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RESEARCH ARTICLE

Waist-to-Height Ratio is independently related with Whole and Central Body Fat Regardless of the Waist Circumference Measurement Protocol, in Non-Alcoholic Fatty Liver Disease Patients

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Key Words: waist-to-height ratio; body composition; body fat; abdominal obesity; NAFLD; hepatic steatosis

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ABSTRACT

Background: Waist-to-height ratio (WHtR) has been reported as a preferable risk related body fat (BF) marker, but no standardized waist circumference measurement protocol (WCmp) has been proposed. The aim of the present study was to investigate whether the usage of different WCmp affects the strength of relation between WHtR and both whole and central BF in Non-alcoholic Fatty Liver Disease (NAFLD) patients.

Methods: 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). All subjects also underwent anthropometric evaluation including height and waist circumference (WC) measurement using four different WCmp (WC1: minimal waist; WC2: iliac crest; WC3: mid-distance between iliac crest and lowest rib; WC4: at the umbilicus) and WHtR was calculated using each WC measurements (WHtR1, WHtR2, WHtR3 and WHtR4, respectively). Partial correlations were conducted to assess the relation of WHtR and DXA assessed BF.

Results: All WHtR were particularly correlated with central BF, including abdominal BF (r=0.80; r=0.84; r=0.84; r=0.78; respectively for WHtR1, WHtR2, WHtR3 and WHtR4) and central abdominal BF (r=0.72; r=0.77; r=0.76; r=0.71; respectively for WHtR1, WHtR2, WHtR3 and WHtR4), after controlling for age, sex and body mass index. There were no differences between the correlation coefficients obtained between all studied WHtR and each whole and central BF variable.

Conclusions: WHtR was found a suitable BF marker in the present sample of NAFLD patients and the strength of the relation between WHtR and both whole and central BF was not altered by using different WCmp in the present sample of NAFLD patients.

INTRODUCTION

Waist-to-height ratio (WHtR) is an index of abdominal obesity initially proposed by Hsieh and Yoshinaga in the mid-nineties [1,2]. By then WHtR was suggested to be a better predictor of multiple coronary heart disease risk factors than other obesity and fat distribution indexes in both men [1] and women [2]. Despite not consensually [3,4], WHtR was further suggested to be preferable to other indexes and clinical assessments, including body mass index (BMI), waist circumference (WC) and waist-to-hip ratio (WHR), to predict cardiovascular risk factors, in different ethnic and age groups [5,6]. WHtR seems also to be at least similarly associated to abdominal fat as is WC, and better than both BMI and WHR [7,8]. To our knowledge few studies have focused on non-alcoholic fatty liver disease (NAFLD) patients using WHtR [9,10]. These studies found rather high WHtR in NAFLD patients [9,10] which is concordant with the increased cardiovascular risk found in NAFLD patients [10-13]. It is therefore utmost important to establish standardized clinical body composition surrogates, and potential therapy targets, particularly in higher risk sub- populations such as patients with NAFLD.

Despite being a promising clinical marker of body composition[8,15] and related cardiometabolic risk[5], there is still some inconsistency considering the WC measurement protocol (WCmp) used to calculate WHtR [16]. Several WCmp have been proposed by sound authorities, and used by prominent authors, but scientific rational is lacking to recommend one single protocol [17–19]. The association of WC to cardiometabolic risk is independent of WCmp [19]. However, measurements using different WCmp have different magnitudes and therefore are not interchangeable [19]. Proposed protocols differ mainly on the anatomical landmarks and correspondent measuring sites. WHtR was initially proposed using WC measured at the umbilicus [1,2]. In subjects without diagnosed diseases WHtR calculated using WC measured at the umbilicus was suggested to be preferable for the estimation of both whole and trunk BF however only two WC measurement protocols were tested (narrowest point between the lower costal border and the top of the iliac crest and at the level of the umbilicus)[15]. In a recent review on WHtR [16], WC measured midpoint between the lowest rib and iliac crest was found to be used in 50% of the reviewed papers, and for that reason its routine use was encouraged.

To our knowledge it is unknown if the use of different commonly used waist circumferences, with different measuring sites, affect the relation between WHtR and both whole and central BF content in NAFLD patients, and what is the independent magnitude of such relation. Therefore the aim of the present study was to find which of the most used WCmp is better to calculate WHtR for use in clinical practice with NAFLD patients as a surrogate for whole and central body fat.

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 substances intake (eg. steroids) and tobacco consumption. Exclusion criteria included alcohol consumption over 20 gr/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 disease (insulin resistance, hypertension or dyslipidemia), with mandatory specific pharmacologic therapy. We studied 28 NAFLD patients (19 males, 51 ± 13 yrs, and 9 females, 47 ± 13 yrs) who were diagnosed through liver biopsy or ultrasound. Cardiorespiratory fitness was assessed as described elsewhere [(20)] for characterization purposes. Subjects were recruited from the outpatient medical departments in Santa Maria Hospital and Curry Cabral Hospital; 59 consecutive patients were selected based on selection criteria; 37 of the selected subjects accepted to participate and 28 were found eligible to enter the study after exclusion criteria was considered. Subjects were taking one or more of the following medication: platelet inhibitors, angiotensin-converting enzyme inhibitors, nitrates, statins, ezetimibe, nicotinic acid and biguanides with similar use among both genders. All participants signed an informed consent before being included in the present study and undergoing any study procedure. 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 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 with DXA in 18 young adults showed a coefficient of variation (CV) of 1.7% for total BF mass and 1.5% for total %BF. All scans were made in the morning after an overnight 12-hour fast. Quality control with spine phantom was made 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, regions body composition, according to a three-compartment model (fat mass, lean tissue and bone mass). The trunk region of interest (ROI) (CV = 0.5%) includes chest, abdomen and pelvis regions from the scan [(21)]. All scans analysis were made by the same observer. All scans were submitted to additional analysis by ROI to assess fat content of the abdominal and central abdominal regions (CV = 1.0 %) [(21)]. The upper and lower limits of the abdominal and central abdominal ROI were determined as the upper edge of the second lumbar vertebra to the lower edge of the fourth lumbar vertebra, respectively [(22–24)]. The lateral limits of the abdominal ROI were determined as to include all trunk length, but exclude any upper limb scan area [(23,24)], whereas the lateral sides of central abdominal ROI were the vertical continuation of the lateral sides of the ribs 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 [(22)], as seen in figure 1. Absolute and relative BF content results were registered 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 WHtR. Some standardization procedures were taken into account, as recommended [(25)], to avoid any bias in the measurements, therefore all WC measurements were made with subjects in a standing comfortable position, in their underwear, in a 12-hour fasting state. All WC measurements were made by the same technician, who was a trained level 2 technician, certified by the International Society for the Advancement of Kinanthropometry, using an inelastic flexible metallic tape (Lufkin - W606PM, Vancouver, Canada) parallel to the floor after a tidal exhalation, to the nearest 0.1cm. The WC measurement sites in the present study were the narrowest torso (WC1) [(26,27)], also called minimal waist [(19)], superior border of the iliac crest (WC2) [(18,28)], midpoint between the lowest rib and iliac crest (WC3) [(29)] and umbilicus (WC4) [(1,2)]. These are the most commonly used protocols endorsed by sound authorities in this field [(17,19)]. 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 [30]. Both weight and height were used to calculate the subjects' BMI, by dividing the weight, in kg, by the squared height, in meters (BMI = weight [kg] / height [m]^2). WHtR was calculated by dividing each WC by the subjects' height, both in centimeters (WHtR = WC [cm] / height [cm]). Because we used four different WCmp for each subject, we calculated four different WHtR using each measured WC. Therefore WHtR1, WHtR2, WHtR3 and WHtR4 were calculated using WC1, WC2, WC3 and WC4, respectively. We considered a boundary value of 0.5 for the identification of high WHtR [9,31]. All anthropometric measurements were repeated two times, and if the second differed more than 1cm (for waist and height measurements) or 0,5kg (for weight measurement) from the first measurement, a third measurement was carried out. We always considered the result obtained in the second measurement unless a third measurement was carried out. When a third measurement was taken we considered the mode or, if mode was absent, the median value of all three measurements. By using this procedure we sought to always use the most suitable value that was actually measured on the subjects (instead of mean values).

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 WHtR. The association of all WHtR with DXA measures was assessed using partial and semipartial correlations [32], 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 coefficients of correlation obtained using different WHtR for each DXA measure were compared, using Z statistic, to find if any WHtR, according to the WC used in its calculation, was more strongly associated to whole and central BF. 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 studied variables are presented in table 1. From among the 28 studied NAFLD patients WHtR above the boundary value of 0.5 was present in nearly 100% of the sample, depending on the WCmp used. Results for WC measurements were considered to be different between all studied WCmp (WC4>WC2>WC3>WC1) and the magnitude of WHtR mean values were also different according to the WC used. Obesity was present in 9 subjects (3 were female), according to BMI classification, with no differences between sexes in mean BMI (p=0.075 on independent samples t test).

Table 2 shows the results for partial and semipartial correlations between each WHtR and each whole or central studied BF depot controlled for sex, age and BMI. All WHtR were correlated with the studied BF depots, even after adjusting for age, sex and BMI, showing coefficients of correlation magnitudes above 0.5. Coefficients of correlation tend to decrease as control variables were added, particularly when the effect of age, sex and BMI was removed, however the strength of association remained for abdominal fat depots.

Table 3 shows the results for the comparison (p-values) between pairs of competing WHtR coefficients of correlation with each dependent variable (listed in table 2). No differences were found between all compared coefficients of correlation.

DISCUSSION

To our knowledge this is the first report to focus on the strength of correlation between WHtR and BF in NAFLD patients, and its variation associated to different WCmp used to calculate WHtR. Mean WHtR was reasonably high and the prevalence of elevated WHtR, considering the 0.5 boundary value, was very high in the present sample. This was expected since it has been shown that NAFLD patients have high values of WHtR [9,10]. The magnitude of WHtR mean values were different according to the WC (WHtR4 > WHtR2 > WHtR3 > WHtR1) used in its calculus meaning they are not interchangeable. This may have large implications in clinical practice and data collection and interpretation in longitudinal assessments (pre - post) as well as between group's comparisons. Several previous studies have reported WC magnitudes (the changeable component of WHtR) to be influenced by WCmp [33–35]. Still it have been proposed that current WC thresholds, generalized using WHO protocol (at the midpoint between lowest rib and iliac crest), could be applied to NIH measurements (at the superior border of the iliac crest) [19] because of small or absent differences, particularly in men, found between measurements using these WCmp [34,35]. As mentioned, the present study does not confirm such interchangeability when absolute values were taken into account. However, when a dichotomous approach was applied based on the boundary value of 0.5, both WHtR1 and WHtR2 only misclassified 1 subject (3,6%) at elevated risk as compared to WHtR2 and WHtR4 whose diagnosed 100% of the sample above the boundary value which may be considered support an interchangeable use of the studied protocols for WHtR assessment.

In the present sample of NAFLD patients, as expected, WHtR was highly associated with whole and central BF, adjusted for age, sex and BMI. Correlation coefficient magnitudes revealed a large effect size (r>0.5) for central BF depots. The association of WHtR with BC, particularly with central BF, has been reported in diverse groups [7,8] but not until now in NAFLD patients. WHtR was also shown to predict higher cardiometabolic risk better than WC and BMI [5]. The present study showed consistent coefficients of correlation of WHtR and central fat depots, even when BMI was added to age and sex as control variables, meaning that WHtR explains the variation of abdominal fat far beyond BMI. This relation was already found in subjects without NAFLD but with no control variables included in the analysis[15]. This may explain the marginally lower correlation coefficients found in the present study.

Comparisons between pairs of competing WHtR correlations results with each dependent variable showed that all studied WHtR are similarly associated with the analyzed BF depots, irrespectively of the WC used for its calculation. Previous studies have already found no differences in the association of WC alone, measured at different sites, with BF depots [33,35]. In a rather recent sound review it was concluded that the use of different WCmp do not change the well-established relationships between WC and morbidity of cardiovascular disease and diabetes and with cardiovascular and all-cause mortality [19]. However since WHtR have proven more sensitive in the prediction of cardiovascular risk, the absence of WCmp influence in risk prediction should be confirmed when WC is used to calculate WHtR.

There are several strengths and limitations to this study. The studied WCmp do not cover all protocols existent in the literature, yet the focus was set on the most commonly used and endorsed by prominent institutions for use in clinical setting [17–19]. 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 magnetic resonance imaging [23] and computed tomography [36]. Patients' physical activity and diet were not assessed, however patients' cardiorespiratory fitness was assessed, which was low (table 1), and reinforced the importance of the study of cardiovascular risk related markers in this population [37]. Finally, we could not be established the usefulness of WHtR to assess changes BF depots based on the present results, because we used a cross-sectional approach and therefore we have no follow-up data.

The present study confirms the strong association between WHtR and BF, specially central body fat, even after controlling for age, sex and BMI, in NAFLD patients, supporting WHtR as an independent central obesity index. Moreover the relation between WHtR and both whole and central BF was not altered by the choice for a particular WCmp in the present sample of NAFLD patients. Unlike previous study in subjects without diagnosed NAFLD[15] , we could not recommend the use of one specific WC measurement protocol over another for the calculation of WHtR as a whole and/or central BF surrogate. Thus present results may endorse an interchangeable use of different WCmp to identify subject's WHtR above boundary value. Additional research is needed to confirm the influence of different WCmp on the variation of WHtR in specific sub-populations and on the relation between WHtR and other NAFLD and Cardiometabolic risk factors beyond body composition alone.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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REFERENCES

1 Hsieh SD, Yoshinaga H. Abdominal fat distribution and coronary heart disease risk factors in men-waist/height ratio as a simple and useful predictor. *Int J Obes Relat Metab Disord* 1995; **19**: 585–9.

2 Hsieh SD, Yoshinaga H. Waist/height ratio as a simple and useful predictor of coronary heart disease risk factors in women. *Intern Med* 1995; **34**: 1147–52.

3 Carmienke S, Freitag MH, Pischon T *et al.* General and abdominal obesity parameters and their combination in relation to mortality: a systematic review and meta-regression analysis. *Eur J Clin Nutr* 2013; **67**: 573–585.

4 Sanyal D, Mukhopadhyay P, Pandit K *et al.* Central obesity but not generalised obesity (body mass index) predicts high prevalence of fatty liver (NRFLD), in recently detected untreated, IGT and type 2 diabetes Indian subjects. *J Indian Med Assoc* 2009; **107**: 755–758.

5 Ashwell M, Gunn P, Gibson S. Waist-to-height ratio is a better screening tool than waist circumference and BMI for adult cardiometabolic risk factors: systematic review and meta-analysis. *Obes Rev* 2012; **13**: 275–86.

6 Freedman DS, Kahn HS, Mei Z *et al.* Relation of body mass index and waist-to-height ratio to cardiovascular disease risk factors in children and adolescents: the Bogalusa Heart Study. *Am J Clin Nutr* 2007; **86**: 33–40.

7 Garnett SP, Baur LA, Cowell CT. Waist-to-height ratio: a simple option for determining excess central adiposity in young people. *Int J Obes* 2008; **32**: 1028–30.

8 Wu H-Y. Waist to Height Ratio as a Predictor of Abdominal Fat Distribution in Men. *Chin J Physiol* 2009; **52**: 441–445.

9 Zheng RD, Chen ZR, Chen JN *et al.* Role of Body Mass Index, Waist-to-Height and Waist-to-Hip Ratio in Prediction of Nonalcoholic Fatty Liver Disease. *Gastroenterol Res Pract* 2012; **2012**: 362147.

10 Yoo HJ, Park MS, Lee CH *et al.* Cutoff points of abdominal obesity indices in screening for non-alcoholic fatty liver disease in Asians: Cutoff points of abdominal obesity indices for NAFLD. *Liver Int* 2010; **30**: 1189–1196.

11 Lonardo A, Ballestri S, Targher G *et al.* Diagnosis and management of cardiovascular risk in nonalcoholic fatty liver disease. *Expert Rev Gastroenterol Hepatol* 2015; **9**: 629–650.

12 Mantovani A, Pernigo M, Bergamini C *et al.* Heart valve calcification in patients with type 2 diabetes and nonalcoholic fatty liver disease. *Metabolism* 2015; **64**: 879–887.

13 Targher G, Arcaro G. Non-alcoholic fatty liver disease and increased risk of cardiovascular disease - letter to the editor. *Atherosclerosis* 2007; **191**: 235–240.

14 Targher G, Day CP, Bonora E. Risk of cardiovascular disease in patients with nonalcoholic fatty liver disease. *N Engl J Med* 2010; **363**: 1341–1350.

15 Kagawa M, Byrne NM, Hills AP. Comparison of body fat estimation using waist:height ratio using different ‘waist’ measurements in Australian adults. *Br J Nutr* 2008; **100**: 1135–1141.

16 Ashwell M, Browning LM. The Increasing Importance of Waist-to-Height Ratio to Assess Cardiometabolic Risk: A Plea for Consistent Terminology. *Open Obes J* 2011; **3**: 70–77.

17 Klein S, Allison DB, Heymsfield SB *et al.* Waist Circumference and Cardiometabolic Risk: a Consensus Statement from Shaping America's Health: Association for Weight Management and Obesity Prevention; NAASO, the Obesity Society; the American Society for Nutrition; and the American Diabetes Association. *Obes Silver Spring* 2007; **15**: 1061–7.

18 McGuire KA, Ross R. Revised Protocol for Measurement of Waist Circumference. In: CSEP (ed). *Canadian physical activity, fitness and lifestyle approach*. Canadian Society for Exercise Physiology: Ottawa, Ont., 2010, pp 13–14.

19 Ross R, Berentzen T, Bradshaw AJ *et al.* Does the relationship between waist circumference, morbidity and mortality depend on measurement protocol for waist circumference? *Obes Rev* 2008; **9**: 312–325.

20 Pimenta NM, Santa-Clara H, Cortez-Pinto H *et al.* Body composition and body fat distribution are related to cardiac autonomic control in non-alcoholic fatty liver disease patients. *Eur J Clin Nutr* 2014; **68**: 241–246.

21 Pimenta NM, Santa-Clara H, Melo X *et al.* Finding the Best Waist Circumference Measurement Protocol in Patients With Nonalcoholic Fatty Liver Disease. *Nutr Clin Pract* 2015; **30**: 537–45.

22 Kamel EG, McNeill G, Van Wijk MC. Usefulness of anthropometry and DXA in predicting intra-abdominal fat in obese men and women. *Obes Res* 2000; **8**: 36–42.

23 Park YW, Heymsfield SB, Gallagher D. Are dual-energy X-ray absorptiometry regional estimates associated with visceral adipose tissue mass? *Int J Obes Relat Metab Disord* 2002; **26**: 978–83.

24 Pimenta NM, Santa-Clara H, Sardinha LB *et al.* Body Fat Responses to a 1-Year Combined Exercise Training Program in Male Coronary Artery Disease Patients. *Obesity* 2013; **21**: 723–30.

25 Agarwal SK, Misra A, Aggarwal P *et al.* Waist circumference measurement by site, posture, respiratory phase, and meal time: implications for methodology. *Obes Silver Spring* 2009; **17**: 1056–61.

26 Callaway CW, Chumlea WC, Boucard C *et al.* Circunferences. In: Lohman TG, Roche AF, Martorell R (eds). *Anthropometric Standardization Reference Manual*. Human Kinetics: Champaign, 1988, pp 39–54.

27 Marfell-Jones M, Olds T, Stewart A *et al. International Standards for Antropometric Assessment*. International Society for the Advancement of Kinanthropometry: Potchefstroom: South Africa, 2006.

28 National Institute of Health. Plan and operation of the Third National Health and Nutrition Examination Survey, 1988-94. Series 1: programs and collection procedures. *Vital Health Stat* 1994; **1**: 1–407.

29 WHO. Measuring obesity-classification and description of anthropometric data. Report on a WHO consultation on the epidemiology of obesity. WHO Regional Office for Europe: Warsaw, 1987.

30 Gordon CC, Chumlea WC, Roche AF. Stature, Recumbent Length, and Weight. In: Lohman TG, Roche AF, Martorell R (eds). *Antropometric Standardization Reference Manual*. Human Kinetics: Champaign, 1988, pp 3–8.

31 Browning LM, Hsieh SD, Ashwell M. A systematic review of waist-to-height ratio as a screening tool for the prediction of cardiovascular disease and diabetes: 0·5 could be a suitable global boundary value. *Nutr Res Rev* 2010; **23**: 247–269.

32 Cohen J, Cohen P. *Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences*. 2nd ed. Lawrence Erkbaum Associates, Inc.: Hillsdale, NJ, 1983.

33 Bosy-Westphal A, Booke CA, Blocker T *et al.* Measurement site for waist circumference affects its accuracy as an index of visceral and abdominal subcutaneous fat in a Caucasian population. *J Nutr* 2010; **140**: 954–61.

34 Mason C, Katzmarzyk PT. Variability in waist circumference measurements according to anatomic measurement site. *Obes Silver Spring* 2009; **17**: 1789–95.

35 Wang J, Thornton JC, Bari S *et al.* Comparisons of waist circumferences measured at 4 sites. *Am J Clin Nutr* 2003; **77**: 379–384.

36 Snijder MB, Visser M, Dekker JM *et al.* The prediction of visceral fat by dual-energy X-ray absorptiometry in the elderly: a comparison with computed tomography and anthropometry. *Int J Obes Relat Metab Disord* 2002; **26**: 984–93.

37 Williams PT. Physical fitness and activity as separate heart disease risk factors: a meta-analysis. *Med Sci Sports Exerc* 2001; **33**: 754–761.

FIGURE LEGENDS:

Figure 1 - Image of a DXA scan showing the abdominal region of interest (R2) defined as the area within the upper edge of the second lumbar vertebra and de lower edge of the fourth lumbar vertebra and central abdominal region of interest (R1) defined as R2 but the vertical sides limited to the continuation of the lateral sides of the ribs cage.

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)		
VO_2max, ml/kg/min	24.9 ± 6.4		13.8 – 38.0	
Type 2 Diabetes Mellitus, n (%)	8	(28.6)		
Insulin resistance, n (%)	12	(42.9)		
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	
WHtR 1 (≥0.5, %)	0.60 ± 0.07†	(96.4)	0.48 – 0.75	
WHtR 2 (≥0.5, %)	0.63 ± 0.08†	(100.0)	0.50 – 0.82	
WHtR 3 (≥0.5, %)	0.62 ± 0.08†	(96.4)	0.49 – 0.81	
WHtR 4 (≥0.5, %)	0.64 ± 0.09†	(100.0)	0.50 – 0.85	
Whole and Regional Body Composition				
BF, kg (%)	27.2 ± 9.3	(31.31 ± 8.20)	13.7 – 51.2	(18.84 – 46.28)
FFM, kg (%)	58.7 ± 9.1	(68.69 ± 8.20)	39.6 – 77.7	(53.72 – 81.16)
Trunk BF, kg (%)	15.2 ± 5.2	(33.15 ± 7.65)	7.4 – 25.0	(20.87 – 48.01)
Trunk FFM kg (%)	29.9 ± 3.9	(66.85 ± 7.65)	21.1 – 38.6	(51.99 –79.13)
Appendicular BF, kg (%)	10.8 ± 4.8	(30.42 ± 10.39)	5.2 – 25.7	(13.63 – 50.40)
Appendicular FFM, kg (%)	24.5 ± 5.1	(69.58 ± 10.39)	14.9 – 34.8	(49.60 – 86.37)
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)

CV – coefficient of variation; BMI – body mass index; WC1 – Waist circumference measured at narrowest torso; WC2 - Waist circumference measured at iliac crest; WC3 - Waist circumference measured at midpoint between lowest rib and iliac crest; WC4 - Waist circumference measured at the umbilicus; WHtR 1 – Waist-to-height ratio calculated using waist circumference measured at narrowest torso; WHtR 2 - Waist-to-height ratio calculated using waist circumference measured at iliac crest; WHtR 3 - Waist-to-height ratio calculated using waist circumference measured at midpoint between lowest rib and iliac crest; WHtR 4 - Waist-to-height ratio calculated using waist circumference measured at the umbilicus; 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 WHtR mean values, $p < 0.05$ in paired samples t-test.

Table 2. Partial and semipartial correlations between all studied waist-to-height ratios and body fat content variables.

Variables		Whole BF	Trunk BF	Abd BF	C Abd BF	Whole %BF	Trunk %BF	Abd %BF	C Abd %BF
WHtR 1	†	0.49	0.63*	0.81*	0.72*	0.51*	0.56*	0.65*	0.63*
	‡	0.41	0.58*	0.80*	0.72*	0.45	0.51*	0.66*	0.63*
	#	0.22	0.38*	0.70*	0.69*	0.22	0.32	0.54*	0.55*
WHtR 2	†	0.61*	0.73*	0.82*	0.74*	0.56*	0.59*	0.61*	0.61*
	‡	0.48	0.64*	0.84*	0.77*	0.46	0.52*	0.66*	0.63*
	#	0.26	0.43	0.74*	0.74*	0.23	0.32	0.54*	0.55*
WHtR 3	†	0.60*	0.72*	0.83*	0.74*	0.55*	0.59*	0.62*	0.61*
	‡	0.48	0.64*	0.84*	0.76*	0.46	0.52*	0.66*	0.62*
	#	0.25	0.42	0.74*	0.73*	0.22	0.32	0.54*	0.54*
WHtR 4	†	0.59*	0.68*	0.76*	0.68*	0.51	0.53*	0.56*	0.57*
	‡	0.44	0.58*	0.78*	0.71*	0.42	0.45	0.62*	0.60*
	#	0.23	0.38	0.68*	0.67*	0.20	0.27	0.49	0.50*

WHtR 1 – Waist-to-height ratio calculated using waist circumference measured at narrowest torso; WHtR 2 - Waist-to-height ratio calculated using waist circumference measured at iliac crest; WHtR 3 - Waist-to-height ratio calculated using waist circumference measured at midpoint between lowest rib and iliac crest; WHtR 4 - Waist-to-height ratio calculated using waist circumference measured at the umbilicus; BF – body fat; Trunk BF – Trunk body fat; Abd BF – Abdominal body fat; C Abd BF – Central abdominal body fat; † - partial correlations between studied WHtR and dependent variables, controlled for age and sex; ‡ - partial correlations between studied WHtR and dependent variables, controlled for age, sex and BMI; # - semipartial correlations between studied WHtR and dependent variables, adjusted for age, sex and BMI; * - significant for $p<0.05$ and $\beta=0.20$.

Table 3. Z statistic P values for the comparison between the coefficients of correlation obtained in partial and semipartial correlation between the studied waist-to-height ratios and all dependent variables.

		WHtR 1		WHtR 2		WHtR 3		WHtR 4			
		p†	p‡	p†	p‡	p†	p‡	p†	p‡		
				0.98	0.99	0.99	1.00	0.89	0.93	%BF	WHtR 1
				0.99	0.99	0.97	0.98	0.76	0.86	Trunk %BF	
				1.00	1.00	1.00	1.00	0.81	0.80	Abd %BF	
				0.98	0.99	0.99	0.99	0.86	0.84	C Abd %BF	
WHtR 2	BF	0.73	0.87			0.99	0.99	0.87	0.92	%BF	WHtR 2
	Trunk BF	0.72	0.86			0.98	0.99	0.75	0.85	Trunk %BF	
	Abd BF	0.66	0.80			0.99	1.00	0.80	0.80	Abd %BF	
	C Abd BF	0.71	0.74			0.97	0.98	0.84	0.83	C Abd %BF	
WC3	BF	0.79	0.90	0.94	0.97			0.88	0.93	%BF	WHtR 3
	Trunk BF	0.74	0.87	0.98	0.99			0.73	0.84	Trunk %BF	
	Abd BF	0.65	0.79	0.98	0.99			0.81	0.81	Abd %BF	
	C Abd BF	0.74	0.78	0.96	0.96			0.87	0.85	C Abd %BF	
WC4	BF	0.88	0.96	0.85	0.91	0.91	0.94				
	Trunk BF	0.98	0.98	0.70	0.84	0.72	0.85				
	Abd BF	0.72	0.87	0.54	0.68	0.52	0.67				
	C Abd BF	0.95	0.90	0.66	0.65	0.70	0.68				

WHtR 1 – Waist-to-height ratio calculated using waist circumference measured at minimal waist; WHtR 2 - Waist-to-height ratio calculated using waist circumference measured at iliac crest; WHtR 3 - Waist-to-height ratio calculated using waist circumference measured at midpoint between lowest rib and iliac crest; WHtR 4 - Waist-to-height ratio calculated using waist circumference measured at the umbilicus; BF – body fat; Trunk BF – Trunk body fat; Abd BF – Abdominal body fat; C Abd BF – Central abdominal body fat; † - comparison between correlation coefficients obtained in partial correlations between different WHtR and all dependent variables, controlled for age, sex and BMI; ‡ - comparison between correlation coefficients obtained in semipartial correlations between different WHtR and all dependent variables, controlling for age, sex and BMI.

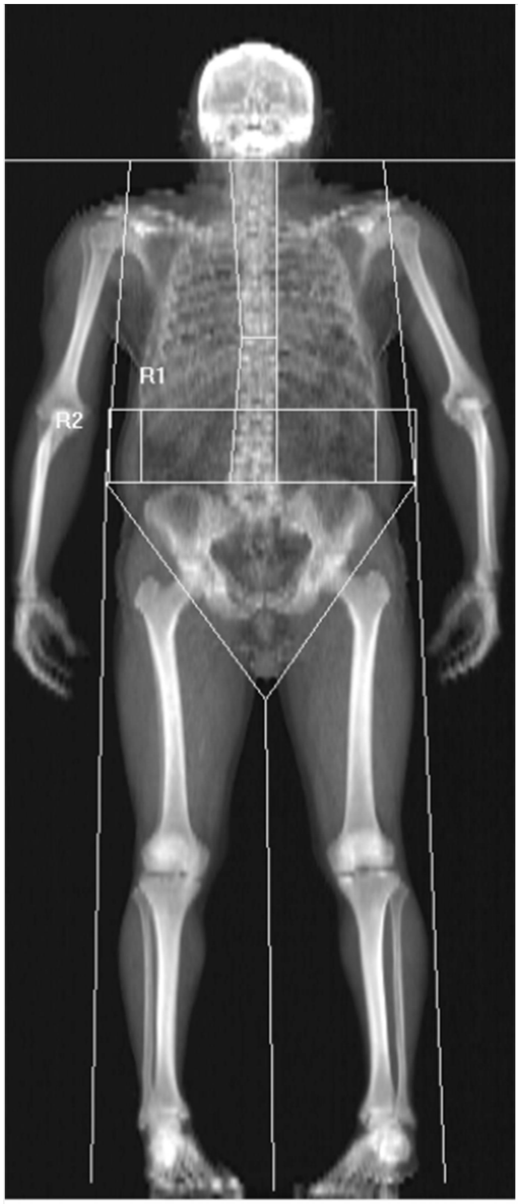

Figure 1 - Image of a DXA scan showing the abdominal region of interest (R2) defined as the area within the upper edge of the second lumbar vertebra and de lower edge of the fourth lumbar vertebra and central abdominal region of interest (R1) defined as R2 but the vertical sides limited to the continuation of the lateral sides of the ribs cage.
118x276mm (300 x 300 DPI)