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1 **Correlates of overall and central obesity in adults from seven European countries: Findings from the Food4Me**
2 **Study**

3 **Running title:** Correlates of obesity

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42   **Background/Objectives:** To identify predictors of obesity in adults and investigate to what extent these predictors

43   are independent of other major confounding factors.

44   **Subjects/Methods:** Data collected at baseline from 1,441 participants from the Food4Me study conducted in seven

45   European countries were included in this study. A food frequency questionnaire was used to measure dietary intake;

46   Accelerometers were used to assess physical activity levels (PA), whereas participants self-reported their body

47   weight, height and waist circumference via the internet.

48   **Results:** The main factors associated ($p < 0.05$) with higher BMI per 1-SD increase in the exposure were age (β:1.11

49   kg/m^2), and intakes of processed meat (β:1.04 kg/m^2), red meat (β:1.02 kg/m^2), saturated fat (β:0.84 kg/m^2),

50   monounsaturated fat (β:0.80 kg/m^2), protein (β:0.74 kg/m^2), total energy intake (β:0.50 kg/m^2), olive oil (β:0.36

51   kg/m^2), sugar sweetened carbonated drinks (β:0.33 kg/m^2) and sedentary time (β:0.73 kg/m^2). In contrast, the main

52   factors associated with lower BMI per 1-SD increase in the exposure were PA (β:-1.36 kg/m^2), and intakes of

53   wholegrains (β:-1.05 kg/m^2), fibre (β:-1.02 kg/m^2), fruits and vegetables (β:-0.52 kg/m^2), nuts (β:-0.52 kg/m^2),

54   polyunsaturated fat (β:-0.50 kg/m^2), Healthy Eating Index (β:-0.42 kg/m^2), Mediterranean diet score (β:-0.40 kg/m^2),

55   oily fish (β:-0.31 kg/m^2), dairy (β:-0.31 kg/m^2) and fruit juice (β:-0.25 kg/m^2).

56   **Conclusions:** These findings are important for public health and suggest that, promotion of increased PA, reduced

57   sedentary behaviours and improving the overall quality of dietary patterns are important strategies for addressing

58   the existing obesity epidemic and associated disease burden.

59   **Key Words –** Obesity; physical activity, diet, healthy eating index, Mediterranean diet.

60   **Trial registration** – Clinicaltrials.gov NCT01530139

INTRODUCTION

62 Excess adiposity, represented by high body-mass index (BMI) and waist circumference (WC), is a known risk factor

63 for cardiovascular diseases , some cancers, and premature mortality.[1] A recent study conducted in more than 19.2

64 million adult worldwide provided evidence that obesity is a growing pandemic, with the prevalence of obesity having

65 increased from 3.2% in 1975 to 10.8% in 2014 in men, and from 6.4% to 14.9% in women.[2] Concerns regarding the

66 health and economic burden of growing obesity rates have led to adiposity being included among the global non-

67 communicable disease (NCD) goals.[2]

68 Changes in lifestyle related to energy balance, including insufficient levels of physical activity (PA) and higher energy

69 intake have been proposed as the main driving force behind the rise in obesity over recent decades.[3, 4] The processes

70 of modernization, urbanization and globalisation of eating behaviours have affected dietary intake and PA patterns

71 and have subsequently contributed to the development of obesity.[5] Thus, a detailed understanding of the

72 behavioural factors associated with obesity is essential for the design and implementation of effective public health

73 interventions aimed to prevent or manage obesity.

74 The present study uses baseline data from the Food4Me study, a pan-European randomized controlled trial,

75 designed to investigate the effect of personalized nutrition (PN) advice on changes in diet and PA after a 6-month

76 intervention.[6, 7] Our study aims to identify predictors of obesity in European adults and to investigate to what extent

77 these predictors are independent of other major confounding factors.

78

79 **MATERIALS AND METHODS**

80 **Study population**

81 The Food4Me Proof of Principle (PoP) study was a 6-month, internet-based, randomised controlled trial (RCT)

82 conducted across seven countries in Europe (www.food4me.org).[6, 7] Out of 5,662 individuals who were interest in

83 this trial (mean age 40 (SD: 12.7); range 15-87 years) between August 2012 and August 2013, the first 1,441

84 volunteers meeting the inclusion criteria and with available data for the analysis were included in the present study.

85 Participants were recruited from the following recruitment sites: Maastricht University (The Netherlands), University

86 College Dublin (Ireland), University of Navarra (Spain), University of Reading (United Kingdom, UK), Harokopio

87 University (Greece), Technical University of Munich (Germany) and National Food and Nutrition Institute (Poland),

88 were included in the study. Participants aged <18 years, pregnant or lactating, with limited access to the Internet,

89 follow a prescribed diet for any reason were excluded from the study. The Research Ethics Committees at each

90 Research Centre granted ethics approval for the study.

91

92 **Study measures**

93 Participants agreed to self-report their measures via the internet. To ensure that procedures were comparable in all

94 recruiting centres, standardised operating procedures were arranged for all measurements.[6, 7]

95 An online screening questionnaire collected detailed self-reported (SR) information on socio-demographic, dietary,

96 food choices, anthropometric and health-related data. At baseline, anthropometric measures were self-measured

97 and self-reported via the internet. Participants were instructed to measure body weight after an overnight fast,

98 barefoot and wearing light clothing using a commercial or home scale, and to measure height using a measuring

99 tape provided by Food4Me study.[6, 7] Waist circumference (WC) was measured at the mid-point between the lower

100 rib and the iliac crest. Central obesity was set as WC >102 cm and >88 cm for men and women, respectively. BMI

101 was calculated from body weight divided by height square. The WHO criteria for BMI was used to define nutritional

102 status (underweight <18.5, normal weight ≥18.5 to ≤24.9, overweight ≥25.0to ≤29.9 and obese ≥30.0 kg/m^2).[8] These

103 self-reported measurements were repeated in a random sub-sample of 140 participants who were invited to

104 participate in a validation study, these results are described in supplementary methods and elsewhere. [9]

105 Occupational activities were grouped according to the European classifications a) professional and managerial, b)

106 intermediate, c) routine and manual, d) service and sales workers, e) elementary occupations, f) students and g)

107 retired.[10]

108 Objective physical activity levels (PAL= total energy expenditure / basal metabolic rate) and time spent in sedentary-

109 related behaviours (min/day) were assessed using triaxial accelerometers (TracmorD, Philips Consumer Lifestyle, The

110 Netherlands). Participants were instructed to wear the accelerometer every day during waking hours, apart from

111 when taking a shower, for the entire duration of the study. Intensities of PA were derived using thresholds for

112 activity energy expenditure for sedentary behaviours (corresponding to <1.5 METs), light (1.5 to <3 METs), moderate

113 (3 to <6 METs), vigorous (≥6 METs) or moderate-equivalent intensity PA.[11] Moderate-equivalent PA was derived

114 using the equation [moderate PA + (vigorous PA x 2)]. Individuals who accumulated ≥150 minutes of moderate-

115   equivalent PA a week were classified as physically active.[11] Additional information on physical activity measure is

116   provided in supplementary material.

117   At baseline, participants completed an online Food frequency questionnaire (FFQ) to estimate usual dietary intake

118   during the last month. This FFQ, was developed for the Food4Me Study[12, 13] and included 157 food items consumed

119   frequently in each of the seven recruitment countries. The reproducibility and validity of the FFQ was assessed and

120   these details are reported in our Supplementary Methods and elsewhere.[14, 15] Intakes of foods and nutrients were

121   computed in real time using a food composition database based on McCance & Widdowson's "The composition of

122   foods".[16] Intakes were assessed using a standardized set of recommendations[17] for foods and food groups including

123   fruit and vegetable, wholegrain products, dairy products, oily fish, red meat, processed meat, fats and spreads, fruit

124   juice, sugar sweetened carbonated drinks, sweets and pastries, nut, vegetable oil and olive oil.[17]

125   Furthermore, two healthy eating scores were derived to measure the overall diet quality. The first one, adherence to

126   the Mediterranean diet (MD) was estimated based on the PREDIMED 14-point criteria[18] (Supplemental Table 1).

127   FFQs at baseline were used to derive each of the following criteria: higher intake of olive oil than other culinary fat,

128   higher intake of white meat than red meat, high intake of fruit (including natural fruit juice), vegetables, olive oil,

129   legumes, nuts, fish, wine and tomato-based sauces and limited intakes of red and processed meats, fats and

130   spreads, soft drinks and commercial bakery goods, sweets and pastries.[18] Participants scored 1 point for each of the

131   14 criterion they met and 0 for each they did not meet; points were summed to create an overall MD score, ranging

132   from 0-14.[18]

133   The second diet quality score was derived using the Healthy Eating Index (HEI), which was updated and validated to

134   reflect the 2010 Dietary Guidelines for Americans and the accompanying USDA Food Patterns.[19] The HEI-2010

135   includes 12 food groups, 9 of which assessed adequacy of the diet, including 1) total fruit; 2) whole fruit; 3) total

136   vegetables; 4) greens and beans; 5) whole grains; 6) dairy; 7) total protein foods; 8) seafood and plant proteins; and

137   9) fatty acids. The remaining three factors, refined grains, sodium, and empty calories (i.e., energy from solid fats,

138   alcohol, and added sugars), assess dietary components that should be consumed in moderation. Higher scores

139   reflected better diet quality. Scores for each of the 12 items are summed to produce a total score with a maximum

140   value of 100.[19]

141   **Statistical analysis**

142 Multivariate Linear Regression analyses were performed to test for associations between the outcomes (BMI and

143 WC) and the exposures of interest, including age, physical activity and dietary intake. For comparison purposes, all

144 continuous exposures were standardised and presented as standard deviation (SD) units. The odds for overweight

145 and obesity (BMI ≥25.0 kg/m^2) and central obesity (WC >88 and >102 cm for women and men, respectively) were

146 estimated by socio-demographics, PA and dietary intake variables. Tertiles for each of these continuous variables

147 were derived using the standardised variables.

148 Analyses were adjusted incrementally. Model 1 was adjusted for age, sex, country and occupation, whereas Model 2

149 was additionally adjusted for total time spent in sedentary behaviours and total PA for dietary outcomes, and

150 monitor wearing time and total energy intake for physical activity outcomes. Total energy intake was included in

151 model 2 for PA exposures to elucidate whether the association between PA and our outcomes of interest goes

152 beyond an effect of total energy intake. Data were analysed using Stata (version 14; StataCorp. TX, USA). Results

153 were deemed significant at *P-value* <0.05.

154

155 **RESULTS**

156 **Cohort characteristics**

157 Of the 1,607 participants randomised into the Food4Me trial, data at baseline on BMI were available for 1,441

158 participants (58% were women and 97% were Caucasian), characteristics of the drop outs have been described

159 elsewhere [20]. As summarised in Table 1, the mean age was 40.1 years (range: 18 to 79), 30% of individuals were

160 overweight and 16% were obese. Although 47% of participants where classified as physically active, 28% of

161 participants recorded less than 1 minute of vigorous intensity PA daily. Dietary intakes of nutrients and food groups

162 and diet quality scores by BMI and WC categories are described in Tables 1 and Table S2.

163

164 **Association of BMI and WC with socio-demographic, dietary and physical activity factors**

165 As presented in Table 2, the main factors associated with higher BMI per 1-SD increase in the exposure or

166 independent variable were age (β:1.11 kg/m^2), and intakes of processed meat (β:1.04 kg/m^2), red meat (β:1.02

167 kg/m^2), saturated fat (β:0.84 kg/m^2), monounsaturated fat (β:0.80 kg/m^2), protein (β:0.74 kg/m^2), total energy

168 (β:0.50 kg/m^2), olive oil (β:0.36 kg/m^2), sugar sweetened carbonated drinks (β:0.33 kg/m^2) and time spent sedentary

169   (β:0.73 kg/m^2). In addition, total sugars intake was negatively associated with WC (β:-1.03 kg/m^2 per 1-SD increase in

170   total sugars intake).

171

172   The main factors associated with BMI per 1-SD increase in the exposure were moderate-equivalent PA (β:-1.36

173   kg/m^2), light PA (β:-0.77 kg/m^2), and intakes of wholegrains (β:-1.05 kg/m^2), fibre (β:-1.02 kg/m^2), fruits and

174   vegetables (β:-0.52 kg/m^2), nuts (β:-0.52 kg/m^2), polyunsaturated fat (β:-0.50 kg/m^2), HEI (β:-0.42 kg/m^2), MD score

175   (β:-0.40 kg/m^2), oily fish (β:-0.31 kg/m^2), dairy products (β:-0.31 kg/m^2) and fruit juice (β:-0.25 kg/m^2). As

176   summarised in Table 2, these associations were independent of sex, occupation and country (Model 1), as well as

177   total PA, sedentary behaviours, total energy intake and total accelerometer wear time. Similar results were found

178   for WC (Table 3), although the magnitudes of the associations per 1-SD increase in the exposure were stronger than

179   for BMI (Table 2).

180

181   **Correlates of overall and central obesity**

182   Figure 1 describes the odds ratio of being overweight or obese (BMI ≥25.0 kg/m^2) and centrally obese (WC >88 cm

183   for females and >102 cm for males). Participants in the highest tertile for moderate-equivalent PA (highly active)

184   were 80% less likely to have a BMI≥25.0 kg/m^2 compared with those in the lowest tertile (less active). Similarly,

185   younger participants were 71% less likely to have BMI ≥25.0 kg/m^2 than older participants (higher tertile). Those

186   participants who were female, students, from Germany and the Netherlands, and those in the lowest tertile for

187   sedentary behaviour, light intensity PA or total PA, were less likely to be overweight or obese compared with their

188   reference group (Figure 1). Similar results, but with stronger effect sizes, were observed when central obesity was

189   used as the outcome (Figure 1).

190

191   When nutrients intake were used as main exposures (Figure 2), participants in the lowest tertile for

192   monounsaturated, saturated and total fats, salt and total energy intake were less likely to have a BMI ≥25.0 kg/m^2

193   than their counterparts in the higher tertile. In contrast, individuals in the lowest tertile for polyunsaturated fat and

194   vegetable oil intake were more likely to have a BMI ≥25.0 kg/m^2 compared with participants in the highest tertile

195   (Figure 2 and Table S3). Similarly, central obesity was less likely among those with lowest intakes of protein,

196   carbohydrates, monounsaturated fat, and salt. However, individuals in the lower tertile for sugar intake were more

197 likely to have central obesity (Figure 2). The odds of having BMI ≥25.0 kg/m^2 or central obesity by food group are

198 presented in Figure 3.

199

200 **Discussion**

201 Our main findings are the associations between intakes of nutrients and of healthy and unhealthy foods as well as

202 healthy eating score with markers of overall and central obesity in adults from seven European countries. Our study

203 found that the strongest positive correlates with adiposity were age and reported intakes of processed meat, red

204 meat or saturated fat (effect size ranging from 1.11 to 0.84 kg/m^2 per 1-SD increase in the exposure), whereas the

205 strongest negative correlates of adiposity were moderate-equivalent PA, and reported intakes of wholegrain or

206 dietary fibre intake, with effect sizes ranging from -1.36 to -1.02 kg/m^2 change in BMI and -3.76 to -0.75 cm change

207 in WC per 1-SD increase in these exposures. These observations may have important implications for the design of

208 future studies aiming to reduce body weight or related adiposity outcomes, by focussing on key lifestyle behaviours

209 that are associated with obesity.

210 Our findings corroborate, and provide new evidence, for associations between PA and obesity outcomes. A recent

211 systematic review that have investigated the association between weight gain with physical activity have reported

212 that physical activity levels that increase the total energy expenditure to > 1.7–1.8 times the basal metabolic rate are

213 needed to decrease obesity risk.[21, 22] This is in agreement with our finding where the magnitude of the effect of PA

214 on obesity outcomes, especially for WC, was greater with higher intensity levels of physical activity (1 SD increase in

215 light, moderate and vigorous intensity PA was associated with -1.70, -1.96 and -2.63 cm lower WC, respectively). In

216 addition, our results confirm previous findings that time spent in sedentary behaviours is associated with increased

217 body weight and risk of obesity, independent of PA levels.[23]

218 Although unhealthy dietary patterns have been associated with obesity, there is inconsistency in the evidence about

219 the role of specific food groups.[24] Our study found that reported intakes of processed and red meat were associated

220 with increased adiposity and obesity risk, independent of other confounding factors including total energy intake,

221 total sugars, sedentary behaviour and physical activity. This is in agreement with previous studies showing that both

222 red meat and processed meat, which have been linked to higher intake of total fat, saturated fat and energy dense

223 food and lower intake of healthy foods such as vegetables, are positively associated with increased risk of obesity.[25]

224 Our findings shows a strong association between fat intake (total, mono and saturated fats) and obesity risk, which

225 is in agreement with a recent review on the effect of reduced fat intake on body weight, which include data from 32

226 trials (approximately 54,000 participants) and from 25 cohort studies.[26] This study reported that eating less fat (diet

227 containing <30% of TE from fat compared with usual diet) reduced mean BMI by -0.5 kg (95% CI: -0.74 to -0.26

228 kg/m^2), with greater weight loss resulting from greater fat reductions.[26] These finding may have important clinical

229 implications since reduced saturated fat intake is associated with a 17% reduction in the risk of cardiovascular

230 disease.[27] Our results are also in agreement with previous studies showing negative associations between intakes of

231 dietary fibre,[28] wholegrains[29] and fruits and vegetable[30] with obesity.

232 Interestingly, total sugar intake was inversely associated with BMI and WC independent of intakes of total energy

233 and of other macronutrients including total fat, as has been reported in the UK Biobank study.[31] However, intakes of

234 sugar sweetened carbonated drinks were positively associated with BMI, WC and obesity risk. There was a similar

235 positive association between intakes of sweets and pastries and obesity risk. This is in agreement with a systematic

236 review which found that sugar sweetened carbonated drinks and sweets snacking were associated with increased

237 obesity risk.[32] The inverse association between sugar intake and obesity may seem counter-intuitive; however, this

238 association may be explained by self-reporting bias, with previous studies suggesting that it may be easier for

239 individuals to report intake of food items (i.e. fizzy drinks, chocolate, etc.) than total sugar intake.[33] The UK's

240 Scientific Advisory Committee on Nutrition concluded that there is a lack of high quality scientific evidence to draw

241 conclusions on the impact of sugars intake on body weight in adults.[34]

242 Although we identified associations between adiposity outcomes and intakes of individual macronutrients or food

243 groups, dietary behaviours may be better captured by using an overall estimation of dietary quality, as dietary

244 patterns correlate more strongly with adiposity and the risk of obesity.[35, 36] Our results agree with previous

245 prospective studies which have reported inverse associations between obesity and overall MD scores.[35, 37, 38] Such

246 inverse associations have also been reported in most,[39-43] but not all,[44] cross-sectional studies. However, our study

247 have found that olive oil consumption, an essential component of the Mediterranean diet, was associated with

248 higher adiposity levels whereas a lower vegetable oil intake was associated a lower risk for obesity. The HEI has been

249 inversely associated with the likelihood of being overweight or obesity.[45]

250

251 **Strengths and limitations**

252 We have collected data from adults aged 18-79 years resident in seven European countries. Just 44.8% of

253 participants had a BMI >25 kg/m^2 which is broadly similar to that of European adults.[46] However, our recruitment

254 strategy was not designed specifically to yield a sample that is necessarily representative of the European adult

255 population,[47] and so that findings with respect to the European population as a whole should be interpreted

256 cautiously. Physical activity data were collected objectively using a triaxial accelerometer which is likely to provide a

257 better estimation of the true relationship with obesity than use of self-report instruments. A potential limitation of

258 the study is that the majority of our data were collected by self-report via the internet, which could have introduced

259 recall bias and measurement error.[48] Although, the precision self-reported anthropometric data collected via the

260 internet is high[49] we cannot rule out a potential dilution bias due under-reporting of BMI, especially by those who

261 were obese. The current study used cross-sectional data, which cannot provide evidence of causal relationships

262 between dietary patterns or other behavioural factors and obesity outcomes.

263

264 In conclusion, healthy diet scores such as MD and HEI as well as food groups, nutrients and physical activity related

265 behaviours were robustly associated with BMI and WC in adults from seven European countries. Our results show

266 that higher levels of PA and higher diet quality attenuate, while more time spent in sedentary behaviours and higher

267 consumption of processed meat, red meat and fats accentuate associations with BMI and WC. These findings are

268 relevant for public health and suggest that promotion of increased PA, reduced sedentary behaviours and improved

269 overall quality of dietary patterns is a key strategy for addressing the existing obesity epidemic and associated

270 disease burden.

275

276 **CONFLICT OF INTEREST**

277 The authors declare no conflict of interest.

278

279 **AUTHOR CONTRIBUTION**

280 Author responsibilities were as follows: CCM, KML, AA, JCM performed the statistical analysis and wrote the

281 manuscript. YM, IT, CAD, ERG, LB, JAL, JAM, WHS, HD, MG and JCM contributed to the research design. JCM was the

282 Food4Me Proof of Principle study leader. CCM, CFMM, HF, CBO, CW, ALM, RF, SNC, RSC, CPL, MG, MCW, ERG, LB

283 and JCM contributed to the developing the Standardized Operating Procedures for the study. CCM, SNC, RSC, CW,

284 CBO, HF, CFMM, AM, RF, CPL, MG, IT, MCW and JCM conducted the intervention. CCM, CFMM and WHS contributed

285 to physical activity measurements.

286

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481 **Figures Legends**

482 **Figure 1. Odds ratios for overall and central obesity by socio-demographic and physical activity**

483 Data presented as adjusted odds ratio and 95% CI. Models were adjusted for age, sex, country and occupation.
484 Physical activity-related exposures were additionally adjusted for total energy intake and wearing time. Physical
485 activity related variables are presented as tertiles. The lowest tertile (Least active) was used as the reference group,
486 except for sedentary behaviour where the highest tertile was used as the reference category. Overweight or obesity
487 was defined as BMI ≥25.0 kg/m^2 and central obesity was defined as waist circumference >88 cm for females and
488 >102 cm for males. PA: physical activity.

489

490 **Figure 2. Odds ratios for overall and central obesity by tertile of nutrients intake**

491 Data presented as adjusted odds ratio and 95% CI. Models were adjusted for age, sex, country and occupation.
492 Dietary fibre and salt were additionally adjusted for total energy intake. All exposures are presented as tertile. The
493 highest tertile (highest intake) was used as reference group, except for dietary fibre, where the lowest tertile (lowest
494 intake) was used as reference group. Overweight or obesity was defined as BMI ≥25.0 kg/m^2 and central obesity was
495 defined as waist circumference >88 cm for females and >102 cm for males.

496

497 **Figure 3. Odds ratios for overall and central obesity by tertile of food groups and diet quality score**

498 Data presented as adjusted odds ratio and 95% CI. Models were adjusted for age, sex, country, occupation and total
499 energy intake. All exposures are presented as tertiles. Overweight or obesity was defined as BMI ≥25.0 kg/m^2 and
500 central obesity was defined as waist circumference >88 cm for females and >102 cm for males.

Table 1. Socio-demographic, physical activity and dietary characteristics by BMI status

	Overall	Normal weight	Overweight	Obese
N	1441	759	448	234
Age (Years), mean (SD)	40.1 (12.0)	36.9 (13.0)	43.0 (12.3)	44.7 (11.4)
Age categories, n (%)				
<30 years	407 (28.2)	295 (38.8)	84 (18.8)	28 (12.0)
30-50 years	643 (44.6)	313 (41.2)	213 (47.5)	117 (50.0)
51-70 years	382 (26.5)	145 (19.1)	150 (33.5)	87 (37.2)
>70 years	9 (0.6)	6 (0.8)	1 (0.2)	2 (0.9)
Gender, n (%)				
Females	832 (57.7)	484 (58.2)	213 (25.6)	135 (16.2)
Males	609 (42.3)	275 (45.1)	235 (38.6)	99 (16.3)
Country, n (%)				
Germany	204 (14.2)	126 (16.6)	59 (13.2)	19 (8.12)
Greece	209 (14.5)	91 (12.0)	74 (16.5)	44 (18.8)
Ireland	208 (14.4)	108 (14.2)	63 (14.1)	37 (15.8)
Netherlands	210 (14.6)	125 (16.5)	58 (13.0)	27 (11.5)
Poland	194 (13.5)	107 (14.1)	54 (12.1)	33 (14.1)
Spain	211 (14.6)	85 (11.2)	83 (18.5)	43 (18.4)
UK	205 (14.2)	117 (15.4)	57 (12.7)	31 (13.3)
Job classification, n (%)				
Professional	569 (39.5)	303 (40.0)	172 (38.4)	94 (40.2)
Intermediate	377 (26.2)	176 (23.3)	133 (29.7)	68 (29.1)
Manual	140 (9.73)	62 (8.1)	51 (11.4)	27 (11.5)
Student	207 (14.4)	162 (21.4)	36 (8.0)	9 (3.8)
Retired/Unemployed	146 (10.2)	54 (7.1)	56 (12.5)	36 (15.4)
Anthropometrics				
Body weight (Kg)	75.3 (15.)	65.4 (9.3)	80.9 (9.5)	96.7 (13.5)
Height (m)	1.7 (0.1)	1.7 (0.1)	1.7 (0.1)	1.7 (0.1)

BMI (kg/m^2)	25.7 (4.7)	22.2 (1.7)	27.2 (1.4)	33.7 (4.2)
Waist circumference (cm)	86.2 (13.6)	77.4 (8.1)	91.3 (8.5)	105.2 (10.8)
Central obesity, n (%)	359 (25.0)	19 (2.5)	128 (28.7)	212 (90.6)
Physical activity				
PAL	1.7 (0.1)	1.7 (0.2)	1.7 (0.1)	1.6 (0.1)
Light PA (min/day)	73.8 (30.3)	78.7 (30.7)	71.9 (29.8)	61.9 (26.0)
Moderate PA (min/day)	33.1 (20.2)	37.7 (19.4))	30.0 (19.8)	24.3 (19.2)
Vigorous PA (min/day)	11.8 (16.2)	15.4 (18.5)	9.30 (12.7)	4.61 (8.7)
Moderate-equivalent PA (min/day)	56.7 (44.9)	68.6 (48.2)	48.6 (38.4)	33.5 (30.7)
Sedentary behaviour (min/day)	745 (76.8)	729 (71.7)	754 (77.1)	777 (79.3)
Physically active, n (%)	587 (47.0)	380 (57.6)	157 (41.3)	50 (23.9)
Nutrients Intake				
Total energy (Kcal)	2563 (1091)	2450 (991)	2566 (1065)	2922 (1349)
Protein (% of TE)	17.1 (3.7)	16.8 (3.5)	17.4 (4.0)	17.5 (3.7)
Total fat (% of TE)	35.9 (5.8)	35.4 (5.8)	36.2 (5.9)	37.1 (5.6)
Saturated fat (% of TE)	14.2 (3.1)	13.9 (3.1)	14.3 (3.1)	14.6 (3.1)
Polyunsaturated fat (% of TE)	5.73 (1.4)	5.7 (1.5)	5.6 (1.3)	5.87 (1.4)
Monounsaturated fats (% of TE)	13.8 (3.1)	13.4 (2.9)	14.0 (3.3)	14.4 (2.9)
Carbohydrates (% of TE)	45.9 (7.5)	46.8 (7.5)	44.8 (7.5)	44.8 (7.2)
Total Sugar (% of TE)	21.0 (5.9)	21.6 (5.8)	20.7 (5.9)	19.8 (5.9)
Alcohol (% of TE)	3.31 (3.8)	3.1 (3.3)	3.8 (4.4)	2.8 (3.7)
Dietary fibre (g/day)	29.8 (14.7)	30.5 (15.8)	28.1 (13.1)	30.6 (13.6)
Salt (g/day)	7.3 (3.7)	7.0 (3.5)	7.2 (3.2)	8.8 (4.7)
Food groups intake				
Fruit and vegetables (g/day)	597 (370)	613 (382)	581.7 (353)	576 (364)
Wholegrains (g/day)	167 (174)	190 (196)	141.5 (139)	145 (145)
Red meat (g/day)	79.0 (74.7)	65.6 (64.8)	85.0 (63.1)	111 (107)
Oily fish (g/day)	21.2 (26.4)	21.5 (28.0)	21.3 (25.7)	20.0 (22.4)
Dairy (g/day)	326 (265)	334 (272)	311.7 (232)	329 (299)

Fruit juice (g/day)	62.4 (61.0)	63.9 (61.2)	62.6 (60.3)	57.4 (61.4)
Processed meat (g/day)	83.6 (77.5)	69.5 (68.9)	89.7 (65.1)	117 (108)
Sugar sweetened carbonated drinks (g/day)	33.1 (129)	27.3 (98.2)	32.5 (79.4)	53.3 (244)
Sweets and pastries (g/day)	94.2 (109)	81.0 (78.5)	99.1 (118)	127.1 (159)
Nuts (g/day)	94.2 (109)	5.9 (11.6)	4.6 (7.2)	4.5 (9.7)
Olive oil (g/day)	7.9 (10.3)	6.8 (8.1)	8.6 (12.8)	10.0 (11.1)
Vegetable oil (g/day)	1.6 (3.4)	1.7 (3.6)	1.3 (3.4)	1.7 (3.4)
Diet quality index				
HEI score	49.3 (9.8)	50.2 (9.4)	48.8 (10.2)	47.1 (9.8)
MD score	5.1 (1.6)	5.2 (1.6)	5.0 (1.7)	4.9 (1.7)

Data presented as mean (SD) for continuous variables or numbers (%) for categorical variables.
HEI: healthy eating index; MD: Mediterranean diet; PA: physical activity, TE: total energy; PAL: physical activity levels.

Table 2. Associations between BMI and socio-demographic, physical activity and diet-related characteristics.

Standardised variables	Model 1			Model 2	
	Beta (95%CI)	P-value		Beta (95%CI)	P-value
Socio-demographic					
Age	1.33 (1.09 to 1.57)	<0.0001		1.11 (0.85 to 1.36)	<0.0001
Physical activity					
PAL	-0.65 (-0.90 to -0.40)	<0.0001		-0.43 (-0.69 to -0.16)	0.002
Light PA	-0.95 (-1.20 to -0.71)	<0.0001		-0.77 (-1.03 to -0.52)	<0.0001
Moderate PA	-1.22 (-1.47 to -0.97)	<0.0001		-1.06 (-1.34 to -0.78)	<0.0001
Vigorous PA	-1.23 (-1.48 to -0.97)	<0.0001		-1.04 (-1.31 to -0.77)	<0.0001
Moderate-equivalent PA	-1.48 (-1.73 to -1.22)	<0.0001		-1.36 (-1.64 to -1.07)	<0.0001
Sedentary behaviour	0.90 (0.64 to 0.15)	<0.0001		0.73 (0.46 to 1.00)	<0.0001
Nutrients					
Total energy	0.61 (0.37 to 0.86)	<0.0001		0.50 (0.25 to 0.76)	<0.0001
Protein*	0.64 (0.40 to 0.88)	<0.0001		0.74 (0.21 to 1.27)	0.006
Total fats*	0.70 (0.46 to 0.94)	<0.0001		0.84 (0.07 to 1.61)	0.032
Saturated fat*	0.58 (0.34 to 0.82)	<0.0001		0.26 (-0.08 to 0.62)	0.134
Polyunsaturated fat*	-0.03 (-0.27 to 0.21)	0.826		-0.43 (-0.71 to -0.15)	0.002
Monounsaturated fats*	0.89 (0.66 to 01.13)	<0.0001		0.80 (0.52 to 1.09)	<0.0001
Carbohydrates*	-0.75 (-0.99 to -0.52)	<0.0001		0.28 (-0.65 to 1.20)	0.559
Total Sugar*	-0.62 (-0.85 to -0.38)	<0.0001		-0.23 (-0.51 to 0.05)	0.108
Alcohol*	-0.18 (-0.43 to 0.06)	0.139		0.20 (-0.35 to 0.74)	0.479
Dietary fibre*[†]	-0.33 (-0.57 to -0.09)	0.006		-1.02 (-1.41 to -0.62)	<0.0001
Salt*[†]	0.67 (0.43 to 0.91)	<0.0001		0.49 (-0.05 to 1.04)	0.080
Food groups					
Fruit and vegetables[†]	-0.42 (-0.66 to -0.19)	<0.0001		-0.52 (-0.79 to -0.26)	<0.0001
Wholegrains[†]	-0.70 (-0.93 to -0.47)	<0.0001		-1.05 (-1.32 to -0.78)	<0.0001
Red meat[†]	1.14 (0.90 to 1.38)	<0.0001		1.02 (0.76 to 1.28)	<0.0001

Oily fish[‡]	-0.21 (-0.45 to 0.04)	0.096	-0.31 (-0.56 to -0.05)	0.017
Dairy[‡]	0.06 (-0.18 to 0.29)	0.640	-0.31 (-0.58 to -0.05)	0.021
Fruit juice[‡]	-0.16 (-0.40 to 0.07)	0.171	-0.25 (-0.50 to -0.01)	0.043
Processed meat[‡]	1.16 (0.92 to 1.39)	<0.0001	1.04 (0.78 to 1.30)	<0.0001
Sugar sweetened carbonated drinks [‡]	0.41 (0.17 to 0.65)	0.001	0.33 (0.08 to 0.57)	0.009
Sweets and pastries[‡]	0.59 (0.36 to 0.83)	<0.0001	0.36 (-0.01 to 0.72)	0.052
Nuts[‡]	-0.42 (-0.66 to -0.18)	0.001	-0.52 (-0.76 to -0.28)	<0.0001
Olive oil (g/day)	0.48 (0.24 to 0.72)	<0.0001	0.36 (0.11 to 0.61)	0.004
Vegetable oil (g/day)	-0.05 (-0.28 to 0.19)	0.697	-0.12 (-0.35 to 0.12)	0.348
Diet quality index				
HEI score[‡]	-0.63 (-0.87 to -0.39)	<0.0001	-0.42 (-0.68 to -0.16)	0.002
MD score[‡]	-0.44 (-0.68 to -0.20)	<0.0001	-0.40 (-0.65 to -0.15)	0.002

Data presented as beta coefficient and their 95%CI. All exposure variables were standardised therefore changes in the outcome is presented per 1-SD change in the exposure.
Model 1 was adjusted for socio-demographics covariates (age, sex, country and occupation)
Model 2 for physical activity variables was also adjusted for total energy intake.
Model 2 for dietary intake variables was additionally adjusted for sedentary behaviour, PAL.
*these variables were additionally adjusted for protein, carbohydrates, total fat and alcohol intake, as appropriate.
[‡] these variables were additionally adjusted for total energy intake.
Physical activity variables were also adjusted for accelerometer wearing time.
HEI: healthy eating index; MD: Mediterranean diet; PA: physical activity, TE: total energy; PAL: physical activity levels.

Table 3. Associations between waist circumference and socio-demographic, physical activity and diet-related factors.

Variables (standardised)	Model 1		Model 2	
	Beta (95%CI)	P-value	Beta (95%CI)	P-value
Socio-demographic				
Age	4.92 (4.32 to 5.51)	<0.0001	4.41 (3.78 to 5.03)	<0.0001
Physical activity				
PAL	-2.25 (-2.87 to -1.64)	<0.0001	-1.70 (-2.36 to -1.04)	<0.0001
Light PA	-2.48 (-3.10 to -1.87)	<0.0001	-1.96 (-2.61 to -1.32)	<0.0001
Moderate PA	-3.16 (-3.78 to -2.53)	<0.0001	-2.63 (-3.34 to -1.94)	<0.0001
Vigorous PA	-3.57 (-4.20 to -2.94)	<0.0001	-3.07 (-3.73 to -2.40)	<0.0001
Moderate-equivalent PA	-4.10 (-4.72 to -3.47)	<0.0001	-3.76 (-4.47 to -3.06)	<0.0001
Sedentary behaviour	2.49 (1.85 to 3.12)	<0.0001	1.83 (1.16 to 2.51)	<0.0001
Nutrients intake				
Total energy	1.65 (1.05 to 2.25)	<0.0001	1.33 (0.69 to 1.97)	<0.0001
Protein*	0.83 (0.24 to 1.43)	0.006	1.38 (0.06 to 2.70)	0.041
Total fats*	1.63 (1.04 to 2.22)	<0.0001	2.45 (0.53 to 4.38)	0.012
Saturated fat*	1.45 (0.86 to 2.05)	<0.0001	0.59 (-0.29 to 1.46)	0.193
Polyunsaturated fat*	-0.05 (-0.64 to 0.54)	0.867	-0.75 (-1.45 to -0.05)	0.034
Monounsaturated fats*	2.23 (1.65 to 2.82)	<0.0001	1.89 (1.17 to 2.60)	<0.0001
Carbohydrates*	-1.52 (-2.10 to -0.93)	<0.0001	1.13 (-1.17 to 0.45)	0.335
Total Sugar*	-1.17 (-2.26 to -1.08)	<0.0001	-1.03 (-1.73 to -0.33)	0.004
Alcohol*	-0.14 (-0.74 to 0.47)	0.657	0.87 (-0.49 to 2.24)	0.212
Dietary fibre*[†]	-0.73 (-1.33 to -0.14)	0.015	-2.30 (-3.30 to -1.30)	<0.0001
Salt*[†]	1.73 (1.13 to 2.33)	<0.0001	1.68 (0.30 to 3.06)	0.017
Food groups intake				
Fruit and vegetables[†]	-1.38 (-1.97 to -0.79)	<0.0001	-1.66 (-2.32 to -1.01)	<0.0001
Wholegrains[†]	-1.66 (-2.24 to -1.07)	<0.0001	-2.34 (-3.01 to -1.68)	<0.0001
Red meat[†]	2.75 (2.16 to 3.34)	<0.0001	2.34 (1.70 to 2.98)	<0.0001

Oily fish[‡]	-0.76 (-1.37 to -0.16)	0.013	-1.02 (-1.65 to -0.40)	0.001
Dairy[‡]	-0.40 (-0.99 to 0.19)	0.182	-1.24 (-1.90 to -0.59)	<0.0001
Fruit juice[‡]	-0.68 (-1.27 to -0.09)	0.025	-1.07 (-1.67 to -0.46)	0.001
Processed meat[‡]	2.76 (2.18 to 3.35)	<0.0001	2.36 (1.72 to 3.00)	<0.0001
Sugar sweetened carbonated drinks [‡]	1.20 (0.61 to 1.79)	<0.0001	0.99 (0.39 to 1.60)	0.001
Sweets and pastries[‡]	1.62 (1.04 to 2.21)	<0.0001	0.72 (-0.17 to 1.62)	0.113
Nuts[‡]	-1.19 (-1.78 to -0.60)	<0.0001	-1.33 (-1.93 to -0.74)	<0.0001
Olive oil (g/day)	1.02 (0.43 to 1.61)	0.001	0.71 (0.10 to 1.32)	0.022
Vegetable oil (g/day)	-0.8 (-0.67 to 0.50)	0.780	-0.23 (-0.83 to 0.36)	0.446
Diet quality index				
HEI score[‡]	-1.94 (-2.53 to -1.34)	<0.0001	-1.25 (-1.91 to -0.60)	<0.0001
MD score[‡]	-1.50 (-2.09 to -0.90)	<0.0001	-1.33 (-1.95 to -0.72)	<0.0001

Data presented as beta coefficient and their 95%CI. All exposure variables were standardised therefore changes in the outcome is presented per 1-SD change in the exposure.
Model 1 was adjusted for socio-demographics covariates (age, sex, country and occupation)
Model 2 for physical activity variables was also adjusted for total energy intake.
Model 2 for dietary intake variables was additionally adjusted for sedentary behaviour, PAL.
*these variables were additionally adjusted for protein, carbohydrates, total fat and alcohol intake, as appropriate.
[‡] these variables were additionally adjusted for total energy intake.
Physical activity variables were also adjusted for accelerometer wearing time.
HEI: healthy eating index; MD: Mediterranean diet; PA: physical activity, TE: total energy; PAL: physical activity levels.

	BMI >25.0				**Central obesity**			
	Odds ratio	Lower limit	Upper limit	p-Value	Odds ratio	Lower limit	Upper limit	p-Value
Age (Years)								
Older (Ref.)								
Middle	0.663	0.503	0.874	0.004	0.675	0.505	0.901	0.008
Younger	0.282	0.204	0.390	0.000	0.215	0.143	0.323	0.000
Gender								
Males (Ref.)								
Females	0.590	0.470	0.741	0.000	1.285	0.991	1.666	0.059
Occupation								
Retired/Unemployed (Ref.)								
Profesional	0.641	0.429	0.956	0.029	0.568	0.381	0.847	0.006
Intermediate	0.795	0.523	1.211	0.286	0.556	0.363	0.851	0.007
Manual	0.850	0.513	1.409	0.528	0.634	0.378	1.063	0.084
Student	0.434	0.252	0.747	0.003	0.267	0.129	0.552	0.000
Country								
Pooled (Ref.)								
Germany	0.603	0.438	0.829	0.002	0.588	0.398	0.867	0.007
Greece	1.497	1.098	2.042	0.011	1.676	1.204	2.335	0.002
Ireland	1.053	0.773	1.434	0.742	1.170	0.832	1.645	0.366
Netherland	0.643	0.470	0.880	0.006	0.939	0.665	1.327	0.723
Poland	1.101	0.797	1.522	0.559	1.104	0.758	1.608	0.606
Spain	1.421	1.044	1.934	0.025	1.027	0.733	1.438	0.878
UK	1.013	0.740	1.387	0.936	0.704	0.473	1.050	0.086
Physical activity Levels (PAL)								
Lower (Ref.)								
Middle	0.879	0.662	1.167	0.373	0.777	0.571	1.057	0.109
Higher	0.609	0.457	0.812	0.001	0.434	0.310	0.608	0.000
Light PA (min/day)					1.500	1.500	1.500	0.000
Lower (Ref.)					1.000	0.999	1.001	1.000
Middle	0.879	0.660	1.171	0.378	0.688	0.505	0.939	0.018
Higher	0.609	0.450	0.824	0.001	0.407	0.291	0.570	0.000
Moderate PA (min/day)								
Lower (Ref.)								
Middle	0.410	0.307	0.548	0.000	0.455	0.334	0.621	0.000
Higher	0.245	0.177	0.339	0.000	0.315	0.220	0.451	0.000
Vigorous PA (min/day)								
Lower (Ref.)								
Middle	0.365	0.270	0.493	0.000	0.418	0.306	0.572	0.000
Higher	0.185	0.130	0.263	0.000	0.138	0.091	0.207	0.000
Moderate-equivalent PA (min/day)								
Lower (Ref.)								
Middle	0.360	0.270	0.480	0.000	0.421	0.309	0.574	0.000
Higher	0.200	0.144	0.278	0.000	0.171	0.115	0.252	0.000
Sedentary Behaviour (min/day)								
Higher (Ref.)								
Middle	0.465	0.349	0.620	0.000	0.674	0.495	0.918	0.012
Lower	0.404	0.299	0.544	0.000	0.490	0.350	0.687	0.000

BMI >25.0 — Odds ratio and 95% CI

0.1   0.2   0.5   1   2

← Less likely to have a BMI >25.0   More Likely to have a BMI >25.0 →

Central obesity — Odds ratio and 95% CI

0.1   0.2   0.5   1   2

← Less likely to have central obesity   More likely to have central obesity →

BMI >25.0
Odds ratio and 95% CI

Central obesity
Odds ratio and 95% CI

	Odds ratio	Lower limit	Upper limit	p-Value	Odds ratio	Lower limit	Upper limit	p-Value
Total energy (Kcal)								
Higher (Ref.)								
Middle	0.749	0.574	0.976	0.033	0.667	0.495	0.900	0.008
Lower	0.690	0.525	0.907	0.008	0.557	0.406	0.763	0.000
Protein (% of TE)								
Higher (Ref.)								
Middle	0.569	0.416	0.777	0.000	0.732	0.514	1.043	0.084
Lower	0.462	0.310	0.689	0.000	0.593	0.376	0.934	0.024
Carbohydrates (% of TE)								
Higher (Ref.)								
Middle	0.902	0.642	1.268	0.553	1.210	0.824	1.776	0.330
Lower	0.872	0.526	1.446	0.595	0.870	0.490	1.544	0.634
Total fat (% of TE)								
Higher (Ref.)								
Middle	0.666	0.478	0.927	0.016	0.791	0.547	1.143	0.212
Lower	0.426	0.264	0.687	0.000	0.637	0.373	1.087	0.098
Saturated fat (% of TE)								
Higher (Ref.)								
Middle	0.822	0.615	1.098	0.184	1.062	0.769	1.467	0.714
Lower	0.593	0.416	0.846	0.004	0.790	0.530	1.178	0.247
Monounsaturated fat (% of TE)								
Higher (Ref.)								
Middle	0.838	0.620	1.132	0.249	1.009	0.723	1.409	0.956
Lower	0.474	0.317	0.710	0.000	0.492	0.309	0.782	0.003
Polyunsaturated fat (% of TE)								
Higher (Ref.)								
Middle	1.147	0.870	1.513	0.331	1.174	0.861	1.600	0.310
Lower	1.489	1.102	2.013	0.010	1.175	0.834	1.655	0.356
Sugar (% of TE)								
Higher (Ref.)								
Middle	1.272	0.960	1.685	0.094	1.388	1.000	1.929	0.050
Lower	1.299	0.964	1.751	0.086	1.678	1.192	2.361	0.003
Alcohol (% of TE)								
Higher (Ref.)								
Middle	0.948	0.676	1.329	0.756	0.908	0.614	1.344	0.631
Lower	1.335	0.911	1.957	0.139	1.423	0.927	2.185	0.107
Dietary fiber (mg/day)								
Lower (Ref.)								
Middle	0.823	0.625	1.085	0.167	1.008	0.735	1.382	0.960
Higher	0.822	0.610	1.106	0.196	1.062	0.758	1.489	0.725
Salt intake (g/day)								
Higher (Ref.)								
Middle	0.652	0.496	0.856	0.002	0.616	0.454	0.835	0.002
Lower	0.649	0.490	0.859	0.003	0.543	0.395	0.746	0.000

BMI >25.0 axis: 0.2 — 0.5 — 1 — 2
Less likely to have a BMI >25.0 ← → More Likely to have a BMI >25.0

Central obesity axis: 0.2 — 0.5 — 1 — 2
Less likely to have central obesity ← → More likely to have central obesity

	BMI >25.0 Odds ratio and 95% CI				**Central obesity** Odds ratio and 95% CI			
	Odds ratio	Lower limit	Upper limit	p-Value	Odds ratio	Lower limit	Upper limit	p-Value
Fruit & Vegetable								
Lower (Ref.)								
Middle	0.617	0.471	0.808	0.000	0.864	0.637	1.171	0.346
Higher	0.515	0.388	0.684	0.000	0.521	0.375	0.723	0.000
Wholegrain								
Lower (Ref.)								
Middle	0.686	0.524	0.898	0.006	0.560	0.411	0.761	0.000
Higher	0.352	0.263	0.471	0.000	0.426	0.308	0.588	0.000
Oily fish								
Lower (Ref.)								
Middle	1.082	0.827	1.416	0.566	1.003	0.739	1.361	0.986
Higher	0.744	0.560	0.989	0.041	0.713	0.514	0.991	0.044
Dairy products								
Lower (Ref.)								
Middle	1.007	0.771	1.317	0.957	0.915	0.677	1.237	0.563
Higher	0.725	0.547	0.962	0.026	0.534	0.384	0.744	0.000
Red meat								
Higher (Ref.)								
Middle	0.633	0.481	0.835	0.001	0.666	0.489	0.905	0.010
Lower	0.327	0.244	0.440	0.000	0.448	0.320	0.627	0.000
Processed meat								
Higher (Ref.)								
Middle	0.685	0.520	0.903	0.007	0.666	0.489	0.905	0.010
Lower	0.340	0.253	0.458	0.000	0.448	0.320	0.627	0.000
Fruit juice								
Higher (Ref.)								
Middle	1.382	1.032	1.851	0.030	1.414	1.006	1.988	0.046
Lower	1.225	0.949	1.581	0.120	1.428	1.061	1.922	0.019
Fizzy drinks								
Higher (Ref.)								
Middle	0.607	0.424	0.868	0.006	0.718	0.468	1.100	0.128
Lower	0.737	0.561	0.969	0.029	0.757	0.553	1.036	0.082
Sweets and pastries								
Higher (Ref.)								
Middle	0.735	0.552	0.978	0.035	0.893	0.649	1.229	0.488
Lower	0.601	0.445	0.813	0.001	0.640	0.452	0.906	0.012
Nuts								
Lower (Ref.)								
Middle	0.769	0.590	1.003	0.053	0.847	0.628	1.143	0.278
Higher	0.523	0.396	0.691	0.000	0.486	0.351	0.673	0.000
MD score								
Lower (Ref.)								
Middle	0.822	0.643	1.050	0.117	0.717	0.542	0.948	0.020
Higher	0.609	0.447	0.830	0.002	0.552	0.385	0.793	0.001
Healthy Eating Index								
Lower (Ref.)								
Middle	0.690	0.530	0.899	0.006	0.771	0.573	1.038	0.087
Higher	0.607	0.457	0.806	0.001	0.506	0.362	0.708	0.000

BMI >25.0 axis: 0.2 — 0.5 — 1 — 2. Less likely to have a BMI >25.0 ← → More Likely to have a BMI >25.0

Central obesity axis: 0.2 — 0.5 — 1 — 2. Less likely to have central obesity ← → More likely to have central obesity