Six studies (Aekplakorn et al., 2006; Cai et al., 2013; Schneider et al., 2007; Tatsumi et al., 2013; Wang et al., 2009; Zeng et al., 2014) also used the ROC curve to establish more appropriate thresholds to diagnose obesity as age advanced.

The studies used four different techniques to measure WC although the specialized literature carries references that standardize this measurement (Lohman et al., 1988; Petroski, 2003). Eight studies (Cai et al., 2013; Guasch-Ferre et al., 2012; Hsu et al., 2014; Jayawardana et al., 2013; Santos et al., 2013; Schneider et al., 2007; Zeng et al., 2014; Zhao et al., 2012) used the mean point between the iliac crest and the last rib as a reference point for measurement, three studies (Hori et al., 2014; Tatsumi et al., 2013; Wang et al., 2009) used the umbilical scar as an anatomical point, four (Esmaillzadeh et al., 2004, 2006; Haghighatdoost et al., 2014; Mirmiran et al., 2004) measured WC at the narrowest level of the waist, and one (Aekplakorn et al., 2006) measured WC 1 cm above the umbilical scar.

Overall, the papers included in the review had high methodological quality, but none received the maximum score. According to the criteria proposed by Downs and Black (1998), the mean score assigned to the papers selected was 15.06 points, ranging between 13 and 17. Five studies (Cai et al., 2013; Guasch-Ferre et al., 2012; Jayawardana et al., 2013; Tatsumi et al., 2013; Wang et al., 2009) stood out with 17 points, and most lost points for not reporting the sample size calculation or whether the study had power to detect the effect expected, besides not informing the external validity or controlling for confounding factors.

Table 2 shows the distribution of the papers analyzed according to the analysis outcomes and the performance of the anthropometric indices either alone or associated with other indices/anthropometric measures. Five manuscripts (Cai et al., 2013; Jayawardana et al., 2013; Mirmiran et al., 2004; Tatsumi et al., 2013; Zhao et al., 2012) reported evidence of the use of WHtR as the best anthropometric index to assess by itself obesity and its relationship with the onset of non-communicable diseases or with clinical and metabolic control parameters in elderly persons. A special mention goes to a prospective study (Tatsumi et al., 2013).

Four studies (Aekplakorn et al., 2006; Schneider et al., 2007; Guasch-Ferre et al., 2012; Zeng et al., 2014) showed that both WHtR and WC had the best discriminatory power to predict cardiovascular risk factor compared to the other measures, while two studies ranked WHtR with the same performance as WHR (Aekplakorn et al., 2006) and BMI (Hori et al., 2014) to predict disorders.

Of the 16 studies included in the review, ten concluded that WHtR is a valid anthropometric measure to diagnose obesity in elderly persons and that this measure is associated with non-communicable diseases, which makes it recommended to predict such diseases (Table 2).

4. Discussion

In face of the relevance of this subject for public health, it was noted that few studies seek more effective anthropometric indices to diagnose obesity and its relation with changes in body composition as age advances associated with non-communicable diseases. In addition, the concentration of studies in Asia is noteworthy, which shows a certain imbalance among the regions that produce science in this field. In face of the differences among the populations, races, and ethnic groups, the need for studies that delve deeper in the evidence amassed in this manuscript stands out.

The results of this review highlight WHtR as a valid anthropometric index that is very useful in assessing adiposity in elderly persons and to predict non-communicable diseases, followed by WC. These findings confirm that abdominal fat accumulation poses a particular risk when compared to other body fat distribution measures in the development of chronic diseases (Després et al., 2008; Despres, 2006). The possible explanation for the findings ranking WHtR as the best index is that it uses two anthropometric measures (WC and height) that show inverse associations with morbidity and mortality (Hsieh & Yoshinaga, 1999; Schneider, Klotsche, Silber, Stalla, & Wittchen, 2011), which leads to the better discriminatory power of this indicator.

WC measurement was not homogeneous and some studies measure abdominal circumference (AC) instead of WC (Aekplakorn et al., 2006; Hori et al., 2014; Tatsumi et al., 2013; Wang et al., 2009). The classic techniques for anthropometric measurements are described by Lohman et al. (1988). WC should be measured with the individual standing with the arms extended along the body and the measurement should be done in the narrowest part of the trunk. AC should also be measured with the individual standing straight, however, the measurement is performed at the widest part of the abdomen. If measuring the anatomical point indicated is impossible, the recommendation is for the mean point between the last rib and the upper edge of the iliac crest for WC and at the height of the umbilical scar for AC.

A systematic review by Ross et al. (2008), which included 120 papers, aimed to analyze the anatomical point of WC measurement and to what extent the discrepancies in the measurements impacted the associations with morbidities due to cardiovascular diseases and diabetes, besides the mortality from cardiovascular diseases and other causes. The results identify that 36% (43) of the studies measured WC at the mean point between the iliac crest and the last rib, 28% (34) at navel height, 25% (30) at the smallest circumference, and 11% (13) used other techniques. Similar association patterns were observed between the health indicators and all WC protocols for all the sample's dimension, sex, age, race, and ethnic group. The authors concluded that the different protocols to measure WC did not substantially impact the association between WC and risk factors for non-communicable diseases or the mortality from all causes or from cardiovascular diseases.

However, other studies (Croft, Keenan, Sheridan, Wheeler, & Speers, 1995; Wang et al., 2003) that analyzed the anatomical point of WC measurement and the impact on health indicators concluded that these discrepancies directly influence the results of the investigations and clinical decision-making since measurements at the umbilical scar may underestimate the actual WC. These studies argue that efforts should be expended for a unified evaluation. The World Health Organization (World Health Organization, 2011) (WHO) has published a protocol guiding WC measurement and has acknowledged that discrepancies may impact public policies. The organization emphasized the need for a specific agenda to discuss this issue.

In the analysis of the papers selected for the present review, of the ten studies that describe positive results in the association of WHtR with non-communicable diseases, six (Cai et al., 2013; Guasch-Ferre et al., 2012; Jayawardana et al., 2013; Schneider et al., 2007; Zeng et al., 2014; Zhao et al., 2012) measured WC following the protocol by the World Health Organization (2011), while two (Hori et al., 2014; Tatsumi et al., 2013) measured it at the umbilical scar, one (Mirmiran et al., 2004) used the narrowest point for WC, and another (Aekplakorn et al., 2006) measured WC 1 cm above the umbilical scar.

The studies considered in this review showed that WHtR was the measure most associated with non-communicable chronic diseases and which had the largest areas under the ROC curve. Nonetheless, it must be taken into account that most studies used cross-sectional designs and that, although they showed such associations, the causal relation of obesity assessed by WHtR and the outcomes analyzed cannot be determined by this type of design. However, a prospective study (Tatsumi et al., 2013) stands out, which showed a strong association of WHtR with cardiovascular diseases, a result confirmed by other studies with the same design in samples including young adults and the elderly (Gelber et al., 2008; Zhang et al., 2004).

Just the same, the strong association of WHtR with chronic diseases, particularly cardiovascular ones, must be mentioned, as the results of some studies (Cai et al., 2013; Tatsumi et al., 2013) suggest a variation according to sex and age. Tatsumi et al. (2013) found an association between WHtR and risk for cardiovascular diseases among younger adults compared with the elderly (above 70 years old), which suggests that stratification by age group is a relevant factor to estimate the association between WHtR and risk for cardiovascular diseases.

Such variations in the associations of WHtR and of other anthropometric indices with chronic diseases can be explained by the changes in body composition as age advances, which is also impacted by sex (Kuczmarski, 1989). The elderly tend to lose weight (Kyle et al., 2001) with aging, likely weakening these associations.

However, a systematic review and meta-analysis carried out in 2012 with over 300,000 subjects concluded that WHtR is the best tool to screen for cardiometabolic risk factors in both sexes and several ethnic and age groups, being better than WC or BMI (Ashwell et al., 2012).

Since such changes in body composition with aging could impact the thresholds for other anthropometric measures (Heiat, Vaccarino, & Krumholz, 2001), WHtR is consolidated as a more advantageous indicator because its direct regulation with height enables the same threshold regardless of age.

Besides the aforementioned clinical advantages, another factor that makes WHtR more advantageous compared to the other anthropometric indices is its easy applicability because it is calculated by simply dividing WC by height. Since excess fat in the central part of the body is associated with the onset of cardiometabolic diseases and high mortality rate, defining single thresholds for indicators that stand out for their operational simplicity and good accuracy in detecting individuals at risk is highly useful for healthcare services and to create preventive and health-fostering public policies.

Finally, another applicability of WHtR is due to its easy understanding by the general population. The message: "*Keep your waist circumference less than half your height*" translates the simplicity of this index regarding the potential benefits for public health.

5. Conclusion

The results of the present review showed that WHtR is a valid anthropometric index to diagnose obesity among the elderly and is considered a good indicator in predicting risk factors for cardiovascular diseases, metabolic syndrome, and diabetes compared to BMI, WC, and WHR, among other parameters. The association between WHtR and chronic diseases differed among age groups and was considered the best predictor among younger elderly persons compared to the older ones. In face of these results, and considering the small number of studies, it is expected that more researches be carried out on this subject since such information is key not only for preventive and health-fostering public policies regarding non-communicable chronic diseases, but also for those that aim at the healthy aging of the population.

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