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Original Research

Waist-to-Hip Ratio is related to Body Fat Content and Distribution regardless of the Waist Circumference Measurement Protocol, in Non-Alcoholic Fatty Liver Disease Patients

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Running head: Waist-to-hip ratio and body fat in NAFLD patients

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ABSTRACT

Central accumulation and distribution of body fat (BF) is an important cardiometabolic risk factor. Waist-to-hip ratio (WHR), commonly elevated in non-alcoholic fatty liver disease (NAFLD) patients, has been endorsed as a risk related marker of central BF content and distribution, but no standardized waist circumference measurement protocol (WCmp) has been proposed. We aimed to investigate whether using different WCmp affects the strength of association between WHR and BF content and distribution in NAFLD patients. BF was assessed with Dual Energy X-ray Absorptiometry (DXA) in 28 NAFLD patients (19 males, 51 ± 13 yrs, and 9 females, 47 ± 13 yrs). Waist circumference (WC) was measured using four different WCmp (WC1: minimal waist; WC2: iliac crest; WC3: mid-distance between iliac crest and lowest rib; WC4: at the umbilicus) and WHR was calculated accordingly (WHR1, WHR2, WHR3 and WHR4, respectively). High WHR was found in up to 84.6% of subjects, depending on the WHR considered. With the exception of WHR1, all WHR correlated well with abdominal BF (r=0.47 for WHR1; r=0.59 for WHR2 and WHR3; r=0.58 for WHR4) and BF distribution (r=0.45 for WHR1; r=0.56 for WHR2 and WHR3; r=0.51 for WHR4), controlling for age, sex and body mass index (BMI). WHR2 and WHR3 diagnosed exactly the same prevalence of high WHR (76.9%). The present study confirms the strong relation between WHR and central BF, regardless of WCmp used, in NAFLD patients. WHR2 and WHR3 seemed preferable for use in clinical practice, interchangeably, for the diagnosis of high WHR in NAFLD patients.

Key Words: body composition; abdominal obesity; hepatic steatosis.

Waist-to-hip ratio (WHR) has been shown to be closely related to the occurrence of non-alcoholic fatty liver disease (NAFLD) (Zheng et al., 2012), a metabolic condition that may lead to advanced fibrosis, cirrhosis, liver failure and death (Angulo, 2002). WHR has also been found to be associated with increased risk of cardiovascular events (Gruson et al., 2010), which is also increased in NAFLD patients (Targher et al., 2005). Besides being a known cardiovascular risk factor (Ritchie et al., 2007), excess whole and in particular central body fat (BF) accumulation, highly common in NAFLD patients (Browning et al., 2004), have also been found to increase the risk of NAFLD (Park et al., 2007). It is therefore important to establish standardized clinical body composition surrogates, and potential therapy targets, particularly in higher risk sub-populations such as patients with NAFLD.

WHR is assumed to reflect the distribution of fat throughout the body meaning that a high WHR should represent a preferential abdominal or central accumulation of BF (Egger, 1992), and it has largely proven to be so (Chan et al., 2003; Savgan-Gurol et al., 2010; Taylor et al., 1998) yet conflicting results have also been found (Ketel et al., 2007). The considerable variation in methodology and results found in the literature may be limiting a standardized and wider usage of this body index. The importance of a single standardized measurement protocol to calculate WHR has been identified (Croft et al., 1995; Houmard et al., 1991), but none has been universally recognized or endorsed, and therefore a wide diversity of methods can be found in the literature (Lear et al., 2009). The use of WHR is described in the literature since the early 1980’s using WC measured at the umbilicus (Larsson et al., 1984), at the minimal waist (Evans et al., 1984) or at the mid distance between the lower rib and the iliac crest (Lapidus et al., 1984). In the early 1990’s WHR was proposed to be calculated using measurements of waist circumference (WC) at the minimal waist (Nesheim, 1990), however WC measured at the mid distance between lowest rib and iliac crest has been the most used protocol (Lear et al., 2009).

To our knowledge it is unknown whether the use of different commonly used waist circumferences, with different measuring sites, affect the relation between WHR and both whole and central BF content and BF distribution. Therefore the aim of the present study was to find if any of the most used WC measurement protocol (WCmp) is better to calculate WHR for use in clinical practice with NAFLD patients as a surrogate of whole and central BF content and BF distribution.

METHODS

Subjects:

This study was conducted at Exercise and Health Laboratory, from the Interdisciplinary Centre for the Study of Human Performance (Faculty of Human Kinetics, Technical University of Lisbon, Portugal). To be selected for the present study subjects had to be over 18 years of age without history of hepatotoxic substance intake (eg. steroids) and tobacco consumption. Exclusion criteria included alcohol consumption over 20 g/day; the presence of other potential causes for fatty liver disease, including viral hepatitis, auto-immune disease and others; any physical and/or mental disabilities or any condition that constituted an absolute restriction to exercise, or other diagnosed diseases, except for metabolic and cardiovascular diseases (insulin resistance, hypertension or dyslipidemia), with mandatory specific pharmacologic therapy. We studied 28 NAFLD patients (19 males and 9 females; 25 – 68 yrs) who were diagnosed through liver biopsy (n=13) or ultrasound (n=15). Subjects were recruited from the outpatient medical departments in Santa Maria Hospital and Curry Cabral Hospital; 59 consecutive patients were invited to participate based on inclusion criteria; 28 of the 37 individuals who accepted the invitation were included in the study after exclusion criteria were considered. All subjects gave their written informed consent before taking part in the study. All methods used in the present study complied with ethics and Portuguese laws and were approved by Faculty of Human Kinetics institutional review board for human studies.

Body composition:

Body composition (BC) was assessed using Dual Energy X-ray Absorptiometry (DXA) (Explorer W, Hologic; Waltham, MA, USA; Fan beam mode) whole body scans and anthropometric measurements. Repeated measurements of whole body DXA scans were performed at our lab in 18 young adults, for precision assessment purposes (Lohman et al., 2005), and showed a coefficient of variation (CV) of 1.7% for total BF mass and 1.5% for total %BF. All scans were performed in the morning after an overnight 12 h fast. Quality control with spine phantom was conducted every morning, and with step phantom every week. By default, DXA software (QDR for windows, version 12.4) estimates the head, trunk, arms and legs, both left and right, regional fat content, according to a three-compartment model (fat mass, lean tissue and bone mass). The analyzed trunk region of interest (ROI) (CV = 0.5%) includes the chest, abdomen and pelvis regions from the scan (figure 1). All scans analyses were made by the same observer. All scans were submitted to additional analysis by ROI to assess fat content of the abdominal (R1) and central abdominal (R2) regions (figure 1) (CV = 1.0 %). The upper and lower limits of R1 and R2 were determined as the upper edge of the second lumbar vertebra to the lower edge of the fourth lumbar vertebra, respectively (Kamel et al., 2000; Park et al., 2002; Pimenta et al., 2014). Lateral limits of R1 were the vertical continuation of the lateral sides of the rib cage, as to exclude the lateral subcutaneous fat of the trunk, including however the anterior and posterior subcutaneous abdominal fat, as well as the intra-abdominal fat (Kamel et al., 2000; Pimenta et al., 2014) , whereas the lateral limits of R2 were determined as to include all trunk width, but exclude any upper limb scan area (Park et al., 2002; Pimenta et al., 2014) (figure 1). Absolute and relative BF content results were reported to the nearest 0.01kg and 0.1%, respectively.

Anthropometric measurements consisted of weight, height and body mass index (BMI) as well as WC and WHR. Standardization procedures were taken into account to minimize error (Agarwal et al., 2009; World Health Organization, 2011). All WC measurements were made with subjects in a standing comfortable position facing the observer, with the arms crossed over their chest, in their underwear, in a 12h fasting state. All measurements were made by the same technician, who was a trained level 2 technician, certified by the International Society for the Advancement of Kinanthropometry. Body weight was measured to the nearest 0.1kg, and height was measured to the nearest 0.1 cm, on a scale with an attached stadiometer (model 770, Seca; Hamburg, Deutschland), according to standard protocol (Lohman, Roche, & Martorell, 1988). Subjects' BMI was calculated by dividing the weight, in kg, by the squared height, in meters (BMI = weight [kg] / height [m]^2). WC was measured using an inelastic flexible metallic tape (Lufkin - W606PM, Vancouver, Canada) parallel to the floor after a tidal expiration, to the nearest 0.1cm, at the following sites: the narrowest torso (WC1) (Lohman et al., 1988), also called minimal waist (Ross et al., 2008); the superior border of the iliac crest (WC2) (McGuire et al., 2010; National Institutes of Health, 1994); the midpoint between the lowest rib and iliac crest (WC3) (WHO, 2011) and the umbilicus (WC4) (Ketel et al., 2007; Savgan-Gurol et al., 2010). Hip circumference (Hip-C) was measured horizontally at the level of the widest portion of the buttocks (Lohman et al., 1988; Nesheim, 1990; WHO, 2011). WHR was calculated by dividing each subject's WC by the Hip-C, both in centimeters (WHR = WC [cm] / Hip-C [cm]).

Four different WHR were calculated for each subject: WHR1, WHR2, WHR3 and WHR4, calculated using WC1, WC2, WC3 and WC4, respectively. The cut off values of 0.95 for men and 0.80 for women were considered for the identification of high WHR (Nesheim, 1990). All anthropometric measurements were repeated two times. A third measurement was taken whenever the second measurement differed more than 1cm (for waist and height measurements) or 0.5kg (for weight measurement) from the first measurement. The results obtained in the second measurement were reported whenever no third measurement was taken. When a third measurement was taken we reported the mode of all three measurements or, if mode was absent, the median was reported. By using this procedure we sought to always use the most suitable value that was actually measured on the subjects (instead of mean values) (Pimenta et al., 2015).

Statistical methods:

Descriptive statistics are presented as mean ± SD and range for all analyzed variables. The Gaussian distribution of the data was assessed with the Shapiro-Wilk goodness-of-fit test. Paired samples t-test was used to compare different WHR. The association of all WHR with the DXA measures was assessed using partial and semipartial (Cohen et al., 1983) correlations, controlling for age, sex and BMI. A statistical power of 80% ($\beta = 0.20$) at a significance level of 5% ($\alpha = 0.05$) was considered statistically significant. Consequently only coefficients of correlation equal or superior to 0.5, corresponding to a large effect size, attained this criteria ($p \leq 0.05$ and $\beta \leq 0.20$) and could be considered significant (this is in accordance with Cohen et al. (1983) to assure that results are unexposed to type I and II errors, despite a rather modest sample size). Pairs of correlation coefficients obtained between each WHR with each dependent variable were compared, using Z statistic, to find if any WHR was more closely associated with BF content and distribution. Statistical calculations were performed using the IBM SPSS Statistics version 19 (SPSS, inc, Chicago, IL), except for Z statistic which was performed using Medcalc version 11.1.1.0 (MedCalc Software, Mariakerke, Belgium).

RESULTS

Mean values for all variables are presented in table 1. High WHR was present in 69 to 85%, according to the WHR used, yet WHR2 and WHR3 diagnosed exactly the same prevalence of high WHR in the studied sample. Results for WHR were different when using different WC (WHR4>WHR2>WHR3>WHR1). Mean age of the studied sample was 51±13 yrs for men and 47±13 yrs for women, with no differences between sexes ($p=0.519$ on independent samples t test). Subjects were taking one or more of the following medications: platelet inhibitors, angiotensin-converting enzyme inhibitors, nitrates, statins, ezitimibe, nicotinic acid and biguanides, with similar use among sexes

The results for partial and semipartial correlations, controlled for sex and age (table 2), showed WHR1 was the only WHR not correlated with any BF depot. All other WHR were positively associated with both Abdominal BF and Central Abdominal BF. Regarding BF distribution markers, WHR1 was the only WHR not correlated with Trunk BF-to-Appendicular BF ratio, but all WHR correlated positively with Abdominal BF-to-Total BF ratio. The results for partial and semipartial correlations, controlled for sex, age and BMI (table 3), showed that all but WHR1 were positively correlated with abdominal region BF depots and both Trunk BF-to-Appendicular BF ratio and Abdominal BF-to-Total BF ratio.

All coefficients of correlation between WHR and BF content variables remained stable either when using partial correlations (when WHR and DXA measures variation associated with control variables was removed from the correlations) or when using semipartial correlations (when only WHR variation associated with control variables was removed from the correlations). Associations were absent for all WHR with all BF distribution markers, when semipartial correlations were used. The differences between coefficients of correlation obtained with and without BMI as a control variable were not significant (p>0.05 in all coefficient of correlation comparisons by Z statistics, using Medcalc version 11.1.1.0 [MedCalc Software, Mariakerke, Belgium], data not shown). Yet WHR1 was found not to be correlated with any BF content or distribution variable when BMI was added as controlling variable (p>0.05). No differences were found in the comparison between pairs of coefficients of correlation (listed in table 2 and 3) obtained between competing WHR with each dependent variable, using Z statistics (p>0.05 in all comparisons, data not shown).

DISCUSSION

Mean WHR was rather high, and the prevalence of elevated WHR was high in the present sample when compared to the general population (69 to 85% found in the present study, depending on the WCmp used to calculate WHR, vs 42 to 58%, reported elsewhere) (Akpinar et al., 2007). This was expected as NAFLD patients have been shown to have higher WHR (Zheng et al., 2012). The differences observed in the WHR mean values, calculated using different WC, suggest WHR calculated using different WCmp are not interchangeable. This has important implications in clinical practice, advising a consistent choice of the WCmp used for the calculation of WHR. But the literature is neither consistent nor consensual regarding which WCmp should be used for the calculation of WHR. Several previous studies have reported WC magnitudes to be influenced by WCmp (Mason et al., 2009; Wang et al., 2003). Even though the present study shows differences between all WHR, both WHR2 and WHR3 diagnosed exactly the same prevalence of high WHR, using proposed cut-off values (Nesheim, 1990), suggesting they could be used interchangeably for the diagnosis of high

WHR in the present sample, as has been proposed for the general population (Ross et al., 2008). WC measured at the umbilicus is commonly used, including in NAFLD patients (Rector et al., 2011; Targher et al., 2008), and has been found useful for the prediction of whole and central BF as well as BF distribution in these patients (Pimenta et al., 2015). However, the use of bony landmarks had been recommended to increase precision (Klein et al., 2007) and reliability (McGuire et al., 2010; Ross et al., 2008) making WC4 and, consequently, WHR4 less appealing.

WHR were only found to be associated with central BF depots. When controlled for age, sex and BMI, WHR1 showed no correlations with all DXA measures and ratios. WHR1 was positively correlated with abdominal BF-to-Total BF ratio, but only when BMI was not included as a controlling variable. The inconsistency of WHR1 correlations suggests that this is more prone to be influenced by general adiposity than all other studied WHR. WHR has been proposed to be calculated using WC measured at minimum waist (Nesheim, 1990) however this seemed to have the least consistent and predictable relation with BF, in the present study. Though not consensual, the association between WHR and central BF has been previously reported (Chan et al., 2003; Savgan-Gurol et al., 2010) but not until now in NAFLD patients. WHR, using WC measured at mid-distance between lowest rib and iliac crest, was previously shown to be positively correlated with abdominal adipose tissue compartments, as assessed by magnetic resonance imaging (MRI) in free-living men (Chan et al., 2003). Coefficients of correlation over 0.70 were also found between WHR, using WC measured at the umbilicus, and both visceral and subcutaneous adipose tissue, as assessed by MRI at L4 (Savgan-Gurol et al., 2010). Even though these results are in accordance to the findings of the present study, to our knowledge no other studies focused on such relationships in non-alcoholic fatty liver disease patients. The considerable differences in methodology, including considerable differences in the studied populations, prevent extended interpretations. Opposing results were also found when correlating WHR, using WC measured at the umbilicus, with DXA assessed BF depots similar to the present study, including central BF ($r<0.28$) and peripheral BF ($r<0.16$) (Ketel et al., 2007). Though these differences may be explained by sample differences, including different health status.

In the present sample of NAFLD patients WHR2, WHR3 and WHR4 were significantly associated with body fat distribution either when controlling only for age and sex (table 2), or when adding BMI as controlling variable (table 3). The present results do not support such previously reported high coefficients of correlation found between WHR using minimal waist, and both DXA derived trunk-to-leg BF ratio ($r=0.62$) and waist-to-hip BF ratio ($r=0.78$) (Taylor et al., 1998). However, these results were observed on a sample of healthy white women, which is profusely different from the sample considered in the present study. Unlike the present results, a small coefficient of correlation ($r<0.3$) was reported between WHR, using WC measured at the umbilicus, and a similar variable to the trunk BF-to-appendicular BF ratio, used in the present study (Ketel et al., 2007). Yet this was found on a sample of adolescent girls. The coefficients of correlation obtained between the different WHR and all studied BF depots and BF distribution variables were not significantly different ($p>0.05$) when comparing results obtained with the all WHR for each dependent variable using Z statistics (data not shown). Both central BF accumulation (Ritchie et al., 2007) and high WHR (Gruson et al., 2010) have been reported to be positively associated with increased risk of cardiovascular diseases. Considering both the high prevalence of elevated WHR and the strong association between WHR and both central body fat content and distribution (particularly WHR 2 and WHR3, which seem more consistent) found in the present sample, it is reasonable to assume that this may suggest a higher cardiometabolic risk in the studied patients. This assumption is concordant with the higher risk of cardiovascular events previously reported in NAFLD patients (Targher et al., 2005).

There are several strengths and limitations to this study. The studied WCmp do not cover all protocols existent in the literature, however the focus was set on the most commonly used and endorsed by prominent institutions for use in clinical setting (Klein et al., 2007; McGuire & Ross, 2010; Ross et al., 2008). Also the used BC assessment method (DXA), a gold standard instrument to assess BC in a three compartment model, is unable to determine visceral adiposity independently from subcutaneous fat. However there is a strong correlation between abdominal fat estimated from selected DXA ROI and visceral fat assessed by MRI (Park et al., 2002) and computed tomography (Snijder et al., 2002). Finally, because a cross-sectional approach was used, there could not be established the usefulness of the studied WHR to assess changes in BF depots content neither in BF distribution, based on the present results.

The present study confirms the strong association between WHR and central BF, even after removing the effect of age, sex and BMI, in NAFLD patients. However WHR using WC measured at minimal waist seems to be less consistent as a BF content or distribution surrogate in NAFLD. Thus, present results may endorse an interchangeable use of WHR2 (measured at the superior border of the iliac crest) and WHR3 (measured at the mid-distance between the lowest rib and the iliac crest) for identifying subjects with high WHR and therefore at higher cardiometabolic risk. Based on present results both WHR2 and WHR3 seem preferable to use in NAFLD patients. Additional research is needed to confirm the influence of different WCmp in the relation of WHR with other NAFLD and cardiometabolic risk factors.

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The authors declare no conflict of interest.

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TABLES:

Table 1. Descriptive data of the studied sample.

	NAFLD Patients (n=28)			
Variables	**Mean ± SD ***		**Min. – Max.**	
Age, yr (median, yr)	49.5 ± 12.8	(49)	25 – 68	
Sex, n female (% female)	9	(32.1)		
Anthropometry				
Weight, kg (CV, %)	87.6 ± 12.7	(0.07)	66.2 – 115.8	
Height, cm (CV, %)	167.2 ± 9.2	(0.03)	149.5 – 183.7	
BMI, kg/m^2 (% obese)	29.1 ± 4.0	(32.1)	22.6 – 42.2	
WC 1, cm (CV, %)	100.7 ± 8.2#	(0.45)	86.0 – 119.8	
WC 2, cm (CV, %)	104.8 ± 10.6#	(0.49)	85.3 – 128.7	
WC 3, cm (CV, %)	103.7 ± 10.4#	(0.47)	85.7 – 129.3	
WC 4, cm (CV, %)	106.3 ± 11.7#	(0.73)	86.7 – 129.1	
Hip C, cm (CV, %)	107.6 ± 12.0	(0.38)	92.3 – 138.3	
WHR 1 (high WHR, %)	0.94 ± 0.07†	(69.2)	0.75 – 1.03	
WHR 2 (high WHR, %)	0.98 ± 0.07†	(76.9)	0.85 – 1.11	
WHR 3 (high WHR, %)	0.97 ± 0.07†	(76.9)	0.82 – 1.09	
WHR 4 (high WHR, %)	0.99 ± 0.06†	(84.6)	0.88 – 1.10	
Whole and Regional Body Fat				
BF, kg (%)	27.2 ± 9.3	(31.31 ± 8.20)	13.7 – 51.2	(18.84 – 46.28)
Trunk BF, kg (%)	15.2 ± 5.2	(33.15 ± 7.65)	7.4 – 25.0	(20.87 – 48.01)
Appendicular BF, kg (%)	10.8 ± 4.8	(30.42 ± 10.39)	5.2 – 25.7	(13.63 – 50.40)
Abdominal BF, kg (%)	3.5 ± 1.2	(37.57 ± 6.59)	1.7 – 6.3	(26.09 – 49.40)
Central Abdominal BF, kg (%)	2.9 ± 0.8	(35.82 ± 5.70)	1.6 – 5.0	(24.28 – 44.64)
Body Fat distribution, ratios				
Trunk BF/ Appendicular BF ratio	1.477 ± 0.371		0.958 – 2.547	
Abdominal BF / Total BF ratio	0.130 ± 0.025		0.045 – 0.185	
Abdominal BF / Trunk BF ratio	1.231 ± 0.039		0.095 – 0.299	

CV – coefficient of variation; BMI – body mass index; WC1 – Waist circumference as measured by Lohman et al. {Lohman, 1988 #908} and Marfell-Jones {Marfell-Jones, 2006 #270}; WC2 - Waist circumference as measured by the National Institute of Health (NIH) from the United States of America {NIH, 1994 #937}; WC3 - Waist circumference as measured by the World Health Organization (WHO) {WHO, 1987 #1015}; WC4 - Waist circumference as measured by Ross et al., Masson et al., Targher et al. and others {Ross, 2008 #969; Mason, 2009 #919; Targher, 2008 #412}; Hip C – Hip circumference; Thigh C – Thigh circumference; Calf C – Calf circumference; Arm C – Arm circumference; BF – body fat; FFM – fat free mass; * Results are presented as mean ± standard deviation, unless otherwise noted; Min. – lowest observed value; Máx. – highest observed value; HRR1 – heart rate recovery at 1 min.; HRR2 – heart rate recovery at 2 min.; BMI – body mass index; BF – body fat; FFM – fat free mass; # - different from all other WC mean values, $p < 0.05$ in paired samples t-test; † - different from all other WHR mean values, $p < 0.05$ in paired samples t-test.

Table 2. Partial and semipartial correlations, controlled for age and sex.

Variables	WHR1		WHR2		WHR3		WHR4	
	†	§	†	§	†	§	†	§
BF	- 0.17	- 0.12	0.13	0.09	0.09	0.06	0.10	0.07
%BF	- 0.02	- 0.02	0.15	0.08	0.13	0.07	0.12	0.06
Trunk BF	0.05	0.04	0.35	0.27	0.31	0.25	0.31	0.25
% Trunk BF	0.12	0.08	0.29	0.19	0.29	0.19	0.24	0.16
Append BF	- 0.42	- 0.28	- 0.16	- 0.11	- 0.21	- 0.13	- 0.17	- 0.11
% Append BF	- 0.18	- 0.08	- 0.06	- 0.03	- 0.08	- 0.04	- 0.05	- 0.02
Abd BF	0.37	0.33	0.57**	0.51**	0.56**	0.50**	0.57**	0.51**
% Abd BF	0.34	0.28	0.44	0.36	0.44	0.36	0.42*	0.35
C Abd BF	0.40	0.39	0.60**	0.58**	0.58**	0.56**	0.57**	0.56**
% C Abd BF	0.25	0.22	0.36	0.32	0.36	0.31	0.34	0.30
Trunk BF/ Appendicular BF	0.45	0.37	0.56**	0.46	0.56**	0.46	0.51*	0.42
Abd BF/ Total BF	0.52*	0.47	0.51*	0.46	0.54**	0.49	0.52*	0.47
Abd BF/ Trunk BF	0.38	0.37	0.30	0.29	0.32	0.32	0.334	0.33

WHR 1 – Waist-to-Hip ratio calculated using waist circumference measured at narrowest torso; WHR 2 - Waist-to-Hip ratio calculated using waist circumference measured at iliac crest; WHR 3 - Waist-to-Hip ratio calculated using waist circumference measured at midpoint between lowest rib and iliac crest; WHR 4 - Waist-to-Hip ratio calculated using waist circumference measured at the umbilicus; BF – body fat; Trunk BF – Trunk body fat; Append BF – appendicular body fat; Abd BF – Abdominal body fat; C Abd BF – Central abdominal body fat; † - partial correlations between studied WHR and dependent variables, controlled for age and sex; § - semipartial correlations between studied WHR and dependent variables, controlled for age and sex ; * - significant for $p<0.05$; ** - significant for $p<0.01$.

Table 3. Partial and semipartial correlations, controlled for age, sex and BMI.

Variables	WHR1		WHR2		WHR3		WHR4	
	†	§	†	§	†	§	†	§
BF	0.06	0.03	0.19	0.13	0.18	0.10	0.15	0.08
%BF	0.13	0.06	0.17	0.08	0.18	0.09	0.13	0.06
Trunk BF	0.29	0.19	0.43	0.28	0.43	0.28	0.38	0.25
% Trunk BF	0.27	0.17	0.33	0.20	0.34	0.21	0.26	0.16
Append BF	- 0.29	- 0.14	- 0.19	- 0.09	- 0.20	- 0.10	- 0.22	- 0.11
% Append BF	- 0.08	- 0.03	- 0.06	- 0.02	- 0.05	- 0.02	- 0.05	- 0.02
Abd BF	0.47	0.41	0.59**	0.52**	0.59**	0.52**	0.58**	0.51**
% Abd BF	0.39	0.32	0.45	0.37	0.44*	0.37	0.42	0.35*
C Abd BF	0.48	0.46	0.61**	0.58**	0.60**	0.58**	0.58**	0.56**
% C Abd BF	0.31	0.27	0.37	0.32	0.37	0.32	0.35	0.30
Trunk BF/ Appendicular BF	0.45	0.38	0.56**	0.46	0.56**	0.46	0.51*	0.42*
Abd BF/ Total BF	0.48	0.43	0.51*	0.46	0.53**	0.48	0.53*	0.47*
Abd BF/ Trunk BF	0.32	0.30	0.30	0.28	0.32	0.30	0.34	0.32

WHR 1 – Waist-to-Hip ratio calculated using waist circumference measured at narrowest torso; WHR 2 - Waist-to-Hip ratio calculated using waist circumference measured at iliac crest; WHR 3 - Waist-to-Hip ratio calculated using waist circumference measured at midpoint between lowest rib and iliac crest; WHR 4 - Waist-to-Hip ratio calculated using waist circumference measured at the umbilicus; BF – body fat; Trunk BF – Trunk body fat; Append BF – appendicular body fat; Abd BF – Abdominal body fat; C Abd BF – Central abdominal body fat; † - partial correlations between studied WHR and dependent variables, controlled for age and sex; § - semipartial correlations between studied WHR and dependent variables, controlled for age and sex ; * - significant for p<0.05; ** - significant for p<0.01.

FIGURE LEGENDS:

Figure 1 Image of a DXA scan showing the central abdominal region of interest (R1) and the abdominal region of interest (R2).