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Comparison of Waist Circumference Measured at Four Sites in Healthy Iranian Adults

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ABSTRACT

Introduction: The waist circumference (WC) is a measure of central obesity in adults. The aim of this study was to compare waist circumference measured at four sites among Iranian adults. **Methods:** A total of 494 Iranian adults attending a university hospital for routine health examination volunteered for the study. WC measurements were taken at the superior border of the iliac crest, midpoint between the iliac crest and the lowest rib, at the umbilicus and minimal waist. Simultaneously, suprailiac (SSF) and triceps skinfold (TSF) thicknesses were measured to determine correlations with the WC measurements. **Results:** In both sexes, the highest mean values for WC were taken above the iliac crest, while the lowest mean values were at minimal waist. In women, mean WC from the four sites were significantly different. For men with BMI<30 kg/m^2, WC from minimal waist and midpoint between the iliac crest and the lowest rib differed significantly from WC from the other sites, while those with BMI≥30 kg/m^2, only WC from minimal waist differed significantly from WC taken at other sites. WC measured at the superior border of the iliac crest showed significance with triceps and suprailiac subcutaneous fat. **Conclusions:** Among Iranian adults, the WC value differs depending on the site measured. Correlations with other indicators of body fatness are recommended for an objective assessment of obesity.

Key words: Body mass index, skinfold thickness, waist circumference

INTRODUCTION

Obesity, a chronic disease, which is increasingly prevalent in adults, adolescents and children, is now considered to be a global epidemic. In most populations, the prevalence of overweight and obesity has increased noticeably over the past 20 years (Flegal *et al*., 2012). Obesity is associated with a significant increase in mortality and risk of many disorders, including diabetes mellitus, hypertension, dyslipidemia, heart disease, stroke, sleep apnea, cancer and many others. Moreover, central adiposity is associated with an increased risk of morbidity and mortality (Janssen, Katzmarzyk & Ross, 2004; Simpson *et al*., 2007; Koster *et al*., 2008; Jacobs *et al*., 2010).

The waist circumference (WC) as a measure of central obesity in adults in the United States and in several other countries has increased over the past two decades (Freedman & Ford, 2015). Unfortunately there is no unanimously accepted protocol for measuring WC. The WHO STEPS protocol for measuring WC instructs that the measurement should be made at the approximate midpoint between the lower margin of the last palpable rib and the top

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of the iliac crest (WHO, 2008). The United States National Institutes of Health (NIH) protocol provided in the NIH Practical guide to obesity and the protocol used in the US National Health and Nutrition Examination Survey (NHANES) III indicate that WC should be measured at the top of the iliac crest (Westat Inc, 1998). The NIH also provides a protocol for the measurement of waist circumference for the Multi-Ethnic Study of Atherosclerosis (MESA), which indicates that the WC should be measured at the level of the umbilicus. Some studies assess the WC at the point of the minimal waist (Ross *et al*., 2008; NIH, 1998). Considering the lack of a universal protocol for WC measurement, the purpose of the current study was to make comparisons among WC measurements based on different protocols, and to determine the differences based on the levels of BMI and the prevalence of obesity at four anatomical sites. This study also aimed to determine protocol with the most correlations with subcutaneous fat at the suprailiac and triceps regions.

METHODS

In this cross-sectional study, we evaluated 494 healthy adult volunteers referred to a university hospital for their routine laboratory examamination. The study was conducted over 11 months in 2014. The study protocol was approved by the ethics committee of Shahid Beheshti University of Medical Sciences and written informed consent was obtained from all subjects. Anthropometric measurements were obtained by a trained dietitian to minimise errors in measurement.

Exclusion criteria were pregnancy, non-fasting subjects, and subjects with a BMI ≥35 kg/m^2. In patients with a BMI ≥35 kg/m^2, WC measurement lacks accuracy and is of little or no use to clinicians (Mahan & Escott-Stump, 2012). The weight of participants was measured while the subjects were minimally clothed, without shoes, using digital scales and recorded to the nearest 0.1 kg (Sohenle, Germany). Height was measured in a standing position, without shoes, using a tape meter fixed to the wall, while the shoulders were in a normal alignment. BMI was calculated as weight (in kg) divided by the square of height (in meter). Overweight and obesity were defined as 25 Kg/m2 ≥BMI< 30 Kg/m2 and BMI ≥ 30 Kg/m2 respectively.

WC was measured while the subject stood with arms at the sides, feet positioned close together, and weight evenly distributed across the feet. Measurement was taken at the end of normal expiration using a flexible, non-stretchable tape placed directly on the skin, parallel to the floor, providing a constant 100 g tension. Measurements were taken at four anatomical sites including superior border of the iliac crest, midpoint between the iliac crest and the lowest rib, umbilicus, and minimal waist while the examiner was standing at the right side of each subject. As the tension of the abdominal wall influences the accuracy of the waist circumference measurement, we asked the subject to relax and take a few deep, natural breaths before the actual measurement was made in order to minimise the inward pull of the abdominal contents during the waist measurement (WHO, 2008). Each measurement was repeated twice; if the difference between the two measurements was within 0.5 cm of one another, the average was calculated; if however the difference exceeded 0.5 cm, the two measurements were repeated. WC cut-off points ≥ 90 cm in women and ≥ 95 cm in men were defined as abdominal obesity (Azizi *et al.,* 2010).

Fat percentage in the trunk region was evaluated by measurement of the suprailac skinfold (SSF).The right side of iliac crest had already been marked from previous measurements; the examiner placed her left thumb on the intersecting marks and picked up the skinfold with her thumb and fingers; the skinfold should slope downwards and forwards at a 45 degree angle, extending toward the pubic symphysis. The caliper (Vogel, Germany) was placed perpendicular to the skinfold about 2 cm medial to the fingers and the skinfold was measured to the nearest 0.1 mm.

Fat percentage in the arm region was measured with triceps skinfold measurements (TSF) on the right arm. The measurement of TSF thickness was taken with the person standing upright, with arms hanging down loosely. The skinfold was pulled away from the muscle and measured with the calipers, taking a reading four seconds after the calipers had been released. The measuring point was halfway between the olecranon process of the ulna and the acromion process of the scapula.

Statistical methods

All statistical analyses were performed with SPSS software version 18 and P values < 0.05 were considered significant. Subjects' characteristics were reported as mean ±SD. For multiple comparisons, repeated measures ANOVA with Bonferroni adjustment were performed. This analysis was also repeated after stratifying the sample according to BMI (BMI<25, 25≤BMI<30, 30≤BMI<35). Correlations between WC measurements at four anatomic sites and correlation between WC measurements and skin fold thickness were assessed by Pearson's coefficient.

RESULTS

The characteristics of subjects are shown in Table 1. Four hundred and ninety-four volunteers (212 males, 282 females) participated in this study. The prevalence of type 1 obesity with 30≥ BMI>35 Kg/m^2 was 22.7% in total, 26.2% in females and 17.9 % in males. The prevalence of overweight with 25 ≥BMI> 30 Kg/m^2 was 32% in total, 27.7% in females and 37.7% in males. The prevalence of abdominal obesity in four anatomic sites with cut-off point of ≥90 cm was higher than the prevalence of obesity based on BMI (Table 2). Highest prevalence of abdominal obesity was with the NIH measurement (55%) and the lowest with minimal waist measure (30.7%).

For both sexes, WC measurements obtained from all four anatomic sites strongly correlated with each other (r = 0.94- 0.96, *p*< 0.0001) (Table 3). The comparisons among the mean WC values at the four sites for each sex are shown in Table 4. The mean measurement for each site was significantly different from all other sites in women (P< 0.001). In men, the overall mean for each measurement site was significantly different from all other

Table 1. Characteristics of subjects (N=494)

Variable	*Male (n=212) (mean ± SD)*	*Female (n=282) (mean ± SD)*	*Total (mean ± SD)*
Age (y)	40.73±17.6	39.41±14.5	39.9 ± 15.90
BMI	25.90±4.43	26.35±5.23	26.15±4.90
WC[1] (cm)			
WHO[2]	94.76±11.63	89.93±12.62	92±12.4
NIH[3]	98.10±10.28	96.36±12.91	97.1±11.8
Umbilicus	96.97±10.34	93.74±12.13	95.1±11.5
Minimal waist	91.77±10.73	85.97±12.17	88.4±11.9
TSF[4] (mm)	14.0±4.82	22.48±5.60	18.8±0.67
SSF[5] (mm)	24.34±7.46	28.02±6.04	26.4±0.69

[1] Waist circumference; [2] World Health Organization; [3] National Institute of Health; [4] Triceps skinfold; [5] Suprailiac skinfold

Table 2. Prevalence of overweight, type 1obesity and abdominal obesity

	Male(n=212) Number (%)	*Female(n=282) Number (%)*	*Total Number (%)*
Overweight	80 (37.7)	78 (27.6)	(32)
Type 1 obesity	38 (17.9)	74 (26.2)	(22.7)
Abdominal obesity			
WHO[1]	108 (50)	102 (36.1)	210 (42.5)
NIH [2]	134 (63.2)	138 (48.9)	272 (55)
Umbilicus	126 (59.4)	122 (43.2)	248 (50.2)
Minimal waist	82 (38.7)	70 (24.8)	152 (30.7)

[1] World Health Organization; [2] National Institute of Health

Table 3. Correlation between waist circumference and skinfolds in women (bold) and men (unbold)*

	WHO	*NIH*	*Umbilicus*	*Minimal waist*	*TSF*	*SSF*
WHO[1]		**0.95**	**0.95**	**0.96**	**0.57**	**0.65**
NIH [2]	0.96		**0.93**	**0.91**	**0.61**	**0.70**
Umbilicus	0.95	0.97		**0.93**	**0.60**	**0.64**
Minimal waist	0.96	0.94	0.94		**0.56**	**0.63**
TSF[3]	0.51	0.52	0.50	0.46		**0.71**
SSF[4]	0.70	0.72	0.67	0.67	0.60	

[1] World Health Organization; [2] National Institute of Health; [3] Triceps skinfold; [4] Suprailiac skinfold
*All correlations significant at P < 0.0001

Table 4. Waist circumferences measurements based on BMI (Mean, SD)

	WHO1	*NIH 2*	*Umbilicus*	*Minimal waist*	*P value*
BMI<25					
Male(n=94)	86.7 ±7.4[a]	89.9±6[b]	88.7±6.8[b]	83.1±6.8[c]	< 0.001
(Min, Max)	71-102	76-104	71-106	70-97	
Female(n=130)	79.5±6.2[a]	85.7±6.7[b]	83.8±5.9[c]	76±6.5[d]	< 0.001
(Min, Max)	63-97	65-102	71-98	62-95	
25≤BMI<29.9					
Male(n=80)	98.1±5.4[a]	100.8±4[b]	99.9±4.2[b]	95.1±5.1[c]	< 0.001
(Min, Max)	85-110	94-111	92-110	86-109	
Female(n=78)	92.4±6.5[a]	99.4±6.6[b]	96.1±6.8[c]	88.3±6[d]	< 0.001
(Min, Max)	82-110	88-114	78-114	77-106	
30≤BMI<35					
Male(n=38)	110±9.9[a]	112.5±8.5[a]	111.1±7.3[a]	106±7.8[b]	< 0.001
(Min, Max)	91-135	99-134	100-128	94-122	
Female(n=74)	105.5±7.3[a]	111.9±7.7[b]	108.6±6.9[c]	100.9±6.9[d]	< 0.001
(Min, Max)	90-119	93-129	96-121	90-117	

For each sex, values with different superscript letters are significantly different
[1]World Health Organization; [2] National Institute of Health

individual site means, with the exception of measures taken at the iliac crest and umbilicus. In both males and females, the highest mean values were measured above the iliac crest and the lowest at the level of minimal waist; in women similar results were seen even after stratifying the sample according to the level of BMI. However, in obese men, the measurements in the iliac crest, umbilicus and WHO areas were very similar and only WC from minimal waist had significant difference with other sites.

Table 3 shows the correlation between waist circumference and skin fold measurement. There was a positive correlation between TSF, SSF and waist circumference at the four anatomic sites and skin fold had the strongest positive correlation with WC measurement above the iliac crest.

DISCUSSION

The results of this cross-sectional study showed that the measurement of WC is affected by the method of measurement. In women with any level of BMI, WC measurements taken at four anatomic sites differed from each other. In men, WC measurements were similar in NIH and umbilicus area with a significant difference, compared to the two other sites. In both sexes, WC above the iliac crest was higher than the three other sites. Our results in women are similar to those of Wang *et al.* (2003), who studied 111 healthy subjects (49 men and 62 women) and found that in both sexes, the mean minimal waist was significantly lower than the means of three other sites, in women; however the mean for each site was significantly different to those of other sites.

A study of 223 men and 319 women also showed that in women, the mean WC for all sites differed significantly from each other, with the exception of the iliac crest and midpoint; in contrast, no significant differences between sites were found in men (Mason & Katzmarzyk, 2009). Our results showed that after categorising BMI, mean WC was not significantly different between umbilicus and NIH sites, although Mason & Katzmarzyk (2009) showed that the magnitude of the differences between WC sites in men and women was consistent across categories of BMI.

In the present study, measurement site affected the apparent prevalence of abdominal obesity, ranging from 38.7 to 63.2% in men and 24.8 to 48.9% in women, with measurement at the iliac crest having the highest prevalence. Mason & Katzmarzyk (2009) also showed that the prevalence of abdominal obesity (>88/102 cm) was influenced by the site measured and ranged between 31 to 55% in women and 23 to 34% in men and the measurement at the level of umbilicus had the highest prevalence of obesity (Mason & Katzmarzyk, 2009). Likewise, Willis *et al.*(2007) reported that the prevalence of abdominal obesity was greater when WC was measured at the umbilicus, compared to at the minimal waist.

We found that skinfold thickness correlated with four WC measurement sites. Both, percentage of fat in the trunk region and percentage of fat in the arm region, had the strongest correlation with WC, measured above the iliac crest. Several technical issues appeared with measurement of each anatomical site in our study as mentioned by other studies. Measurements of WC taken at the narrowest point or minimal waist, although reported to be easy for identification of majority of the subjects, it was difficult for us to determine the single narrowest part of the waist in some subjects with abdominal obesity or in those who were underweight, a problem also reported by others (Wang *et al.,* 2003; Mason & Katzmarzyk, 2009). Furthermore, as no anatomical landmarks are used to identify this site, waist measures taken at this location may be prone to greater inter- and intra-observer errors than at other sites.

The measurement of WC in the midpoint between iliac crest and lowest rib was time-consuming, because the two landmarks had to be first located and then the distance between them measured. As reported by others, misplacing either of the two marks has a significant impact on the WC measurement (Wang *et al*., 2003; Mason & Katzmarzyk, 2009); however use of this method is recommended by the World Health Organization.

Measurement of WC at the umbilicus is common, likely due in part to the ease at which this site can be identified. Reports also indicate that this site is associated with cardio metabolic morbidity and mortality (Willis *et al*., 2007; Ross *et al*., 2008). Measurement at this site has not been recommended by any national or international bodies, but is likely to coincide with measurements taken at the upper border of the iliac crest in most subjects. In some subjects with suspended abdomen, the umbilicus was located below the level of the iliac crest, especially in women with previous multiple pregnancies, making the measurement of WC difficult. Published reports indicate that measurements of waist circumference made at the level of the umbilicus may underestimate the true waist circumference (Croft *et al*., 1995).

Measurement of WC in the upper border of the iliac crest was not as time-consuming, as there is only one landmark and it can be easily located by palpating the right hip bone; the measurement is taken immediately superior to the uppermost border of the right ileum. WC measurements taken at this site are reproducible and strongly related to intra-abdominal adipose tissue and total body adiposity (Wang *et al.,* 2003). This site was used in the National Health and Nutrition Examination Survey, and is recommended by the National Institutes of Health and several other professional medical societies in the United States (Klein *et al*., 2007).

One difference between our study and the above mentioned studies is that we excluded subjects with type 2 and 3 obesity. Another difference is the time of measurement. Since the amount of water, food or gas in the gastrointestinal tract would affect the accuracy of the waist measurement (Gibson, 1990), we performed examinations in fasting state.

CONCLUSION

The WC measurement above the iliac crest has the most correlation with subcutaneous fat in triceps and suprailiac areas compared to other measurements. It seems that protocols using bony landmarks are superior to other protocols because they are easily reproducible by others and hence may be better parameters for evaluating abdominal obesity. Furthermore, the use of one landmark is faster and has fewer intra-observer calculation errors. Since there is no uniformly accepted approach to the measurements of WC, the interpretation of WC measurements should be done taking into account the location of the measurement.

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Conflict of interest

The authors declare that there is no conflict of interest.

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