

1 **Prevalence of obesity in Italian adolescents. Does the use of different growth charts make the**
2 **difference?**

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18 **Declarations**

19 *Ethics approval and consent to participate:*

20 The study protocol was approved by the Ethical Committee of the University of Turin on the 11th of
21 January 2012, and the procedures were in compliance with the Helsinki Declaration principles.

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36 **Abstract**

37 **Background:** Since populations are becoming increasingly multi-ethnic, the use of local or
38 international charts is a matter of debate.

39 **Objectives:** To evaluate: how the choice of cut-off thresholds affected prevalence of underweight
40 (UW), overweight (OW), obesity (OB) in 1,200 11-12-y Italian adolescents, and how their somatic
41 growth depended on parental origin.

42 **Methods:** The height, weight and BMI were expressed as SDS using Italian (ISPED-2006) and UK
43 (UK-1990) charts. The classification of UW/OW/OB was computed with the IOTF international cut-
44 offs, and thresholds were identified as centiles corresponding to BMI values of 18.5/25.0/30.0 kg/m² at
45 18-y in ISPED-2006 or UK-1990 references.

46 **Results:** About 30% participants had non-Italian parents, above all from North-Africa and Romania.
47 Referring to the UK-1990 charts, all groups showed negative mean SDS for height, and positive SDS
48 for weight and BMI. Referring to the ISPED-2006 charts, all mean SDS were negative. Percentage of
49 UW individuals was higher in accordance with ISPED-2006 than with UK-1990 charts, whereas
50 percentages of OW/OB were higher with UK-1990 than ISPED-2006 charts. The results obtained by
51 using IOFT cut-offs were similar to UK-1990 cut-offs. These results were due to the different shape of
52 age-dependent cut-off centiles. Independently by the parental origin, the percentages of adolescents
53 classified as OW/OB were closer to the expected values by using the ISPED-2006 then the UK-1990
54 cut-offs. The results suggested the use of the Italian references for adolescents with immigrant parents.

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55 **Conclusions:** The use of local charts seems more appropriate at least in Italian adolescents in the age
56 range studied.

57 **Key words:** cut-off thresholds, immigration, overweight, underweight.

58

59

60 **Introduction**

61 Populations are becoming increasingly multi-ethnic owing to the increasing immigration processes. In
62 Italy, immigration is particularly evident in North-Western regions.^[1] In Turin, the percentage of
63 immigrants has more than doubled from 2004 to 2013. Approximately 30% of a cohort of students
64 attending the first year of secondary schools in Turin had non-Italian parents.^[2-4]

65 A highly controversial topic is whether charts used to monitor stature and weight growth should be
66 local or international, since growth reflects the condition of the society where individuals live.^[5] The
67 World Health Organization (WHO) children growth standards were developed on the assumption that
68 under optimal environmental conditions, a single standard can fit all subjects, regardless of ethnicity.^[6]
69 Nevertheless, recent data showed significant differences in growth patterns among European children,
70 and authors advocated the use of national references rather than the-WHO growth charts adoption.^[7]

71 The British-1990 body mass index (BMI) reference charts provided cut-off thresholds to define
72 overweight, but the choice of a given cut-off centile and of cross-sectional data were criticized.^[8-10]

73 Therefore, the International Obesity Task Force (IOTF) proposed that the adult cut-off points for
74 underweight (UW), overweight (OW) and obesity (OB) could be used also in children.^[11-12] A few
75 studies, however, raised doubts about the validity of international charts, since the same BMI centiles
76 do not reflect the health risks in populations from different countries.^[10,13-15]

77 In Italy, the situation is complex, owing to the prevalence of youth with OW and OB, which is the
78 highest in Europe, and the increasing immigration rate.^[5,16-17] An Italian nutrition survey promoted by
79 the Italian Ministry of Health, involving more than 45,000 third-grade students reported a >30%
80 prevalence of OW/OB,^[17-18] according to the international cut-off thresholds proposed by Cole et al,^[12]
81 even if Italian cut-off thresholds are available.^[16,19]

82 The aim of the present study was to evaluate how the cut-off thresholds of different growth references
83 affect the estimate of UW, OW, and OB prevalence in a group of 1,200 adolescents, and to evaluate
84 the extent to which somatic growth of these adolescents depends on parental origin.^[12]

85

86 **Methods**

87 All the students attending the first year of middle school in Turin routinely undergo a health status and
88 physical performance assessment.^[3-4] In Italy, students attend this class at 11-12-y; however, a few
89 individuals who failed the exams during their schooling, repeated the class and were older. Out of
90 7,263 students attending this class in Turin in 2011-2012, 6,876 (94.7%) participated in the
91 assessment. Among participants, 1,200 students were selected by a simple random sampling. They
92 received a questionnaire on health status and had a clinical examination. Their age, sex, weight,
93 height, BMI, and percentages of individuals with UW/OW/OB were almost overlapping to those of the
94 whole sample who participated in the assessment.^[3-4]

95 Children's parents or legal representatives signed a consent form for the study participation. The study
96 protocol was approved by the local Ethical Committee; the procedures were in compliance with the
97 Helsinki Declaration principles.

98

99 *Measurements*

100 A week before the assessment, students were given questionnaires to be filled by parents at home,
101 indicating their country of origin. We considered as coming from North Africa parents from Morocco,
102 Algeria, Tunisia and Libya.

103 Weight and height were measured in all the participants by trained researchers. Weight was measured
104 to the nearest 0.1 kg by a mechanical column scale (SECA model 711, Hamburg, Germany), and
105 height to the nearest 0.1 cm with a stadiometer (SECA 220 measuring rod, Hamburg, Germany) with
106 the participants wearing light clothes and no shoes. The measurements were performed after 8-10 h
107 fasting in the morning, after few exercises of spine stretching. The weight scale was calibrated before
108 each measurement session.

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109 The pubertal stages were assessed by clinical examination according to the methods of Marshall and
110 Tanner by trained personnel, by evaluating breast maturation (girl), testicular volume (boys) and pubic
111 hair stages.^[20-21]

112

113 *Statistical analyses*

114 The BMI was expressed as SDS (Standard Deviation Score) using ISPED-2006 charts (growth
115 reference for Italy) and UK-1990 charts (reference for UK).^[19,8] Both the charts express the
116 distribution of auxological variables in term of three age-dependent smoothing splines called L
117 (parameter that allows for the distribution skewness), M (median) and S (coefficient of variation). This
118 parametrization allows to compute the SDS corresponding to the value (y) of the auxological variable
119 as $SDS = [(y/M)^L - 1] / (L \times S)$.^[22]

120 To provide international cut-off thresholds consistent with the WHO adult cut-offs, Cole derived from
121 about 200,000 girls and boys from 6 countries the centiles of the age-dependent BMI distribution
122 (IOTF-2007 cut-off thresholds) that assumed the values of 18.5 (UW), 25 (OW), and 30kg/m² (OB) at
123 18-y (i.e. the adult-thresholds by the WHO).^[23] Similarly, we considered as "local" thresholds the
124 centiles that in ISPED-2006 or UK-1990 charts corresponded to 18.5, 25.0, and 30.0kg/m² at 18-y.<sup>[11-
125 12,23]</sup> The cut-off centiles strictly depend on the reference set taken into account.

126 The percentages of subjects classified as UW/OW/OB were computed according to the cut-off
127 thresholds cited above. For definition, if the study population is similar to the population on which the
128 charts were traced, the expected percentages of UW/OW/OB subjects were: the corresponding UW
129 cut-off centile (UW subjects), [100-the corresponding OB cut-off centile] (OB subjects), and [100-the
130 corresponding OW cut-off centile -the expected percentage of OB individuals] (OW, but not OB
131 subjects).

132

133 **Results**

134 About 70% of our students had Italian parents (**Tab.1**). Out of the remaining, 32.6% had parents from
135 North-Africa, 30% from Romania, and "other" included Albania (7.6%), Peru (5.4%), Turkey (3.7%),

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136 China (2.8%), Chile (2.0%), Nigeria (2.0%), and many others with ≤ 5 children each. Owing to the low
137 number of subjects in these subgroups, we considered only students with parents from Italy, North-
138 Africa and Romania.

139 For girls, the cut-off centiles for UW/OW/OB derived from UK-1990 and ISPED-2006 charts have
140 similar grade: about the 12th centile for the UW definition, the 88th for OW, and 98th for OB (**Tab.2**).
141 For boys, the cut-off centiles derived from UK-1990 have higher grade than those derived from
142 ISPED-2006 charts.

143 **Figure 1** shows how ISPED-2006, UK-1990, and IOTF cut-off thresholds vary with increasing age.
144 The first two cut-off centiles largely differ in value and shape, even for girls where centile grade is
145 similar. For example, for girls at 11-y, the age of most participants (**Tab.1**), the BMI values of
146 OB/OW/UW cut-off thresholds are respectively 25.6 vs 29.4kg/m², 21.1 vs 23.9kg/m², 15.5 vs
147 16.3kg/m² (UK-1990 vs ISPED-2006). The corresponding cut-off thresholds for boys are: 24.8 and
148 28.4kg/m², 20.4 and 22.4kg/m², 15.2 and 15.5kg/m². Noteworthy, the absolute differences for girls are
149 higher than for boys even if the cut-off centile grades are closer. The IOTF cut-off thresholds for OW
150 and OB are close to those derived from UK-1990.

151 Height-, weight- and BMI-SDS derived from UK-1990 and ISPED-2006 charts are reported by
152 country of parental origin (**Tab.3**). When referred to the UK-1990 charts, all groups show negative
153 mean (and median) SDS for height, and positive for weight and BMI, suggesting that these students
154 differ in body shape from their UK peers, i.e., on average, they are shorter and heavier. On the
155 contrary, when referred to ISPED-2006 charts, all mean (and median) SDS are negative. Standard
156 deviations (SD) for height-SDS are close to 1 (the expected value), but slightly higher for weight- and
157 BMI-SDS. The dispersion of SDS values derived from ISPED-2006 charts is lower than that of SDS
158 derived from UK-1990. The 1st centile is lower than expected (i.e. -2.33), except for height-SDS (UK-
159 1990) of adolescents with North-African parents, and for the SDS (UK-1990) of all the traits
160 adolescents of Romanian children (**Tab.2**). The 99th centile is always lower than expected (i.e. +2.33)
161 for height-SDS (both charts), and higher for weight- and BMI-SDS (UK-1990), but lower for weight-
162 SDS of adolescents with Italian and Romanian parents (ISPED-2006).

163 The differences in height-SDS and weight-SDS between stages of breast maturation, testicular volume
164 $<$ or ≥ 4 mL, and pubic hair stages (both sexes) are negligible (results not reported).

165 **Table 4** reports the percentage of UW/OW/OB subjects in accordance with the different cut-off
166 thresholds. From Table 2, we can derive that the expected percentages of UW, OW -but not OB-, and
167 OB adolescents are 12.3%, 10.3% and 1.7% (girls), and 6.3%, 15.8% and 2.3% (boys), respectively,
168 with ISPED-2006, and 12.2%, 10.5% and 1.2% (girls), and 11.0%, 8.7% and 0.9% (boys), with UK-
169 1990 cut-offs.

170 In both sexes, the percentage of UW subjects is about 2-fold higher than expected adopting the
171 ISPED-2006 reference. According to UK-1990, the percentage of UW boys, independently of parental
172 origin, and UW girls with Romanian parents are less than expected, whereas the percentage of UW
173 girls with Italian or North-African parents is similar to the expected value. The differences between
174 observed and expected percentages of OW/OB subjects in accordance with ISPED-2006 are rather
175 small, with the exception of boys with North-African parents, whose prevalence of OB is 2-fold the
176 expected value. When defined in accordance with UK-1990, the prevalence of OW girls is about twice
177 than expected, whereas the prevalence OW boys ranges from 1.6 (Romanian parents) to 2.9 (Italian
178 and North-African parents) times than expected; the prevalence of OB girls ranges from 2 (North-
179 African parents) to 6.5 (Italian parents), and that of OB boys ranges from 8.6 (Italian parents) to 11.3
180 (Romanian parents) times the expected value.

181 As it could be anticipated from **Figure 1**, the percentages of UW, OW and OB defined in accordance
182 to IOTF cut-off thresholds are similar to those derived from UK-1990.

183

184 **Discussion**

185 The present study indicates that UK-1990 cut-off thresholds applied to a group of Italian adolescents,
186 identified more subjects as OW or OB than ISPED-2006 cut-off thresholds, independent of parental
187 origin. By contrast, UK-1990 identified less UW subjects than ISPED-2006. These results remained
188 substantially unchanged considering also the pubertal status.

189 The observed differences derived from the different shape of the centiles used as cut-off thresholds.
190 The UK-1990 centiles are steeper and do not reach a plateau, whereas ISPED-2006 centiles reach the
191 plateau within 16-y (girls) and 18-y (boys). Moreover, from 6 to 18-y, ISPED-2006 thresholds are
192 consistently higher than UK-1990 thresholds. Similar differences in growth shape, i.e. in the velocity
193 to approach adult body proportion, emerged between Italy and UK or USA, and between Northern
194 (Continental) and Southern (Mediterranean) Italy.^[16,19] Although, on the average, Italian adolescents
195 show higher BMIs, the prevalence of OW/OB in adulthood is lower than in Northern Europe and
196 USA.^[24]

197 A possible explanation for these differences may be the age of the “adiposity rebound”, i.e. the normal
198 rebound in BMI after it reaches its lowest point, usually occurring after 4-6 years,^[25] which is critical
199 for the adult development of chronic diseases.^[26] An early adiposity rebound (before 5-y) is associated
200 with obesity, hypertension and metabolic syndrome in adulthood.^[27-28] The BMI rebound reaching the
201 50th centile occurs between 5-6 years in UK-1990 and between 3.5-4.5 years in ISPED-2006
202 charts.^[8,19] The earlier adiposity rebound of Italian children may account, at least in part, for the higher
203 percentage of OW/OB subjects according to the UK-1990 or IOTF cut-off threshold, but not for the
204 slowdown in BMI growth of Italian individuals approaching adulthood.

205 Differences in dietary habits, social factors, genetic determinants or in puberty-onset age might be
206 other explanations. In Europe, pubertal age shows a North-South gradient with menarche occurring at
207 a mean age of 12-y in Italy and 13-y in UK.^[29] As a consequence, the weight target is reached earlier
208 in the Italian youths. An association has been suggested between early puberty and obesity.^[30]

209 However, it is unclear whether the early sexual maturation influences the fat depot or vice-versa.^[31]

210 Our participants were slightly shorter than those on which ISPED-2006 charts are based. This may be
211 due to the earlier pubertal age of Southern-Mediterranean adolescents. Our participants with North-
212 African and Romanian parents showed a similar distribution of height-, weight- and BMI-SDS than
213 those with Italian parents, suggesting that anthropometric characteristics of these adolescents
214 resembled those of their Italian peers. Analogously, height growth of Maghreb infants living in France
215 showed no significant difference than those of their French peers.^[32] By contrast, Moroccan children

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216 living in Netherlands showed substantially shorter height and increased BMI than Dutch children, and
217 North-African children living in Sweden had higher odds of being OW/OB than Swedish children.<sup>[33-
218 34]</sup> These findings suggest that immigration to Europe may be associated with higher OW risk.^[35] An
219 increasing prevalence of OW/OB has been reported in children of Moroccan and Middle
220 Eastern/North African origin living in Europe than the native children.^[36] The prevalence of OW/OB
221 in Moroccan children living in Rabat was much lower than that of Moroccan children living in the
222 Netherlands.^[33,37] Socio-cultural factors such as the westernization of eating habits, the body image
223 perception and the level of physical activity have been suggested to play an important role in this
224 phenomenon.^[38] We found the percentage of OW/OB subjects by the ISPED-2006 cut-off thresholds
225 similar to the one expected independent of parental origin. Therefore, for the largest groups of children
226 of immigrants in Italy, it might be advisable to employ the same charts used for their Italian peers, at
227 least in this age-range.

228 Identifying appropriate growth charts is of paramount importance, since growth charts determine the
229 cut-off thresholds used in clinical guidelines to monitor growth, with consequences for public
230 healthcare. Our results showed that using non-Italian references likely overemphasizes the problem of
231 OW/OB, whereas understates that of UW. The existence among adolescents of the double burden of
232 OW and UW is proven, even if only the former is, at present, a recognized and publicized problem in
233 Italy.^[18]

234 The prevalence of UW subjects in Italy varied among studies: 1.2% (age range 8-9-y);^[18] 13% (6-19-
235 y);^[39] 10.1% (11-y);^[40] 2% (6.5-11.5-y).^[41] In Italy, from 2008 to 2014, UW prevalence increased in 8-
236 9-y children, while OW (23.2 to 20.9%) and OB (12.0 to 9.8%) decreased, although remained
237 alarmingly high.^[17-18,42] The proportion of UW children is increasing also in other countries, such as
238 Spain, France, Sweden.^[43-45] Possible explanations for this trend may be sociocultural factors
239 associated with beauty standards and media exposure to images of ideally thin models, and the
240 increment in adolescent body dissatisfaction.^[46]

241 *Limitations and strengths*

242 A main weakness of the study was the narrow participants' age-range, which limited the
243 generalizability of the results. The limitations of the BMI in assessing body fatness have been
244 suggested,^[47,13] but the reported high specificity of BMI as a measure of fatness at 11-12-y, and the
245 high correlation between BMI and percent body fat, when appropriate cut-offs are chosen, are
246 reassuring.^[13-15,48] In the present report, the ISPED-2006 charts have been used, instead of those
247 specific for Central-North Italy, because a high proportion of residents in Turin migrated from
248 Southern Italy.^[2]

249 The study strengths were the measurement of all the anthropometric variables by trained researchers,
250 and the similarity of our participants to all the adolescents living in Turin with the same age-range, as
251 previously shown.^[3-4]

252

253 **Conclusions**

254 In adolescents from North-Western Italy in the age range studied, the use of local charts seems to be
255 more appropriate to monitor growth. It would be important that rates and SDS values among countries
256 using their local growth charts will be compared, in order to develop international growth charts best
257 suited for the populations not previously included.

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258 **Figure 1. Cut-off centiles for underweight (UW), overweight (OW) and obesity (OB)**
 259 **derived from UK-1990 (dots) and ISPED-2000 (dashed line) charts. Continuous lines are**
 260 **the IOTF-2000/7 thresholds cut-off.**
 261

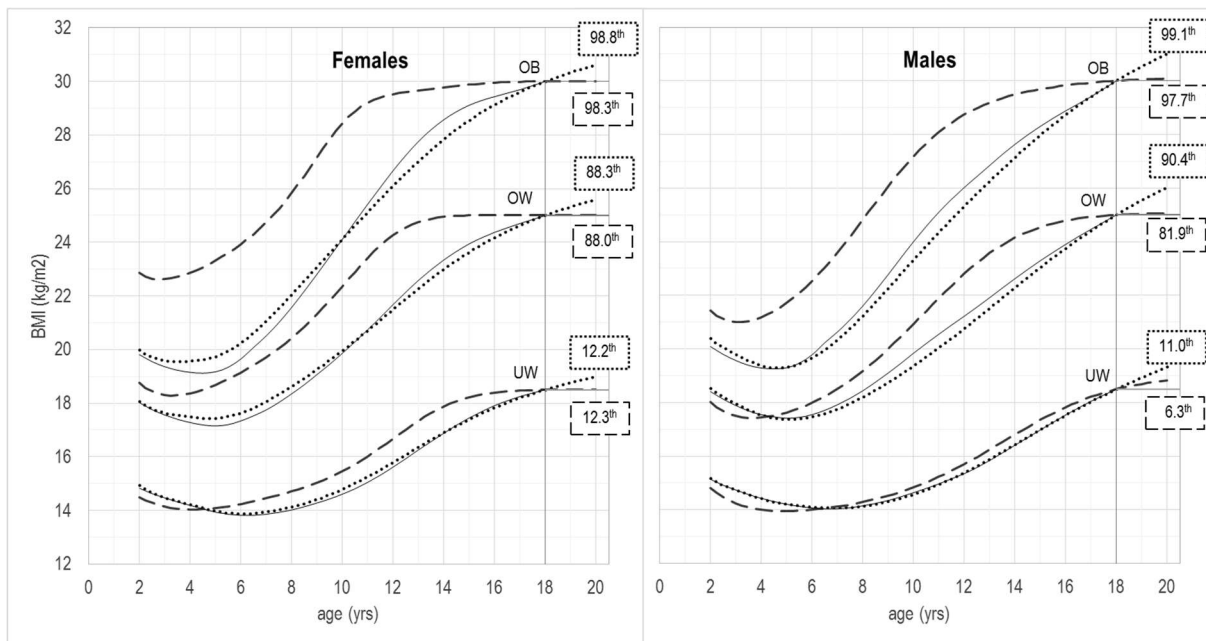


Table 1. Distribution of the participants by age, sex and country of parental origin

Age (years)	Country of parental origin								Total
	Italy		North Africa*		Romania		Others**		
	F	M	F	M	F	M	F	M	
11	35	17	2	3	1	1	5	4	68
12	378	369	36	57	34	35	41	52	1002
>12	21	27	3	14	12	23	16	14	130
Total	434	413	41	74	47	59	62	70	1200

*North Africa includes Moroccans, Algerians, Tunisians, and Libyans

**Other countries of origin, grouped as “other” included Albania (7.6%), Peru (5.4%), Turkey (3.7%), China (2.8%), Chile (2.0%), Nigeria (2.0%), Senegal (1.4%), Moldavia (1.1%), and many others with 3 or less children each.

Table 2. Cut-off centiles for underweight (UW), overweight (OW) and obesity (OB) derived from UK-1990 and ISPED-2006 references

	UK-1990		ISPED-2006	
	F	M	F	M
UW	12.2	11.0	12.3	6.3
OW	88.3	90.4	88.0	81.9
OB	98.8	99.1	98.3	97.7

In accordance with IOFT, the adolescent cut-off centiles for UW, OW and OB were computed by using the centiles corresponding to the BMI values respectively of 18.5 kg/m², 25 kg/m², and 30 kg/m² at 18 years.

Table 3. Mean values of height-, weight-, and body mass index (BMI)-SDS derived by UK-1990 and ISPED-2006 charts

		Mean (SD)	Centile				
			1st	25th	50th	75th	99th
Italy (n=847)							
UK-1990	height	-0.34 (1.03)	-2.58	-0.98	-0.31	+0.34	+2.22
	weight	+0.16 (1.27)	-2.75	-0.79	+0.15	+1.11	+2.87
	BMI	+0.38 (1.35)	-2.86	-0.63	+0.41	+1.45	+3.03
ISPED-2006	height	-0.62 (1.02)	-2.95	-1.25	-0.58	+0.06	+1.92
	weight	-0.47 (1.15)	-2.95	-1.32	-0.52	+0.35	+2.14
	BMI	-0.27 (1.19)	-2.87	-1.17	-0.27	+0.63	+2.39
North Africa (n=115)							
UK-1990	height	-0.14 (1.05)	-2.21	-0.93	-0.18	+0.49	+2.22
	weight	+0.30 (1.31)	-2.77	-0.57	+0.22	+1.28	+3.31
	BMI	+0.44 (1.45)	-3.46	-0.70	+0.46	+1.45	+3.16
ISPED-2006	height	-0.42 (1.04)	-2.49	-1.22	-0.45	+0.27	+1.92
	weight	-0.34 (1.20)	-2.98	-1.18	-0.47	+0.53	+2.60
	BMI	-0.22 (1.28)	-3.32	-1.31	-0.28	+0.68	+2.56
Romania (n=106)							
UK-1990	height	-0.26 (1.04)	-2.11	-1.11	-0.25	+0.49	+2.02
	weight	+0.15 (1.26)	-2.28	-0.80	+0.02	+1.07	+2.81
	BMI	+0.37 (1.20)	-2.29	-0.33	+0.25	+1.26	+2.96
ISPED-2006	height	-0.52 (1.01)	-2.44	-1.31	-0.40	+0.18	+1.61
	weight	-0.48 (1.14)	-2.55	-1.31	-0.67	+0.35	+2.11
	BMI	-0.30 (1.09)	-2.45	-1.01	-0.51	+0.41	+2.18
All (n=1200)							
UK-1990	height	-0.29 (1.04)	-2.63	-0.98	-0.31	+0.41	+2.22
	weight	+0.18 (1.26)	-2.75	-0.74	+0.15	+1.11	+2.89
	BMI	+0.39 (1.33)	-2.82	-0.61	+0.37	+1.43	+3.06
ISPED-2006	height	-0.57 (1.03)	-2.91	-1.25	-0.58	+0.12	+1.92
	weight	-0.45 (1.14)	-2.95	-1.29	-0.50	+0.37	+2.16
	BMI	-0.27 (1.19)	-2.87	-1.16	-0.35	+0.59	+2.41

Table 4. Percentage of females and males defined as underweight (UW), overweight (OW) and obese (OB) in accordance with the cut-off thresholds under comparison

	Females			Males		
	UW (%)	OW (%)	OB (%)	UW (%)	OW (%)	OB (%)
Italy (n=847)						
<i>UK-1990</i>	13.59	17.97	7.83	9.93	25.42	7.75
<i>ISPED-2006</i>	27.19	11.29	1.84	14.29	14.77	2.42
<i>IOTF-2000/7</i>	11.98	18.20	6.22	9.44	23.73	6.05
North Africa (n=115)						
<i>UK-1990</i>	12.20	26.83	2.44	10.81	25.68	9.46
<i>ISPED-2006</i>	26.83	9.76	2.44	13.51	17.57	5.41
<i>IOTF-2000/7</i>	9.76	24.39	2.44	9.46	25.68	6.76
Romania (n=106)						
<i>UK-1990</i>	8.51	21.28	4.26	5.08	13.56	10.17
<i>ISPED-2006</i>	23.40	8.51	2.13	10.17	13.56	3.39
<i>IOTF-2000/7</i>	8.51	21.28	4.26	5.08	11.86	8.47
All (n=1200)						
<i>UK-1990</i>	12.50	19.18	7.02	9.42	22.89	8.44
<i>ISPED-2006</i>	26.54	10.96	1.88	13.47	14.61	2.76
<i>IOTF-2000/7</i>	11.13	18.66	5.82	8.77	21.75	6.49