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Height, weight, body composition, and waist circumference references for 7- to 17-year-old children from rural Portugal

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ABSTRACT

The purpose of this study was (1) to develop references of height, weight, body mass index (BMI), waist circumference and body fat for rural Portuguese children and adolescents and (2) to compare these results with other international references. The sample comprised 3094 children and adolescents aged 7–17 years from Vouzela, a central region in Portugal. Height, weight, BMI, waist circumference and body fat were measured. Centile curves were constructed using the LMS method. The Vouzela sample showed similar height median values compared to Centers for Disease Control and Prevention (CDC) and World Health Organization (WHO) percentile curves but greater values for weight and BMI. Percent body fat 50th percentile was greater in Vouzela children and adolescents compared to their international peers, except for boys aged 8–12 years. Boys' waist circumference median values were similar to those from the USA, whilst girls were similar until 12 years of age, after which the differences increased with age. The percentile curves constructed provide population specific references for growth and body composition of children and adolescents from rural Portugal. It is expected that they will be a useful tool for clinical and public health settings in rural Portugal.

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Introduction

Growth charts are a valuable reference tool in clinical settings for assessing and monitoring individual growth. They also serve as a valuable screening tool for the whole population (Wright et al., 2002). Furthermore, growth charts provide relevant public health information about age and sex specific statural growth and weight status, and may be used as putative indicators to infer information related to a child's nutritional and health status (Grummer-Strawn et al., 2002).

Standing height and weight are considered the most important indicators of children and adolescents' growth (WHO, 1995). In addition, public health studies have also used body mass index (BMI) as an indicator of weight status at both individual and population levels. For example, growth charts have been used to show growth trends in various communities such as, the northeast of Brazil (Silva et al., 2012), Belgium (Roelants et al., 2009), China (Pan et al., 2009) and the USA (Kuczmarski et al., 2000). Although BMI is a widely documented measure for monitoring obesity trends in populations, it does not distinguish excess fat mass from excess lean mass (Prentice and Jebb, 2001), and may classify individuals with large muscle mass as overweight or obese. Furthermore, as obesity is a metabolic and neuroendrocrine disease (Hebebrand and Hinney, 2009), characterized by an excess of adipose tissue (Fortuno et al., 2003), percent total body fat and waist circumference can more accurately estimate obesity status.

Fat mass development has been characterized using measures of bio-impedance derived body fat curves for the USA (Mueller et al., 2004) and UK (McCarthy et al., 2006) samples. Reference charts have also been developed for waist circumference (Brannsether et al., 2011; McCarthy et al., 2001). Waist circumference is regarded as an indirect anthropometric indicator of visceral adipose tissue and has been shown to be a significant obesity-related health risk factor (Pouliot et al., 1994; Rankinen et al., 1999) that is highly correlated to coronary heart disease (Dalton et al., 2003; Maffeis et al., 2001). Waist circumference centile curves are available for children and youth from several countries namely: the USA (Fernandez et al., 2004), UK (McCarthy et al., 2001), Spain (Moreno et al., 1999), Germany (Kromeyer-Hauschild et al., 2011), Norway (Brannsether et al., 2011) and Portugal (Sardinha et al., 2012).

Although waist circumference reference charts of Portuguese mainland boys and girls aged 10–18 years are available (Sardinha et al., 2012), national reference charts for growth and body fat are lacking, as are specific regional curves. It has been shown that local reference charts report different growth patterns and health status among populations, even when controlling for the same strict inclusion criteria to construct them (Juliusson et al., 2011). This suggests the influence of environmental, cultural and genetic differences specific to each population (Eveleth and Tanner, 1976). Furthermore, differences in somatic growth can be observed, also within the same country, related to social and health inequality by environmental and socioeconomic conditions, as well as differences in nutritional intake and lifestyle between regions (Cacciari et al., 2002, 2006).

Therefore, the purposes of this study were: (1) to develop references for height, weight, BMI, waist circumference and body fat of children and adolescents from a rural region in Portugal; and (2) to compare these references to the Centers for Disease Control and Prevention (CDC) 2000 reference charts (Kuczmarski et al., 2000), the 2007 World Health Organization (WHO) reference charts (de Onis et al., 2007) and other international data sets.

Materials and methods

The sample

In 2008, 2010 and 2012 repeated cross sectional samples of children and adolescents of both sexes, aged 7–17 years, who participated in "*Active Vouzela*", were recruited into this study. "*Active Vouzela*" investigated the growth, development and health of children and adolescents from all Vouzela's schools and their families. Vouzela is a small region (193.7 km^2) in central Portugal. Agriculture is the predominant income source for most families.

Table 1 identifies the number of participants recruited grouped by sex and age categories. The participants represent about 80% of this region's children and adolescents between 7 and 17 years

Table 1
Sample sizes for anthropometric measures (height, weight, BMI and waist circumference) and percent body fat by age and sex.

Age	Height/weight/BMI			WC			% Body fat		
	Girls	Boys	Total	Girls	Boys	Total	Girls	Boys	Total
7	131	132	263	71	71	142	88	90	178
8	178	175	353	83	69	152	75	84	159
9	146	142	288	77	90	167	95	95	190
10	190	189	379	123	115	238	131	125	256
11	137	155	292	73	76	149	81	84	165
12	124	156	280	87	72	159	93	93	186
13	139	140	279	77	88	165	100	98	198
14	140	151	291	74	75	149	82	100	182
15	124	121	245	50	53	103	68	64	132
16	113	110	223	35	46	81	61	56	117
17	115	86	201	24	43	67	62	36	98
Total	1537	1557	3094	774	798	1572	936	925	1861

BMI, body mass index.
WC, waist circumference.
% Body fat, percent body fat.

of age. The age intervals were as follows: at 7 year-old = 7.00–7.99; at 8 year-old = 8.00–8.99 and so on. The sample also represents all socioeconomic conditions of Vouzela. The "*Active Vouzela*" project was approved by the Ethics Committee of the Faculty of Sport, University of Porto, all school directors in the region, as well as the Vouzela Health Center. Informed consents were obtained for all parents and/or legal guardians of the participants.

Anthropometric and body fat measurements

Measurements were made by trained, experienced staff following International Society for the Advancement of Kinanthropometry protocols (Ross and Ward, 1986). Height was measured to the nearest 1 mm using a portable stadiometer (Holtain Ltd, UK). Weight (kg) and percent body fat (%, assessed by bio-impedance) were measured using a TANITA BC-418 MA Segmental Body Composition Analyser (Tanita, Corporation, Tokyo, Japan) with a precision of 0.1 kg and 0.1% respectively. Body fat derived measures from the impedance scale have been validated previously with one of the gold standards of body fat assessment, namely dual-energy X-ray absorptiometry (DXA) (Pietrobelli et al., 2005). BMI was derived by calculating the ratio of weight to height, expressed in kg/m^2. Waist circumference was obtained using a non-elastic tape (Sanny, American Medical do Brasil, São Paulo, Brazil) measured to the nearest 1 mm, anatomically identified as the smallest circumference between the lowest rib and the iliac crest's top.

Information quality control

Quality control was assessed in three steps: (1) training and careful supervision of all team members concerning anatomical landmarks, and measurement techniques; (2) retesting 209 randomly sampled youth; (3) estimating technical error of the measurement: 2 mm for height, 0.1 kg for weight, 0.4% for percent body fat and 5 mm for waist circumference. The ANOVA-based intraclass correlation coefficients were: 0.99 for height, 0.98 for weight, 0.98 for percent body fat, 0.99 for waist circumference.

Statistical analysis

Exploratory data analysis was performed to identify input data errors and outliers, as well as to obtain descriptive information (means, standard deviations and range). Height, weight, BMI, body fat and waist circumference centiles, as well as *z*-scores, were derived for boys and girls separately

Table 2
Distribution of z-scores of height, weight, BMI, waist circumference and percent body fat for the Vouzela sample compared to expectations that assume normality.

Percentile	Expected (%)	Height (%)	Weight (%)	BMI (%)	WC (%)	% Body fat (%)
Girls						
3	3	2.7	2.4	2.5	2.5	2.7
10	7	7.2	7.4	7.7	7.8	7.9
25	15	15.0	16.8	15.0	15.1	13.9
50	25	25.4	24.5	26.4	25.5	28.3
75	25	25.2	23.7	23.1	23.1	20.6
90	15	15.2	14.4	14.1	14.6	16.5
97	7	6.3	7.5	7.9	8.6	7.4
Boys						
3	3	2.9	2.6	2.7	2.7	1.8
10	7	6.8	6.8	6.8	5.2	9.7
25	15	14.9	14.4	15.1	17.0	13.9
50	25	24.5	27.2	28.5	28.5	26.5
75	25	27.4	24.6	21.8	20.7	22.4
90	15	14.6	14.3	13.5	13.3	14.0
97	7	5.8	5.8	8.1	9.8	8.6

BMI, body mass index.
WC, waist circumference.
% Body fat, percent body fat.

using the LMS method (Cole and Green, 1992) and obtained using LMSchartmarker Pro version 2.54 software (Pan and Cole, 2004). In brief, the LMS method assumes the Box–Cox power transformation to normalize the data at each age to independent positive values; L, M and S values are cubic splines with knots at each distinct age (t) that have been fitted by maximum penalized likelihood to create three smooth curves: $L(t)$ Box–Cox power transformation; $M(t)$ median; and $S(t)$ coefficient of variation. Centiles curves at age t were obtained as:

$$C_{100\alpha}(t) = M(t)[1 + L(t)S(t)Z_\alpha]^{1/L(t)}$$

where Z_α is the standard deviation of the total sample, and $C_{100\alpha}(t)$ is the corresponding percentile. Equivalent numbers of degrees of freedom (edf) to determine the smoothing's degree to each curve $L(t)$, $M(t)$ and $S(t)$, were selected as described by Pan and Cole (2004), based on deviance statistic (Cole and Green, 1992), Q-tests (Royston and Wright, 2000) and worm plots (van Buuren and Fredriks, 2001).

The data were compared at each age to sex specific CDC 2000 references (Kuczmarski et al., 2000) and WHO 2007 reference (de Onis et al., 2007) centiles for height, weight and BMI. However, WHO 2007 reference for weight only provided percentiles for children aged 5 and 10 years. To compare body fat percentiles, UK (McCarthy et al., 2006), Spanish (Moreno et al., 2007) and USA (Laurson et al., 2011; Mueller et al., 2004) reference samples were used. Waist circumference reference data were compared to the UK (McCarthy et al., 2001), German (Kromeyer-Hauschild et al., 2011), Norwegian (Brannsether et al., 2011), USA (Fernandez et al., 2004) and Portuguese data (Sardinha et al., 2012). The 50th percentiles (median values) were used for all comparisons.

Results

Table 2 shows the distribution of z-scores of height, weight, BMI, waist circumference and percent body fat for girls and boys, respectively. Expected values of the normal distribution for each centile were compared to the proportions of the data in the following fitted centiles: 3rd, 10th, 25th, 50th, 75th, 90th and 97th. The results suggest that a good fit was obtained, as indicated by the closeness among expected and fitted values.

Reference curves for height, weight, BMI and percent body fat for children and adolescents between 7 and 17 years of age of both sexes are presented in Figs. 1 and 2, and numerical results are shown in Tables 3 and 4. Height and weight curves show expected sigmoidal shape patterns. Girls height

Table 3
Percentile values for height (m), weight (kg), BMI, waist circumference (m) and percent body fat in girls.

Age	*L*	*S*	3rd	10th	25th	50th (M)	75th	90th	97th
7	1.51	0.06	1.10	1.15	1.20	1.24	1.29	1.33	1.38
8	1.48	0.05	1.14	1.19	1.23	1.28	1.33	1.37	1.42
9	1.44	0.05	1.18	1.23	1.28	1.32	1.37	1.42	1.46
10	1.40	0.05	1.23	1.28	1.33	1.38	1.43	1.47	1.52
11	1.37	0.05	1.29	1.34	1.39	1.44	1.49	1.54	1.59
12	1.33	0.05	1.35	1.40	1.45	1.51	1.56	1.60	1.65
13	1.29	0.05	1.40	1.46	1.51	1.56	1.61	1.66	1.71
14	1.26	0.05	1.44	1.49	1.55	1.60	1.65	1.70	1.75
15	1.22	0.05	1.47	1.52	1.57	1.62	1.67	1.72	1.77
16	1.18	0.05	1.49	1.54	1.59	1.64	1.69	1.74	1.79
17	1.15	0.04	1.51	1.56	1.61	1.66	1.71	1.76	1.80
7	−0.46	0.20	18.30	20.59	23.32	26.62	30.64	35.62	41.88
8	−0.45	0.21	19.63	22.15	25.15	28.79	33.24	38.77	45.73
9	−0.44	0.21	21.29	24.06	27.39	31.42	36.36	42.51	50.27
10	−0.43	0.21	23.51	26.59	30.29	34.76	40.25	47.06	55.66
11	−0.42	0.21	26.52	29.96	34.07	39.03	45.08	52.56	61.93
12	−0.41	0.20	30.32	34.14	38.66	44.08	50.64	58.66	68.60
13	−0.40	0.19	34.54	38.68	43.55	49.32	56.22	64.56	74.73
14	−0.39	0.18	38.40	42.72	47.75	53.65	60.61	68.90	78.85
15	−0.38	0.17	41.61	45.98	51.01	56.83	63.61	71.56	80.95
16	−0.37	0.15	44.40	48.73	53.65	59.28	65.76	73.25	81.95
17	−0.36	0.14	47.09	51.32	56.08	61.46	67.58	74.55	82.54
7	−1.37	0.13	13.82	14.77	15.89	17.22	18.86	20.93	23.63
8	−1.33	0.14	13.94	14.94	16.12	17.55	19.32	21.57	24.53
9	−1.30	0.14	14.12	15.17	16.43	17.96	19.86	22.29	25.54
10	−1.26	0.15	14.28	15.39	16.72	18.33	20.35	22.94	26.43
11	−1.23	0.15	14.53	15.68	17.07	18.75	20.86	23.59	27.25
12	−1.19	0.15	14.98	16.18	17.62	19.38	21.57	24.39	28.17
13	−1.16	0.15	15.64	16.90	18.40	20.22	22.49	25.37	29.20
14	−1.12	0.15	16.27	17.57	19.11	20.97	23.26	26.16	29.94
15	−1.09	0.14	16.82	18.14	19.70	21.57	23.85	26.69	30.35
16	−1.05	0.14	17.32	18.65	20.21	22.07	24.32	27.09	30.59
17	−1.02	0.13	17.75	19.08	20.64	22.47	24.67	27.35	30.68
7	−1.46	0.10	0.49	0.51	0.55	0.58	0.63	0.68	0.74
8	−1.57	0.11	0.50	0.53	0.56	0.60	0.64	0.70	0.77
9	−1.69	0.11	0.51	0.54	0.57	0.61	0.66	0.72	0.80
10	−1.81	0.11	0.52	0.55	0.59	0.63	0.68	0.74	0.83
11	−1.92	0.11	0.54	0.57	0.60	0.64	0.69	0.76	0.85
12	−2.04	0.10	0.55	0.58	0.61	0.66	0.71	0.77	0.86
13	−2.15	0.10	0.57	0.59	0.63	0.67	0.72	0.78	0.87
14	−2.27	0.10	0.58	0.61	0.64	0.68	0.73	0.79	0.88
15	−2.38	0.09	0.59	0.62	0.65	0.69	0.74	0.80	0.89
16	−2.50	0.09	0.60	0.63	0.66	0.70	0.75	0.81	0.89
17	−2.62	0.09	0.61	0.64	0.67	0.71	0.75	0.81	0.90
7	−0.20	0.18	17.15	19.16	21.46	24.10	27.15	30.66	34.74
8	−0.32	0.18	17.43	19.44	21.76	24.46	27.62	31.35	35.76
9	−0.42	0.18	17.66	19.66	22.01	24.77	28.06	31.99	36.76
10	−0.48	0.19	17.72	19.73	22.10	24.92	28.30	32.40	37.44
11	−0.47	0.19	17.67	19.71	22.11	24.96	28.39	32.55	37.68
12	−0.39	0.19	17.66	19.75	22.21	25.10	28.55	32.70	37.73
13	−0.25	0.19	17.82	20.03	22.60	25.59	29.10	33.23	38.12
14	−0.08	0.19	18.06	20.45	23.18	26.32	29.92	34.06	38.82
15	0.12	0.19	18.18	20.80	23.74	27.04	30.74	34.87	39.49
16	0.36	0.20	18.12	21.03	24.23	27.72	31.52	35.64	40.08
17	0.61	0.20	17.89	21.18	24.68	28.39	32.29	36.39	40.67

BMI - body mass index.

Table 4
Percentile values for height (m), weight (kg), BMI, waist circumference (m) and percent body fat in boys.

Age	*L*	*S*	3rd	10th	25th	50th (M)	75th	90th	97th
7	−0.68	0.05	1.13	1.17	1.21	1.25	1.30	1.35	1.40
8	−0.20	0.05	1.16	1.20	1.24	1.29	1.34	1.39	1.44
9	0.28	0.05	1.20	1.24	1.29	1.33	1.38	1.43	1.48
10	0.76	0.05	1.24	1.29	1.34	1.38	1.43	1.48	1.54
11	1.24	0.05	1.29	1.34	1.39	1.44	1.49	1.54	1.59
12	1.73	0.05	1.34	1.40	1.45	1.50	1.56	1.61	1.65
13	2.21	0.05	1.40	1.45	1.51	1.57	1.62	1.67	1.72
14	2.69	0.05	1.44	1.51	1.57	1.62	1.67	1.72	1.77
15	3.17	0.05	1.49	1.55	1.61	1.67	1.72	1.76	1.81
16	3.65	0.05	1.52	1.58	1.64	1.70	1.75	1.79	1.84
17	4.13	0.04	1.54	1.61	1.66	1.72	1.76	1.81	1.85
7	−1.07	0.18	19.70	21.57	23.84	26.68	30.32	35.18	41.97
8	−0.93	0.19	20.69	22.81	25.39	28.61	32.73	38.16	45.65
9	−0.79	0.20	22.25	24.71	27.70	31.42	36.13	42.28	50.59
10	−0.65	0.21	24.18	27.06	30.54	34.83	40.21	47.12	56.23
11	−0.51	0.21	26.65	30.02	34.07	39.01	45.12	52.79	62.61
12	−0.37	0.21	29.68	33.62	38.31	43.95	50.78	59.15	69.52
13	−0.23	0.21	33.05	37.60	42.94	49.24	56.72	65.63	76.33
14	−0.08	0.20	36.43	41.57	47.51	54.38	62.33	71.56	82.29
15	0.06	0.20	39.67	45.35	51.79	59.08	67.34	76.68	87.22
16	0.20	0.19	42.42	48.55	55.38	62.94	71.32	80.57	90.75
17	0.34	0.18	44.85	51.37	58.49	66.23	74.61	83.67	93.43
7	−3.06	0.10	14.40	15.06	15.85	16.85	18.17	20.04	23.07
8	−2.70	0.11	14.33	15.07	15.98	17.13	18.66	20.86	24.50
9	−2.35	0.13	14.36	15.20	16.23	17.53	19.28	21.78	25.85
10	−2.04	0.14	14.50	15.43	16.58	18.03	19.96	22.68	26.98
11	−1.78	0.14	14.73	15.76	17.01	18.60	20.67	23.54	27.88
12	−1.56	0.15	15.08	16.19	17.54	19.23	21.41	24.36	28.65
13	−1.42	0.15	15.52	16.71	18.14	19.91	22.17	25.17	29.38
14	−1.34	0.15	16.01	17.25	18.74	20.58	22.89	25.93	30.11
15	−1.33	0.15	16.54	17.82	19.35	21.23	23.59	26.67	30.89
16	−1.34	0.15	17.01	18.31	19.87	21.77	24.17	27.30	31.58
17	−1.37	0.14	17.43	18.75	20.32	22.25	24.68	27.85	32.18
7	−4.36	0.07	0.51	0.53	0.55	0.57	0.60	0.64	0.71
8	−4.10	0.08	0.52	0.54	0.56	0.59	0.63	0.68	0.76
9	−3.85	0.09	0.53	0.55	0.58	0.61	0.65	0.71	0.82
10	−3.59	0.10	0.54	0.56	0.59	0.63	0.67	0.75	0.87
11	−3.33	0.10	0.55	0.58	0.61	0.65	0.70	0.78	0.91
12	−3.08	0.11	0.56	0.59	0.62	0.66	0.72	0.80	0.94
13	−2.82	0.11	0.58	0.61	0.64	0.68	0.74	0.82	0.96
14	−2.56	0.11	0.59	0.62	0.66	0.70	0.76	0.84	0.97
15	−2.31	0.11	0.61	0.64	0.68	0.72	0.78	0.86	0.98
16	−2.05	0.11	0.62	0.66	0.70	0.74	0.81	0.88	0.99
17	−1.79	0.11	0.64	0.67	0.71	0.76	0.83	0.91	1.01
7	−2.05	0.14	15.85	16.90	18.20	19.85	22.07	25.28	30.52
8	−1.86	0.17	15.45	16.63	18.12	20.07	22.77	26.85	34.09
9	−1.66	0.19	15.08	16.40	18.07	20.29	23.42	28.29	37.33
10	−1.48	0.21	14.63	16.06	17.89	20.34	23.83	29.32	39.59
11	−1.30	0.23	13.89	15.39	17.34	19.96	23.73	29.67	40.72
12	−1.15	0.25	12.97	14.51	16.51	19.22	23.10	29.18	40.18
13	−1.02	0.26	12.10	13.64	15.64	18.33	22.16	28.05	38.27
14	−0.93	0.26	11.42	12.93	14.89	17.51	21.19	26.72	35.94
15	−0.86	0.26	11.03	12.52	14.43	16.96	20.47	25.60	33.77
16	−0.78	0.26	10.89	12.38	14.27	16.73	20.08	24.84	32.06
17	−0.70	0.25	10.86	12.35	14.24	16.66	19.89	24.34	30.79

BMI - body mass index.

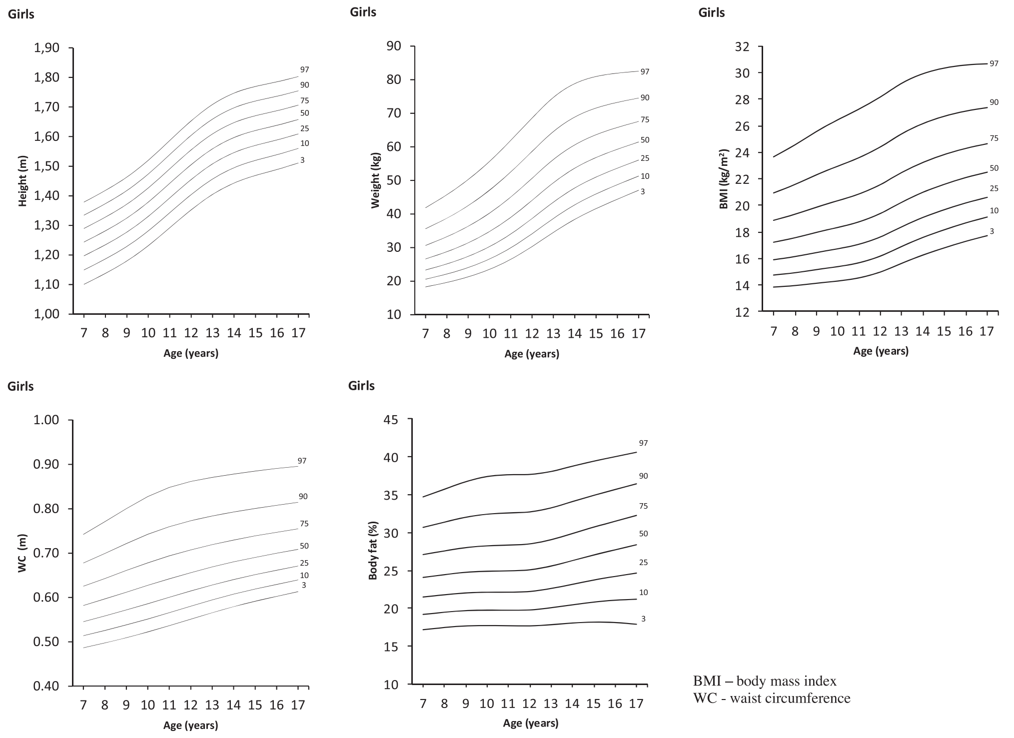

Fig. 1. Vouzela girls' reference charts for height, weight, BMI, waist circumference and percent body fat.

median values (50th percentile) indicate a more pronounced increases from 10 to 13 years, ranging from ~54 to ~63 mm. From 15 to 17 years growth gradually slows down. In boys, the median values' largest increase is from 11 to 14 years (60 mm), with a gradual slowing down by 16 years of age.

Median values (50th percentile) for weight show a curvilinear rise in both sexes, being more pronounced (~5 kg) from 13 to 14 years in boys, and 12–13 years in girls. In general, girls are lighter than boys. Largest differences between sexes are at ages 16 and 17 in the 90th and 97th percentiles, where the differences range from ~7.3 to ~10.9 kg respectively.

In both sexes the BMI median values increased across age, from about 17 kg/m^2 to 22 kg/m^2, with no substantial differences between them. In the BMI values for the 50th percentile, differences are between 0.15 and 0.43 kg/m^2. Median values of percent body fat increase with increasing age (7–17 years) only in girls, ~4%; in boys there is a small decrease of 3%. Girls show greater median values of percent body fat than boys at all ages and percentiles, with the exception of the 97th percentile, where boys from 8 to 12 years of age have about 0.6–3% more percent body fat than girls of the same age. Median values of waist circumference increase with age in both sexes; however boys have greater growth rates, as well as greater absolute values at almost all ages and percentiles.

Comparison with CDC and WHO references

Fig. 3 illustrates the comparison of the 50th percentile between the Vouzela data, CDC reference charts (Kuczmarski et al., 2000) and WHO 2007 reference charts (de Onis et al., 2007). Height, weight and BMI curves show similar shapes between samples with curvilinear increases across the ages. In both sexes, height's median values are very close to each other. With regard to weight, the 50th percentile is higher for Vouzela than observed in CDC and WHO data, a similar pattern is observed in the Vouzela BMI median values for each sex.

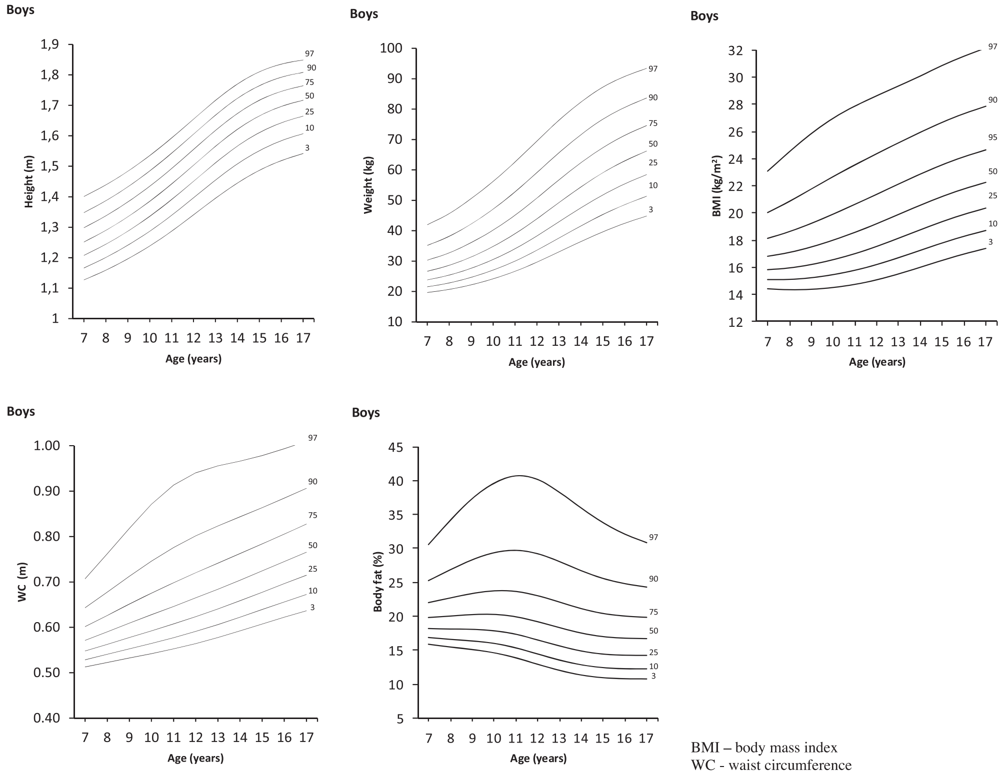

Fig. 2. Vouzela boys' reference charts for height, weight, BMI, waist circumference and percent body fat.

Body fat comparisons

Comparison of current reference (50th percentile) for percent body fat against data from other populations is shown in Fig. 4. In general, median values are higher for Vouzela children at all ages, mostly in girls but also, in 8–12 year old boys compared to the USA 2004 data. The greatest discrepancy among these studies is observed between 7 and 12 years of age. From 12 years onwards differences decrease. Even though there are differences in the shapes of percent body fat curves, all samples show that girls increase their percent body fat median values with age whilst boys demonstrate a decrease, the exception being observed in the Spanish sample.

Waist circumference comparisons

Median values show linear increase with age and the shape of centile curves shows similarity across samples (Fig. 5). In comparison with the US sample and another Portuguese youth reference, Vouzela girls have lower 50th percentile values after 11 years, and the differences increase with age, whilst in boys these values are very close. Furthermore, compared with the UK, Germany, and Norway samples, waist circumference median values are higher, mainly in girls. The UK sample has the lowest median values.

Discussion

This study provides population specific references for height, weight, BMI, waist circumference and percent body fat for children and youth from Vouzela. Vouzela is a small region with a rural

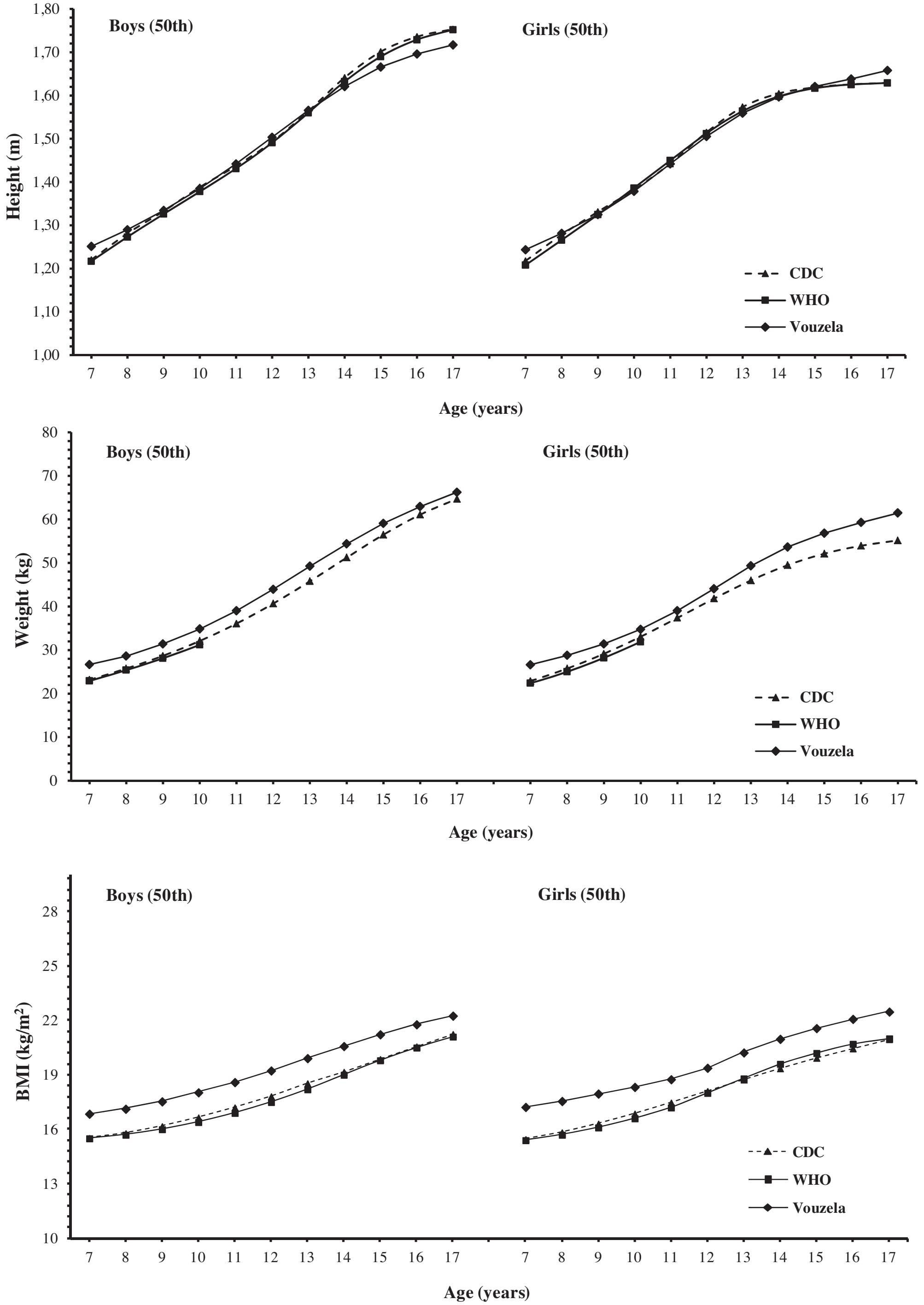

Fig. 3. Comparison of the 50th percentiles from Vouzela, Centers for Disease Control and Prevention (CDC) and WHO charts.

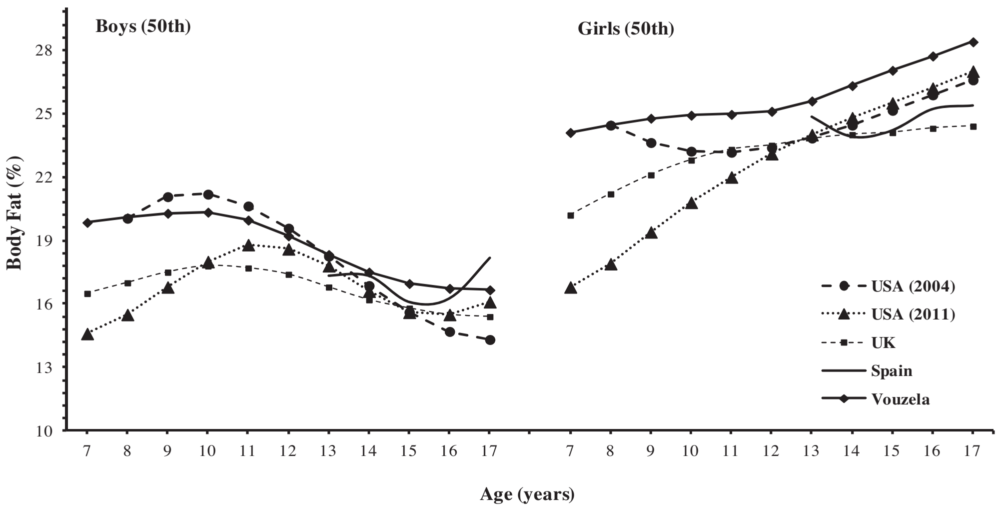

Fig. 4. Comparison of Vouzela reference charts (50th percentile) for percent body fat development with the UK, Spain and USA charts.

predominance in primary sector activities influencing the populations' economy and development. The orographic and environmental characteristics have distinguished Vouzela from other more industrialized urban centers of Portugal. Reasons for this include difficult road access and significant altitude variability (about 900 m in some areas) as well as a great sprawl of housing construction. Moreover, insufficient basic infrastructure, namely water supply and sanitation, low education levels and lack of activities for child and youth leisure time, have been revealed as serious problems for this region, affecting the municipality development and Vouzela's population health (Câmara Municipal de Vouzela, 2010, 2011). The purpose of this study is not to present normal percentile charts, as this may make

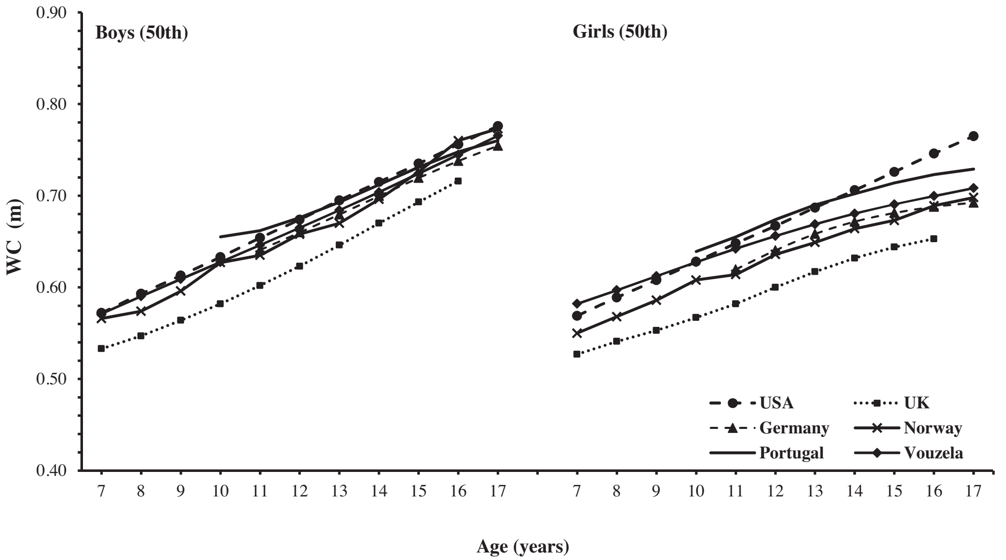

Fig. 5. Comparison of Vouzela reference charts (50th percentile) for waist circumference development with the UK, Portugal, Canada and USA charts.

some obese individuals appear normal, but to provide reference data for comparisons which can be used for other children in similar regions of Portugal. However, the reference centile curves provided in the present paper for height and weight do suggest, at most ages, that Vouzela boys are taller and heavier than Vouzela girls, an expected pattern observed in similar studies (de Onis et al., 2007; Kuczmarski et al., 2000; Roelants et al., 2009; Silva et al., 2012).

Since no references for height, weight or BMI have been documented for Portuguese children and adolescents, it is customary practice for Portuguese Pediatricians to use CDC growth charts (Kuczmarski et al., 2000) to monitor and screen individuals and investigate population growth, to help in the assessment of health and nutritional status.

Present findings show that median values of Vouzela children and adolescent's median heights are similar to those from the CDC and WHO references, while weight median values appear to be higher. These differences and variability can be attributed to several reasons.

The CDC growth reference, published in 2000, refers to five surveys conducted at different time points between 1963 and 1994, with healthy children and adolescents, including NCHS 1977 growth reference (Hamill et al., 1977), also referred to as NCHS/CDC/WHO growth charts; all had conditions that enhanced growth and development without environmental insults to their genetic potential (Kuczmarski et al., 2000), which may not be the case in Vouzela. The WHO's 2007 growth charts are a complex combination of data sets from the (i) NCHS/WHO 1977 growth reference (Hamill et al., 1977) comprising non-obese individuals, (ii) expected heights derived from the Fels Research Institute surveys during the 1929–1975 period, (iii) the NCHS data for children and youth 2–18 years of age sampled between 1963 and 1974, (iv) and the WHO Child Growth Standards (WHO, 2006). In contrast, the Vouzela sample included all social and economic strata, and all possible children and adolescents' weight categories.

Vouzela's children and youth weight and BMI median values need to be considered with reference to their body composition; it is unknown if the high BMI and weight median values are due to greater fat mass values or greater fat-free mass values. Since neither the CDC nor the WHO references provided any body composition data, comparisons of percent body fat were made with two the USA samples (Laurson et al., 2011; Mueller et al., 2004) and two European studies from Spain (Moreno et al., 2007) and the UK (McCarthy et al., 2006). Body fat reference values for the USA from the NHANES population-based sample (Kelly et al., 2009) were not included in our comparison, inasmuch as the results were provided only for selected age groups (8–11 years, 12–15 years, and 16–19 years).

It was found that reference centiles for percent body fat showed similar sex differences; girls appeared to increase median values with age, and boys decreased with age, although the centile curves showed different changes in the magnitude of the effect. These sex differences occur in all human populations, physiologically provided for by hormonal factors, observed prior to puberty (Kirchengast, 2010; Malina, 1986; Wells, 2007). Vouzela girls show greater percent body fat median values at all ages than those in the comparison groups, an effect also observed in boys between 12 and 17 years. These differences may be due to the different methods used to estimate percentage body fat (Laurson et al., 2011; Moreno et al., 2007; Mueller et al., 2004). Only the British study ($n = 1985$) used the same method and protocol as had been used in Vouzela children and youth to estimate percent body fat (McCarthy et al., 2006), suggesting lower median values than Vouzela data and other compared samples.

As indicated previously, the Vouzela region reflects, partially, a peripheral location in the national context due to serious problems associated with its basic infrastructure, relatively low education levels and few opportunities for physical activity practices, especially for leisure-time (Câmara Municipal de Vouzela, 2010, 2011). These issues are clearly demonstrated in the lower developmental indices, namely, demography, social and health support, family income, education and culture, employment and economic activity below the district and country averages (Fonseca, 2002). Despite the absence of specific, valid, and reliable references related to Portuguese nutritional habits, the Portuguese food balance (PFB) (INE, 2006, 2010) documented during the period 1990–2003, that an average Portuguese had an imbalanced diet deficient in fruits, vegetables and legumes. Between 2003 and 2008 this imbalance worsened with excessive energy and saturated fats intakes, as well as, excessive consumption of meat, fish, eggs, oils and other fats. These nutritional factors could have contributed to the observed increases in percent body fat.

Comparisons of waist circumference centiles with previous studies are also difficult, mainly due to different measurement protocols and lack of standardization between them (Inokuchi et al., 2007). For example, in the Vouzela children and adolescents, the waist circumference was measured at the point of noticeable waist narrowing; on the other hand, in the German, Norway and UK samples, it was measured midway between the tenth rib and the top of iliac crest, whereas in the USA sample it was measured at just above the uppermost lateral border of the right ilium.

The differences in weight, BMI, percent body fat and waist circumference could also derive from differences in the populations' genetic constitution. It is well documented in previous studies (Katzmarzyk et al., 2000; Rice et al., 1997; Wu et al., 2003) that a moderate to strong genetic influence is present in obesity-related phenotypes, and a wide range of the estimated genetic factors among various populations (Yang et al., 2007). It is also possible that built and natural environment specific features, linked to nutritional trends, public health care and physical activity levels may have differently affected the differences found (Guedes and Guedes, 1997).

One limitation of this study may be ascribed to its sample size (n = 1572 for waist circumference, 1869 for percent body fat, and 3094 for height, weight, and BMI), although it represents about 80% of all children and adolescents, as well as all socioeconomic conditions found in Vouzela. On the other hand, the small standard errors found in the LMS curve estimates, ensure good fit of the data. It is also important to highlight that previous studies have used samples of similar sizes in order to construct reference charts (McCarthy et al., 2006; Moreno et al., 1999; Mueller et al., 2004). For example, to construct percent body fat references for European children and adolescents aged 5–18 years the sample was 1985, for the USA the sample of 8–17 year olds was 678, and in the Spanish waist circumference references the sample of 6–14.9 year old children and adolescents was 1360 individuals. This study has two important strengths that should be acknowledged. Firstly, the LMS method is highly elegant, robust and powerful (Pan and Cole, 2004) in computing precise and consistent estimates of interindividual variability in growth and body composition characteristics, and has been shown to have clear advantages compared to other estimation methods (Roelants et al., 2009). Furthermore, the software, LMS ChartMaker Pro, provides distinct graphical representation of reference curves, displays them accurately, smoothes out values' distribution and maintains a balance between data reliability and adjusted models parsimony. Secondly, the present anthropometric and body composition measurements are highly reliable and within expected error limits (Lohman et al., 1988). Thirdly, these reference data will be of great assistance to pediatricians, nutritionists, and all those involved in the growth and development of these children.

In conclusion, this study adds new data on growth, body composition and waist circumference and produces references for rural Portuguese children and adolescents. These are important information for educationists, pediatricians, nutritionists, exercise pediatric scientists and coaches involved in youth sports. The present report makes available relevant local references about growth and body composition of children and adolescents, and may be useful for establishing specific population growth patterns and for assessing health status.

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