



## 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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6 RESEARCH ARTICLE

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

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13 Nuno M Pimenta<sup>1,2</sup>, Helena Cortez-Pinto<sup>3</sup>, Xavier Melo<sup>1,2</sup>, José Silva-Nunes<sup>4</sup>, Luís B  
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15 Sardinha<sup>1</sup>, Helena Santa-Clara<sup>1</sup>

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18 <sup>1</sup> Exercise and Health Laboratory, Interdisciplinary Centre for the Study of Human  
19 Performance, Faculty of Human Kinetics, Technical University of Lisbon, Cruz-Quebrada,  
20 Portugal; <sup>2</sup> Sport Sciences School of Rio Maior, Polytechnic Institute of Santarém, Portugal; <sup>3</sup>  
21 Unidade de Nutrição e Metabolismo, FML, IMM. Departamento de Gastrenterologia,  
22 Hospital Universitário de Santa Maria, Lisbon, Portugal; <sup>4</sup> Curry Cabral Hospital, Lisbon,  
23 Portugal.  
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32 hepatic steatosis  
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37 **Corresponding author:** Nuno Manuel Pimenta, Sport Sciences School of Rio Maior,  
38 Polytechnic Institute of Santarém, Av. Dr. Mário Soares, 2040-413, Rio Maior, Portugal,  
39 phone: +351 243 999 280; fax: +351 243 999 292; E-mail: [npimenta@esdrm.ipsantarem.pt](mailto:npimenta@esdrm.ipsantarem.pt)  
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44 **Statement of authorship:** Nuno M Pimenta, Helena Cortez-Pinto and Helena Santa-Clara  
45 equally contributed for the conception/design of the research; Nuno M Pimenta and Xavier  
46 Melo contributed for the acquisition, analysis, and interpretation of the data; Helena Cortez-  
47 Pinto and José Silva-Nunes contributed for the acquisition of data; Helena Santa-Clara  
48 contributed for the analysis of data. Luis B Sardinha contributed for the interpretation of the  
49 data; Nuno N Pimenta drafted the manuscript; All authors critically revised the manuscript,  
50 agree to be fully accountable for ensuring the integrity and accuracy of the work, and read  
51 and approved the final manuscript.  
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3 33 **ABSTRACT**  
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5 34 **Background:** Waist-to-height ratio (WHtR) has been reported as a preferable risk related body fat  
6 (BF) marker, but no standardized waist circumference measurement protocol (WCmp) has been  
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10 36 proposed. The aim of the present study was to investigate whether the usage of different WCmp  
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12 37 affects the strength of relation between WHtR and both whole and central BF in Non-alcoholic Fatty  
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14 38 Liver Disease (NAFLD) patients.

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17 39 **Methods:** BF was assessed with Dual Energy X-ray Absorptiometry (DXA) in 28 NAFLD patients (19  
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19 40 males,  $51 \pm 13$  yrs, and 9 females,  $47 \pm 13$  yrs). All subjects also underwent anthropometric  
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21 41 evaluation including height and waist circumference (WC) measurement using four different WCmp  
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23 42 (WC1: minimal waist; WC2: iliac crest; WC3: mid-distance between iliac crest and lowest rib; WC4: at  
24  
25 43 the umbilicus) and WHtR was calculated using each WC measurements (WHtR1, WHtR2, WHtR3 and  
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27 44 WHtR4, respectively). Partial correlations were conducted to assess the relation of WHtR and DXA  
28  
29 45 assessed BF.

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33 46 **Results:** All WHtR were particularly correlated with central BF, including abdominal BF ( $r=0.80$ ;  
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35 47  $r=0.84$ ;  $r=0.84$ ;  $r=0.78$ ; respectively for WHtR1, WHtR2, WHtR3 and WHtR4) and central abdominal  
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37 48 BF ( $r=0.72$ ;  $r=0.77$ ;  $r=0.76$ ;  $r=0.71$ ; respectively for WHtR1, WHtR2, WHtR3 and WHtR4), after  
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39 49 controlling for age, sex and body mass index. There were no differences between the correlation  
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41 50 coefficients obtained between all studied WHtR and each whole and central BF variable.

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44 51 **Conclusions:** WHtR was found a suitable BF marker in the present sample of NAFLD patients and the  
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46 52 strength of the relation between WHtR and both whole and central BF was not altered by using  
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48 53 different WCmp in the present sample of NAFLD patients.  
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## 55 INTRODUCTION

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

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

85           To our knowledge it is unknown if the use of different commonly used waist  
86 circumferences, with different measuring sites, affect the relation between WHtR and both

87 whole and central BF content in NAFLD patients, and what is the independent magnitude of  
88 such relation. Therefore the aim of the present study was to find which of the most used  
89 WCmp is better to calculate WHtR for use in clinical practice with NAFLD patients as a  
90 surrogate for whole and central body fat.

## 92 **METHODS**

### 93 **Subjects:**

94 This study was conducted at Exercise and Health Laboratory, from the  
95 Interdisciplinary Centre for the Study of Human Performance (Faculty of Human Kinetics,  
96 Technical University of Lisbon, Portugal). To be selected for the present study subjects had  
97 to be over 18 years of age without history of hepatotoxic substances intake (eg. steroids)  
98 and tobacco consumption. Exclusion criteria included alcohol consumption over 20 gr/day;  
99 the presence of other potential causes for fatty liver disease, including viral hepatitis, auto-  
100 immune disease and others; any physical and/or mental disabilities or any condition that  
101 constituted an absolute restriction to exercise, or other diagnosed diseases, except for  
102 metabolic and cardiovascular disease (insulin resistance, hypertension or dyslipidemia), with  
103 mandatory specific pharmacologic therapy. We studied 28 NAFLD patients (19 males,  $51 \pm 13$   
104 yrs, and 9 females,  $47 \pm 13$  yrs) who were diagnosed through liver biopsy or ultrasound.  
105 [Cardiorespiratory fitness was assessed as described elsewhere <sup>\(20\)</sup> for characterization](#)  
106 [purposes](#). Subjects were recruited from the outpatient medical departments in Santa Maria  
107 Hospital and Curry Cabral Hospital; 59 consecutive patients were selected based on selection  
108 criteria; 37 of the selected subjects accepted to participate and 28 were found eligible to  
109 enter the study after exclusion criteria was considered. Subjects were taking one or more of  
110 the following medication: platelet inhibitors, angiotensin-converting enzyme inhibitors,  
111 nitrates, statins, ezetimibe, nicotinic acid and biguanides with similar use among both  
112 genders. All participants signed an informed consent before being included in the present  
113 study and undergoing any study procedure. All methods used in the present study complied  
114 with ethics and Portuguese laws and were approved by Faculty of Human Kinetics  
115 institutional review board for human studies.

### 116 **Body composition:**

117 Body composition was assessed using Dual Energy X-ray Absorptiometry (DXA)  
118 (Explorer W, Hologic; Waltham, MA, USA; Fan beam mode) whole body scans and

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3 119 anthropometric measurements. Repeated measurements with DXA in 18 young adults  
4 120 showed a coefficient of variation (CV) of 1.7% for total BF mass and 1.5% for total %BF. All  
5 121 scans were made in the morning after an overnight 12-hour fast. Quality control with spine  
6 122 phantom was made every morning, and with step phantom every week. By default DXA  
7 123 software (QDR for windows, version 12.4) estimates the head, trunk, arms and legs, both left  
8 124 and right, regions body composition, according to a three-compartment model (fat mass,  
9 125 lean tissue and bone mass). The trunk region of interest (ROI) (CV = 0.5%) includes chest,  
10 126 abdomen and pelvis regions from the scan <sup>(21)</sup>. All scans analysis were made by the same  
11 127 observer. All scans were submitted to additional analysis by ROI to assess fat content of the  
12 128 abdominal and central abdominal regions (CV = 1.0 %) <sup>(21)</sup>. The upper and lower limits of the  
13 129 abdominal and central abdominal ROI were determined as the upper edge of the second  
14 130 lumbar vertebra to the lower edge of the fourth lumbar vertebra, respectively <sup>(22-24)</sup>. The  
15 131 lateral limits of the abdominal ROI were determined as to include all trunk length, but  
16 132 exclude any upper limb scan area <sup>(23,24)</sup>, whereas the lateral sides of central abdominal ROI  
17 133 were the vertical continuation of the lateral sides of the ribs cage, as to exclude the lateral  
18 134 subcutaneous fat of the trunk, including however the anterior and posterior subcutaneous  
19 135 abdominal fat, as well as the intra-abdominal fat <sup>(22)</sup>, as seen in figure 1. Absolute and  
20 136 relative BF content results were registered to the nearest 0.01kg and 0.1%, respectively.

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35 137 Anthropometric measurements consisted of weight, height and body mass index  
36 138 (BMI) as well as WC and WHtR. Some standardization procedures were taken into account,  
37 139 as recommended <sup>(25)</sup>, to avoid any bias in the measurements, therefore all WC  
38 140 measurements were made with subjects in a standing comfortable position, in their  
39 141 underwear, in a 12-hour fasting state. All WC measurements were made by the same  
40 142 technician, who was a trained level 2 technician, certified by the International Society for the  
41 143 Advancement of Kinanthropometry, using an inelastic flexible metallic tape (Lufkin -  
42 144 W606PM, Vancouver, Canada) parallel to the floor after a tidal exhalation, to the nearest  
43 145 0.1cm. The WC measurement sites in the present study were the narrowest torso (WC1)  
44 146 <sup>(26,27)</sup>, also called minimal waist <sup>(19)</sup>, superior border of the iliac crest (WC2) <sup>(18,28)</sup>, midpoint  
45 147 between the lowest rib and iliac crest (WC3) <sup>(29)</sup> and umbilicus (WC4) <sup>(1,2)</sup>. These are the most  
46 148 commonly used protocols endorsed by sound authorities in this field <sup>(17,19)</sup>. Body weight was  
47 149 measured to the nearest 0.1kg, and height was measured to the nearest 0.1 cm, on a scale  
48 150 with an attached stadiometer (model 770, Seca; Hamburg, Deutschland), according to

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3 151 standard protocol <sup>(30)</sup>. Both weight and height were used to calculate the subjects' BMI, by  
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5 152 dividing the weight, in kg, by the squared height, in meters ( $BMI = \text{weight [kg]} / \text{height [m]}^2$ ).  
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7 153 WHtR was calculated by dividing each WC by the subjects' height, both in centimeters (WHtR  
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9 154 =  $WC [cm] / \text{height [cm]}$ ). Because we used four different WCmp for each subject, we  
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11 155 calculated four different WHtR using each measured WC. Therefore WHtR1, WHtR2, WHtR3  
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13 156 and WHtR4 were calculated using WC1, WC2, WC3 and WC4, respectively. We considered a  
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15 157 boundary value of 0.5 for the identification of high WHtR <sup>(9,31)</sup>. All anthropometric  
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17 158 measurements were repeated two times, and if the second differed more than 1cm (for  
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19 159 waist and height measurements) or 0,5kg (for weight measurement) from the first  
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21 160 measurement, a third measurement was carried out. We always considered the result  
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23 161 obtained in the second measurement unless a third measurement was carried out. When a  
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25 162 third measurement was taken we considered the mode or, if mode was absent, the median  
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27 163 value of all three measurements. By using this procedure we sought to always use the most  
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29 164 suitable value that was actually measured on the subjects (instead of mean values).

#### 165 **Statistical methods:**

166 Descriptive statistics are presented as mean  $\pm$  sd and range for all analyzed variables.  
167 The Gaussian distribution of the data was assessed with the Shapiro-Wilk goodness-of-fit  
168 test. Paired samples t-test was used to compare different WHtR. The association of all WHtR  
169 with DXA measures was assessed using partial and semipartial correlations <sup>(32)</sup>, controlling  
170 for age, sex and BMI. A statistical power of 80% ( $\beta = 0.20$ ) at a significance level of 5% ( $\alpha =$   
171 0.05) was considered statistically significant. Consequently, only coefficients of correlation  
172 equal or superior to 0.5, corresponding to a large effect size, attained this criteria ( $p \leq 0.05$   
173 and  $\beta \leq 0.20$ ) and could be considered significant [this is in accordance with Cohen et al.  
174 (1983) to assure that results are unexposed to type I and II errors, despite a rather modest  
175 sample size]. Pairs of coefficients of correlation obtained using different WHtR for each DXA  
176 measure were compared, using Z statistic, to find if any WHtR, according to the WC used in  
177 its calculation, was more strongly associated to whole and central BF. Statistical calculations  
178 were performed using the IBM SPSS Statistics version 19 (SPSS, inc, Chicago, IL), except for Z  
179 statistic, which was performed using Medcalc version 11.1.1.0 (MedCalc Software,  
180 Mariakerke, Belgium).

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#### 182 **RESULTS**

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3 183 Mean values for all studied variables are presented in table 1. From among the 28  
4 184 studied NAFLD patients WHtR above the boundary value of 0.5 was present in nearly 100%  
5 185 of the sample, depending on the WCmp used. Results for WC measurements were  
6 186 considered to be different between all studied WCmp (WC4>WC2>WC3>WC1) and the  
7 187 magnitude of WHtR mean values were also different according to the WC used. Obesity was  
8 188 present in 9 subjects (3 were female), according to BMI classification, with no differences  
9 189 between sexes in mean BMI ( $p=0.075$  on independent samples t test).

10 190 Table 2 shows the results for partial and semipartial correlations between each WHtR  
11 191 and each whole or central studied BF depot controlled for sex, age and BMI. All WHtR were  
12 192 correlated with the studied BF depots, even after adjusting for age, sex and BMI, showing  
13 193 coefficients of correlation magnitudes above 0.5. Coefficients of correlation tend to decrease  
14 194 as control variables were added, particularly when the effect of age, sex and BMI was  
15 195 removed, however the strength of association remained for abdominal fat depots.

16 196 Table 3 shows the results for the comparison ( $p$ -values) between pairs of competing  
17 197 WHtR coefficients of correlation with each dependent variable (listed in table 2). No  
18 198 differences were found between all compared coefficients of correlation.

## 19 199 **DISCUSSION**

20 200 To our knowledge this is the first report to focus on the strength of correlation  
21 201 between WHtR and BF in NAFLD patients, and its variation associated to different WCmp  
22 202 used to calculate WHtR. Mean WHtR was reasonably high and the prevalence of elevated  
23 203 WHtR, considering the 0.5 boundary value, was very high in the present sample. This was  
24 204 expected since it has been shown that NAFLD patients have high values of WHtR<sup>(9,10)</sup>. The  
25 205 magnitude of WHtR mean values were different according to the WC (WHtR4 > WHtR2 >  
26 206 WHtR3 > WHtR1) used in its calculus meaning they are not interchangeable. This may have  
27 207 large implications in clinical practice and data collection and interpretation in longitudinal  
28 208 assessments (pre - post) as well as between group's comparisons. Several previous studies  
29 209 have reported WC magnitudes (the changeable component of WHtR) to be influenced by  
30 210 WCmp<sup>(33-35)</sup>. Still it have been proposed that current WC thresholds, generalized using WHO  
31 211 protocol (at the midpoint between lowest rib and iliac crest), could be applied to NIH  
32 212 measurements (at the superior border of the iliac crest)<sup>(19)</sup> because of small or absent  
33 213 differences, particularly in men, found between measurements using these WCmp<sup>(34,35)</sup>. As  
34 214 mentioned, the present study does not confirm such interchangeability when absolute



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3 215 values were taken into account. However, when a dichotomous approach was applied based  
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5 216 on the boundary value of 0.5, both WHtR1 and WHtR2 only misclassified 1 subject (3,6%) at  
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7 217 elevated risk as compared to WHtR2 and WHtR4 whose diagnosed 100% of the sample  
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9 218 above the boundary value which may be considered support an interchangeable use of the  
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11 219 studied protocols for WHtR assessment.

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13 220 In the present sample of NAFLD patients, as expected, WHtR was highly associated  
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15 221 with whole and central BF, adjusted for age, sex and BMI. Correlation coefficient magnitudes  
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17 222 revealed a large effect size ( $r > 0.5$ ) for central BF depots. The association of WHtR with BC,  
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19 223 particularly with central BF, has been reported in diverse groups <sup>(7,8)</sup> but not until now in  
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21 224 NAFLD patients. WHtR was also shown to predict higher cardiometabolic risk better than WC  
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23 225 and BMI <sup>(5)</sup>. The present study showed consistent coefficients of correlation of WHtR and  
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25 226 central fat depots, even when BMI was added to age and sex as control variables, meaning  
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27 227 that WHtR explains the variation of abdominal fat far beyond BMI. This relation was already  
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29 228 found in subjects without NAFLD but with no control variables included in the analysis<sup>(15)</sup>.  
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31 229 This may explain the marginally lower correlation coefficients found in the present study.

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33 230 Comparisons between pairs of competing WHtR correlations results with each  
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35 231 dependent variable showed that all studied WHtR are similarly associated with the analyzed  
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37 232 BF depots, irrespectively of the WC used for its calculation. Previous studies have already  
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39 233 found no differences in the association of WC alone, measured at different sites, with BF  
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41 234 depots <sup>(33,35)</sup>. In a rather recent sound review it was concluded that the use of different  
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43 235 WCmp do not change the well-established relationships between WC and morbidity of  
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45 236 cardiovascular disease and diabetes and with cardiovascular and all-cause mortality <sup>(19)</sup>.  
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47 237 However since WHtR have proven more sensitive in the prediction of cardiovascular risk, the  
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49 238 absence of WCmp influence in risk prediction should be confirmed when WC is used to  
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51 239 calculate WHtR.

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53 240 There are several strengths and limitations to this study. The studied WCmp do not  
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55 241 cover all protocols existent in the literature, yet the focus was set on the most commonly  
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57 242 used and endorsed by prominent institutions for use in clinical setting <sup>(17-19)</sup>. Also the used  
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59 243 BC assessment method (DXA), a gold standard instrument to assess BC in a three  
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244 compartment model, is unable to determine visceral adiposity independently from  
245 subcutaneous fat. However there is a strong correlation between abdominal fat estimated  
246 from selected DXA ROI and visceral fat assessed by magnetic resonance imaging <sup>(23)</sup> and

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3 247 computed tomography <sup>(36)</sup>. Patients' physical activity and diet were not assessed, however  
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5 248 patients' cardiorespiratory fitness was assessed, which was low (table 1), and reinforced the  
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7 249 importance of the study of cardiovascular risk related markers in this population <sup>(37)</sup>. Finally,  
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9 250 we could not be established the usefulness of WHtR to assess changes BF depots based on  
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11 251 the present results, because we used a cross-sectional approach and therefore we have no  
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13 252 follow-up data.

14 253 The present study confirms the strong association between WHtR and BF, specially  
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16 254 central body fat, even after controlling for age, sex and BMI, in NAFLD patients, supporting  
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18 255 WHtR as an independent central obesity index. Moreover the relation between WHtR and  
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20 256 both whole and central BF was not altered by the choice for a particular WCmp in the  
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22 257 present sample of NAFLD patients. Unlike previous study in subjects without diagnosed  
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24 258 NAFLD<sup>(15)</sup>, we could not recommend the use of one specific WC measurement protocol over  
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26 259 another for the calculation of WHtR as a whole and/or central BF surrogate. Thus present  
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28 260 results may endorse an interchangeable use of different WCmp to identify subject's WHtR  
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30 261 above boundary value. Additional research is needed to confirm the influence of different  
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32 262 WCmp on the variation of WHtR in specific sub-populations and on the relation between  
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34 263 WHtR and other NAFLD and Cardiometabolic risk factors beyond body composition alone.

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#### 36 265 **CONFLICT OF INTEREST**

37 266 The authors declare no conflict of interest.

38 267

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3 378 **FIGURE LEGENDS:**

4 379 **Figure 1** - Image of a DXA scan showing the abdominal region of interest (R2) defined as the  
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7 380 area within the upper edge of the second lumbar vertebra and de lower edge of the fourth  
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9 381 lumbar vertebra and central abdominal region of interest (R1) defined as R2 but the vertical  
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For Peer Review

## TABLES:

Table 1. Descriptive data of the studied sample.

Variables	NAFLD Patients (n=28)	
	Mean ± sd *	Min. – Max.
Age, yr (median, yr)	49.5 ± 12.8 (49)	25 – 68
Sex, n female (% female)	9 (32.1)	
VO <sub>2</sub> max, 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)	
<b>Anthropometry</b>		
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 <sup>2</sup> (% 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
<b>Whole and Regional Body Composition</b>		
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
<b>WHtR 1</b>	†	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*
<b>WHtR 2</b>	†	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*
<b>WHtR 3</b>	†	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*
<b>WHtR 4</b>	†	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 <sup>†</sup>	p <sup>‡</sup>	p <sup>†</sup>	p <sup>‡</sup>	p <sup>†</sup>	p <sup>‡</sup>	p <sup>†</sup>	p <sup>‡</sup>		
				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.

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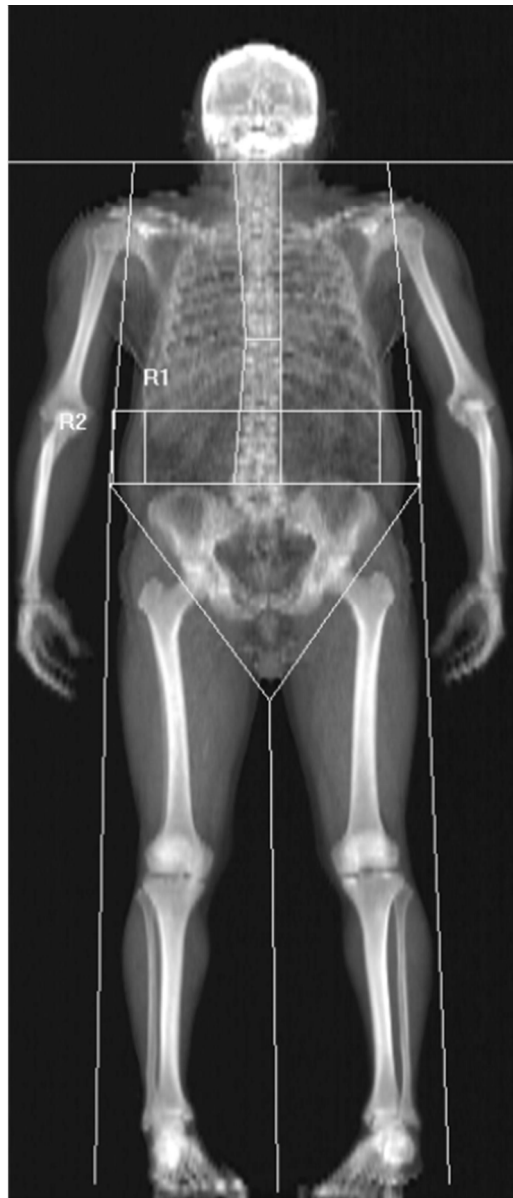


Figure 1 - Image of a DXA scan showing the abdominal region of interest (R2) defined as the area within the upper edge of the second lumbar vertebra and de lower edge of the fourth lumbar vertebra and central abdominal region of interest (R1) defined as R2 but the vertical sides limited to the continuation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