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NEW HEIGHT AND WEIGHT GROWTH REFERENCES FOR BOYS AND GIRLS FROM BISCAY (4–21 YEARS)

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Abstract: *New growth references of height and weight for Biscay were derived by the application of LMS method to three cross-sectional surveys, from 1988 to 1998, pooled together. External validity of the references proposed was tested checking the homogeneity of techniques and performance of the practitioners in data collection, lack of a noticeable effect of secular trend among surveys (homogeneity of morphology across samples), and also the improvement of the accuracy of the determination of extreme centiles due to wide sample sizes and variability. The references based on 2,686 boys and 2,898 girls aged 4 to 21 years represented urban and rural variability from Biscay, as well as ecological variability due to socio-economic effects in Basque people. The performance of the new references was analysed by means of the identification of the proportion of subjects above or below selected cut-off points. Height growth reference of Sobradillo et al. (2004), proposed to be used for Spanish people, showed always less subjects above high cut-off points (97th percentile and +2SDS) in both sexes with respect the new proposed reference. These differences in classification above the 97th percentile were significant ($\chi^2(1df)=12.251$, $p<0.001$ in males and $\chi^2(1df)=4.653$, $p<0.05$ in females) and also above +2SDS ($\chi^2(1df)=8.000$, $p<0.01$ in males). Significant differences between proportions of above +2SDS females were also found ($\chi^2(1df)=4.77$, $p<0.05$) due to the more frequent identification of heavy subjects by the reference of Sobradillo et al. (2004) with respect to the new reference (present study). The findings are interpreted as a result of differences in the origin of the samples used to construct references. Finally, authors recommend the use of the new references for Basque people from Biscay because they can describe a wider geographic and ecological variability in population studies to follow-up adolescent public health and physical status.*

Keywords: *Basque population; Growth charts; Height references; Weight references; LMS.*

Introduction

Growth charts have been often developed from a wide sample and then adapted to produce externally valid references to be used as National charts in UK (Cameron 2002) and Spain (Sobradillo et al. 2004). They can be used to identify subjects under selected cut-off lines, thus the use of new charts and reference values can change diagnostics and the proportion of identified subjects. Pooling surveys to gather wider ranges of biological variability has been the chosen method for updating National references in UK (Freeman et al. 1995) and USA (Kuczmarski et al. 2000) by means of the LMS procedure. In fact the use of the LMS (Cole and Green 1992) is adequate to pool together surveys of different periods or origin. Surveys can be weighted as done in the reference of CDC 2000 (CDC 2002) to construct new charts. Moreover, flexible models also permit the inclusion of published references to pool centile values as it has been proposed to construct the new Spanish (National) references by the LMS (Rebato et al. 2002).

However, the performance of new references needs to be evaluated by means of an analysis of the classification of new collected data as done by de Onís and Onyango (2003) by computing z scores and proportions below and above specific diagnostic cut-off lines on a sample of infants.

In Spain a longitudinal growth reference from surveys done in the Basque Country was developed (Hernández et al. 1988), and it is available for clinical use by health practitioners (Ruiz 1989). However, subjects were drawn from urban sampling and had the limitation of not covering the environmental rural/urban variability of the population and also did not cover the end of adolescence age range and earlier adulthood. These references have been recently up-dated by Sobradillo et al. (2004) by means of a new survey based again on urban population. In the late 80's and 90's, some studies based on cross-sectional surveys were undertaken by the University of Basque Country from 1988 to 1998 to study biological variability caused by the diversity of human environments either in rural (Rosique 1992) or urban (González-Apraiz 1997) and post-industrialized locations of Biscay (Rosique et al. 2001, Bilbao et al. 2003/2004).

The aim of this study is constructing an updated reference of growth curves of height and weight for boys and girls from Biscay based on pooling three cross-sectional growth surveys done from 1988 to 1998, by the application of the LMS method. External validity criteria were checked to recommend the new references for their use by practitioners. The classification of subjects above or below selected cut-off lines of the growth charts was chosen as an adequate method of studying the performance of the reference against the cross-sectional reference for Spain (Sobradillo et al. 2004).

Material and Methods

The total sample was 2,686 boys and 2,898 girls aged 4 to 21 years. The sample was collected from three different growth surveys aimed to cover environmental and geographic variability of the Biscayan population (Basque Country). Surveys were undertaken in 1988–91 (in rural coastal locations), 1992–95 (in an urban population) and 1996–98 (in a post-industrialized urban population). Corresponding growth studies were presented in Rosique (1992), González-Apraiz (1997), Rosique et al. (2001) and Bilbao et al. (2003/2004). Only three trained and standardized anthropometrists took the measures (height and weight) with the same measurement protocol under the criterion of the same supervisor. Decimal ages were calculated in years as the difference between date of birth and date of measurement.

The homogeneity of the data was tested after pooling surveys in one data base by means of computing, for each survey, the residuals of each data point to the median by (each) age, as suggested by Rebato et al. (2006). The residuals were homogeneous enough to permit pooling surveys because they largely accomplished the criteria of homogeneity: a) no deviations from normality checked by means of the Kolmogorov-Smirnov test of normality, b) a random distribution checked by means of a RUNS test, and c) homogeneity of variances checked by the absence of correlation between typified residuals and expected values.

LMS procedures to fit original data

LMS pro 1.29 software (Cole and Pan 2004) licensed to the Laboratory of Anthropology of the University of Basque Country was used to fit seven percentiles (3rd, 10th, 25th, 50th, 75th, 90th and 97th). During fitting procedures a detrended Q-Q plot was used to identify those "outliers" influencing the fit to a normal distribution, and then some heterogeneous data points were excluded. The visual display of the normal worm line was used as a criterion of exclusion. After clearing some extreme residuals, data were refitted to obtain the best distribution of the set of centile curves.

Fitting procedures started with the recommended LMS values of equivalent degrees of freedom (edf) 3, 5, and 3. The final edf of 3, 7, and 5 for height boys and 3, 5, and 4 for height girls, with rescaled age to fit data, yielded significant changes in deviance ranging from 76.6 to 10.9 for boys and from 98.2 to 9.6 for girls. Weight was fitted by final edf of 3, 7, and 4 for boys and girls, rescaling age to find either a better distribution of centiles or greater change in deviance. Those changes ranged from 46.5 to 5.2 in boys and from 84.5 to 4.5 in girls. In both sexes, the lowest deviance changes found in height and weight always were significant (equivalent chi-square with 1df, $p<0.05$). LMS values, and centiles at each age (every half a year) were computed in boys and girls to draw new growth charts and reference tabulated values for boys and girls from Biscay.

Analysis of reference performance

The performance of the new reference was studied by comparing the proportion of subjects (from an external sample) above or below selected cut-off lines of the new charts in comparison with the proportions found by the cross-sectional references of Sobradillo et al. (2004). The external sample of adolescents (10–20 years) was built by pooling: 1) a representative sample of 1,201 boys and girls (14–16 years) collected by Fernández-López (2006) and 2) a sample of 1,542 subjects of both sexes (10–20 years) from the Coast of Biscay from the survey of Rosique (1992). The samples pooled had a wide coverage of the Biscay geography. Selected cut-off points of height and weight were, on the one hand percentiles 3rd and 97th (±1.88 SDS) and on the other hand SDS≤–2.00 and SDS≥+2.00. From the reference values, two sets of z scores of the pooled sample were computed using the LMS standardization method on the subjects:

when L does not equal 1, $Z = [(x_i / M)^L - 1]/(L \times S)$,

when L equals 1, $Z = [Ln\ (x_i / M)]/S$,

when L equals 0, $Z = (x_i - M)/(S \times M)$.

Frequencies of subjects were identified by the corresponding z score below cut-off lines (3rd and –2SDS) and above cut-off lines (97th and +2SDS) in both references. The proportion of identified subjects was compared by a chi-square test (χ^2) with 1df.

Results

New references from Biscay

Tables 1 and 2, for boys and girls respectively, show the obtained reference values of L, M and S parameters and also height by age centile values smoothed by the application of the LMS pro 1.29. Obtained parameters and smoothed centiles for weight are shown in Table 3, for boys, and Table 4 for girls. Mean adult height at 21.0 years in the new reference (M values) was 174.4 cm in boys and 162.0 cm in girls, and mean weight at 21.0 years was 72.95 kg in boys and 57.17 kg in girls. While M values displayed the 50th centile of the fit, S values for height references were close to 0.04 in boys (Table 1) and ranged from 0.02 to 0.05 in girls (Table 2).

Weight references displayed S values ranging between 0.1 and 0.2 in both sexes (Tables 3–4). L values coped with departures from normality in height and weight for boys and girls. In height references, for boys, L values were positive in the whole age range showing left asymmetry of the distribution and thus a lack of frequencies of short boys (Table 1). In girls, signs of L changed along the age range for height references. Starting with negative values up to 7.0 years of age, changing to positive values up to 13.0 years of age and finally again to negative values up to 21 years of age (Table 2). As a consequence girls tended to show higher frequencies of short subjects than boys. However, L values of weight references in boys and girls were negative in the whole age range (Tables 3–4) and only tended to approach normality in males at the end of the age range analysed (Table 3).

Table 1. Centile values of height by age in boys (3rd, 10th, 25th, 50th shown as M, 75th, 90th, 97th) and final values of the L, M and S parameters by intervals of 0.5 from 4 to 21 years.

Age (ys)	L	M	S	3	10	25	75	90	97
4.0	1.473	104.589	0.039	96.9	99.3	101.8	107.3	109.7	112.1
4.5	1.474	107.467	0.040	99.3	101.9	104.6	110.3	112.9	115.3
5.0	1.475	110.646	0.041	102.0	104.8	107.6	113.7	116.4	119.0
5.5	1.475	113.814	0.042	104.7	107.6	110.6	117.0	119.8	122.6
6.0	1.473	116.930	0.043	107.3	110.4	113.5	120.3	123.3	126.2
6.5	1.465	119.886	0.044	109.8	113.1	116.3	123.4	126.5	129.6
7.0	1.448	122.696	0.045	112.2	115.6	119.0	126.4	129.6	132.8
7.5	1.413	125.455	0.045	114.7	118.2	121.6	129.2	132.6	135.9
8.0	1.356	128.290	0.045	117.3	120.8	124.4	132.2	135.6	139.0
8.5	1.284	131.124	0.045	120.0	123.6	127.2	135.1	138.6	142.0
9.0	1.207	133.873	0.044	122.6	126.2	129.8	137.9	141.5	145.0
9.5	1.129	136.461	0.044	125.0	128.7	132.4	140.5	144.2	147.8
10.0	1.055	138.933	0.044	127.3	131.0	134.8	143.1	146.8	150.5
10.5	0.990	141.363	0.045	129.4	133.2	137.1	145.6	149.5	153.3
11.0	0.938	143.772	0.046	131.4	135.4	139.3	148.2	152.2	156.2
11.5	0.904	146.261	0.047	133.4	137.5	141.6	150.9	155.1	159.2
12.0	0.891	148.856	0.048	135.4	139.7	144.0	153.7	158.1	162.4
12.5	0.901	151.662	0.049	137.6	142.1	146.6	156.7	161.3	165.8
13.0	0.923	154.783	0.050	140.2	144.8	149.5	160.0	164.8	169.5
13.5	0.940	158.125	0.051	143.1	147.9	152.7	163.5	168.4	173.2
14.0	0.932	161.546	0.050	146.6	151.3	156.2	166.9	171.8	176.6
14.5	0.892	164.739	0.047	150.1	154.7	159.5	170.0	174.8	179.5
15.0	0.834	167.395	0.045	153.3	157.8	162.3	172.5	177.1	181.7
15.5	0.772	169.512	0.043	156.0	160.3	164.6	174.4	178.9	183.3
16.0	0.716	171.170	0.041	158.2	162.3	166.5	175.9	180.2	184.4
16.5	0.670	172.433	0.039	159.9	163.8	167.9	177.0	181.2	185.3
17.0	0.637	173.307	0.038	161.0	164.9	168.9	177.8	181.9	185.9
17.5	0.617	173.838	0.038	161.7	165.6	169.5	178.3	182.3	186.3
18.0	0.607	174.108	0.037	162.1	165.9	169.8	178.5	182.5	186.5
18.5	0.603	174.207	0.037	162.2	166.0	169.9	178.6	182.6	186.5
19.0	0.602	174.237	0.037	162.3	166.0	169.9	178.6	182.6	186.5
19.5	0.601	174.259	0.037	162.3	166.1	169.9	178.6	182.6	186.6
20.0	0.599	174.299	0.037	162.4	166.1	170.0	178.7	182.6	186.6
20.5	0.597	174.351	0.037	162.4	166.2	170.0	178.7	182.7	186.6
21.0	0.596	174.392	0.037	162.5	166.2	170.1	178.7	182.7	186.6

Table 2. Centile values of height by age in girls (3rd, 10th, 25th, 50th shown as M, 75th, 90th, 97th) and final values of the L, M and S parameters by intervals of 0.5 from 4 to 21 years.

Age (ys)	L	M	S	97	90	75	25	10	3
4.0	−1.938	102.612	0.040	95.7	97.7	100.0	105.5	108.3	111.3
4.5	−1.641	105.895	0.040	98.7	100.8	103.1	108.9	111.7	114.7
5.0	−1.334	109.304	0.040	101.7	104.0	106.4	112.3	115.3	118.3
5.5	−1.032	112.675	0.040	104.8	107.2	109.7	115.8	118.8	121.9
6.0	−0.736	115.968	0.040	107.7	110.2	112.9	119.2	122.3	125.4
6.5	−0.439	119.158	0.041	110.5	113.2	115.9	122.5	125.6	128.8
7.0	−0.135	122.201	0.041	113.1	115.9	118.9	125.6	128.8	132.1
7.5	0.169	125.120	0.042	115.6	118.6	121.6	128.7	132.0	135.3
8.0	0.458	127.942	0.042	118.0	121.1	124.3	131.6	135.0	138.4
8.5	0.713	130.707	0.043	120.2	123.5	126.9	134.5	138.0	141.5
9.0	0.914	133.484	0.044	122.5	126.0	129.5	137.5	141.0	144.6
9.5	1.045	136.327	0.045	124.8	128.5	132.2	140.4	144.1	147.8
10.0	1.096	139.253	0.045	127.3	131.1	135.0	143.5	147.3	151.1
10.5	1.073	142.212	0.045	130.0	133.9	137.8	146.6	150.5	154.3
11.0	0.980	145.142	0.045	132.8	136.7	140.7	149.6	153.6	157.5
11.5	0.825	147.975	0.045	135.6	139.5	143.5	152.5	156.5	160.5
12.0	0.624	150.648	0.044	138.4	142.3	146.2	155.1	159.2	163.3
12.5	0.394	153.085	0.043	141.1	144.8	148.7	157.5	161.6	165.7
13.0	0.157	155.213	0.041	143.5	147.2	150.9	159.6	163.6	167.7
13.5	−0.063	156.988	0.040	145.6	149.2	152.8	161.3	165.3	169.3
14.0	−0.252	158.403	0.039	147.3	150.8	154.3	162.6	166.5	170.5
14.5	−0.402	159.477	0.038	148.7	152.0	155.5	163.6	167.5	171.4
15.0	−0.513	160.252	0.037	149.6	152.9	156.3	164.3	168.2	172.1
15.5	−0.592	160.792	0.037	150.3	153.5	156.9	164.8	168.6	172.5
16.0	−0.646	161.164	0.036	150.8	153.9	157.3	165.2	169.0	172.8
16.5	−0.684	161.422	0.036	151.1	154.2	157.6	165.4	169.2	173.0
17.0	−0.709	161.593	0.036	151.3	154.4	157.8	165.6	169.3	173.2
17.5	−0.724	161.698	0.036	151.4	154.6	157.9	165.7	169.4	173.3
18.0	−0.732	161.754	0.036	151.5	154.6	157.9	165.7	169.5	173.3
18.5	−0.734	161.767	0.036	151.5	154.6	157.9	165.7	169.5	173.3
19.0	−0.738	161.791	0.036	151.5	154.7	158.0	165.8	169.5	173.3
19.5	−0.745	161.841	0.036	151.6	154.7	158.0	165.8	169.5	173.4
20.0	−0.754	161.905	0.036	151.7	154.8	158.1	165.9	169.6	173.4
20.5	−0.765	161.976	0.036	151.8	154.9	158.2	165.9	169.7	173.5
21.0	−0.769	162.005	0.035	151.8	154.9	158.2	166.0	169.7	173.5

When comparing mean height and weight (50th centile) in both references, means were higher in Sobradillo et al. (2004) at almost all ages, for both sexes. The same was found for other centile height lines. On the contrary, upper weight centiles were higher in the new proposed reference.

The lower and upper centiles (3rd and 97th) of the non-smoothed reference of Sobradillo et al. (2004), in both sexes, were plotted against the growth charts for height (Fig. 1) and weight (Fig. 2) in the age range of 10 to 18 years. The lower centile (3rd) of the non-smoothed reference of Sobradillo et al. (2004) showed heights above the same centile of the new reference for both sexes in almost all ages (Fig. 1). The opposite was found when the upper centile (97th) was plotted against the new reference (Fig. 1). However in weight charts, for both sexes, the lower centile (3rd) of Sobradillo et al.

(2004), from 10 to 18 years, lied below the same centile of the new reference and, moreover, the upper centile (97th) was, in girls, below the same centile of the updated reference in almost all ages (Fig. 2).

Table 3. Centile values of weight by age in boys (3rd, 10th, 25th, 50th shown as M, 75th, 90th, 97th) and final values of the L, M and S parameters by intervals of 0.5 from 4 to 21 years.

Age (ys)	L	M	S	97	90	75	25	10	3
4.00	–1.32	18.11	0.15	14.33	15.32	16.51	20.12	22.44	25.44
4.50	–1.26	19.20	0.15	15.12	16.20	17.48	21.37	23.87	27.09
5.00	–1.21	20.32	0.15	15.92	17.08	18.46	22.65	25.33	28.77
5.50	–1.16	21.51	0.15	16.77	18.02	19.51	24.02	26.90	30.57
6.00	–1.10	22.81	0.16	17.68	19.03	20.64	25.52	28.60	32.54
6.50	–1.04	24.14	0.16	18.60	20.06	21.81	27.06	30.37	34.57
7.00	–0.98	25.51	0.16	19.53	21.11	22.99	28.64	32.18	36.65
7.50	–0.92	26.99	0.17	20.53	22.24	24.27	30.36	34.15	38.90
8.00	–0.85	28.63	0.17	21.64	23.49	25.69	32.26	36.33	41.38
8.50	–0.79	30.33	0.17	22.78	24.78	27.16	34.23	38.57	43.93
9.00	–0.73	31.99	0.17	23.88	26.04	28.59	36.14	40.75	46.39
9.50	–0.67	33.57	0.18	24.93	27.24	29.97	37.97	42.82	48.72
10.00	–0.62	35.13	0.18	25.96	28.42	31.31	39.76	44.83	50.95
10.50	–0.56	36.72	0.18	27.02	29.63	32.69	41.57	46.86	53.19
11.00	–0.51	38.35	0.18	28.12	30.88	34.12	43.44	48.93	55.45
11.50	–0.46	40.11	0.18	29.32	32.24	35.66	45.42	51.12	57.84
12.00	–0.41	42.03	0.18	30.65	33.75	37.35	47.57	53.48	60.39
12.50	–0.36	44.28	0.18	32.25	35.54	39.36	50.09	56.23	63.34
13.00	–0.31	47.04	0.18	34.26	37.77	41.83	53.13	59.53	66.88
13.50	–0.28	50.19	0.17	36.63	40.38	44.69	56.58	63.24	70.84
14.00	–0.24	53.54	0.17	39.25	43.22	47.77	60.21	67.11	74.91
14.50	–0.22	56.76	0.17	41.86	46.03	50.77	63.63	70.70	78.63
15.00	–0.19	59.56	0.16	44.24	48.55	53.43	66.55	73.70	81.67
15.50	–0.18	61.88	0.16	46.29	50.69	55.66	68.92	76.08	84.02
16.00	–0.16	63.75	0.15	47.99	52.46	57.49	70.81	77.95	85.83
16.50	–0.14	65.31	0.15	49.43	53.95	59.03	72.37	79.48	87.30
17.00	–0.13	66.60	0.15	50.63	55.19	60.30	73.66	80.74	88.50
17.50	–0.12	67.65	0.15	51.62	56.21	61.34	74.71	81.77	89.48
18.00	–0.11	68.52	0.14	52.44	57.06	62.20	75.56	82.60	90.27
18.50	–0.10	69.27	0.14	53.16	57.79	62.94	76.30	83.32	90.94
19.00	–0.10	69.97	0.14	53.83	58.48	63.64	76.99	83.98	91.57
19.50	–0.09	70.67	0.14	54.51	59.18	64.34	77.68	84.65	92.19
20.00	–0.08	71.40	0.14	55.22	59.90	65.08	78.40	85.34	92.84
20.50	–0.08	72.16	0.14	55.97	60.65	65.84	79.14	86.05	93.51
21.00	–0.07	72.95	0.13	56.73	61.43	66.62	79.91	86.79	94.20

Analysis of reference performance

Table 5 shows the percentage of boys and girls of the pooled sample below or above selected cut-off lines (3rd percentile, 2SDS, 97th percentile and +2SDS). In height by age charts, the proportion of short stature at adolescence, regardless of sex, ranged from 4.2 to 4.8% (below 3rd percentile) or from 3.4 to 4.1% (below 2SDS). In spite that the reference of Sobradillo et al. (2004) displayed a slightly greater proportion of short stature, differences between proportions identified by the references were not significant whatever the sex or the cut-off line considered. Thus, the performance of both references was quite similar when classifying short stature at adolescence. The proportion of tall subjects, disregarding sex, ranged from 2.0 to 4.4% (above 97th percentile) or from 1.6 to 3.3% (above +2SDS). The reference of Sobradillo et al. (2004) identified always less subjects above high cut-off points (97th percentile and +2SDS) in both sexes. However, significant differences were found when classifying males and females above the 97th percentile (χ^2(1df)=12.251, p<0.001 in males and χ^2(1df)=4.653, p<0.05 in females) and also when classifying males above 2SDS (χ^2(1df)=8.000, p<0.01).

Table 4. Centile values of weight by age in girls (3rd, 10th, 25th, 50th shown as M, 75th, 90th, 97th) and final values of the L, M and S parameters by intervals of 0.5 from 4 to 21 years.

Age	L	M	S	97	90	75	25	10	3
4.00	–1.16	18.09	0.13	14.62	15.56	16.66	19.81	21.70	24.00
4.50	–1.10	19.00	0.13	15.27	16.28	17.46	20.86	22.89	25.35
5.00	–1.04	19.96	0.13	15.94	17.03	18.30	21.95	24.13	26.75
5.50	–0.97	21.00	0.14	16.67	17.84	19.21	23.15	25.49	28.30
6.00	–0.89	22.23	0.14	17.51	18.79	20.29	24.57	27.10	30.13
6.50	–0.81	23.75	0.15	18.54	19.96	21.60	26.31	29.08	32.38
7.00	–0.72	25.49	0.15	19.70	21.28	23.11	28.33	31.37	34.98
7.50	–0.63	27.36	0.16	20.91	22.67	24.72	30.50	33.86	37.81
8.00	–0.54	29.16	0.16	22.03	23.98	26.24	32.61	36.29	40.59
8.50	–0.46	30.79	0.17	22.98	25.12	27.60	34.55	38.54	43.17
9.00	–0.38	32.35	0.17	23.85	26.18	28.88	36.42	40.70	45.65
9.50	–0.31	34.00	0.18	24.78	27.32	30.24	38.38	42.98	48.26
10.00	–0.24	35.83	0.18	25.85	28.60	31.78	40.55	45.47	51.08
10.50	–0.18	37.79	0.18	27.04	30.02	33.44	42.84	48.07	53.99
11.00	–0.14	39.95	0.18	28.45	31.65	35.31	45.30	50.83	57.06
11.50	–0.12	42.19	0.18	30.04	33.43	37.30	47.82	53.60	60.09
12.00	–0.11	44.62	0.18	31.94	35.48	39.52	50.46	56.45	63.16
12.50	–0.14	47.13	0.18	34.12	37.76	41.91	53.10	59.23	66.07
13.00	–0.19	49.53	0.17	36.48	40.14	44.30	55.52	61.65	68.51
13.50	–0.25	51.57	0.16	38.72	42.33	46.42	57.46	63.50	70.25
14.00	–0.32	53.13	0.15	40.60	44.13	48.12	58.86	64.74	71.32
14.50	–0.38	54.27	0.14	42.06	45.50	49.39	59.84	65.55	71.96
15.00	–0.42	55.05	0.14	43.08	46.46	50.27	60.49	66.08	72.34
15.50	–0.45	55.56	0.13	43.77	47.09	50.85	60.92	66.41	72.57
16.00	–0.47	55.90	0.13	44.22	47.52	51.24	61.21	66.64	72.73
16.50	–0.48	56.15	0.13	44.55	47.83	51.52	61.41	66.80	72.84
17.00	–0.49	56.34	0.13	44.82	48.07	51.75	61.58	66.93	72.93
17.50	–0.50	56.53	0.13	45.07	48.31	51.96	61.73	67.06	73.02
18.00	–0.51	56.71	0.13	45.31	48.53	52.17	61.88	67.17	73.10
18.50	–0.52	56.87	0.13	45.51	48.72	52.34	62.01	67.28	73.17
19.00	–0.53	56.98	0.12	45.66	48.86	52.47	62.10	67.35	73.22
19.50	–0.53	57.04	0.12	45.75	48.95	52.55	62.16	67.39	73.25
20.00	–0.53	57.09	0.12	45.81	49.00	52.60	62.20	67.42	73.27
20.50	–0.54	57.13	0.12	45.87	49.06	52.65	62.23	67.45	73.29
21.00	–0.54	57.17	0.12	45.92	49.11	52.69	62.27	67.48	73.31

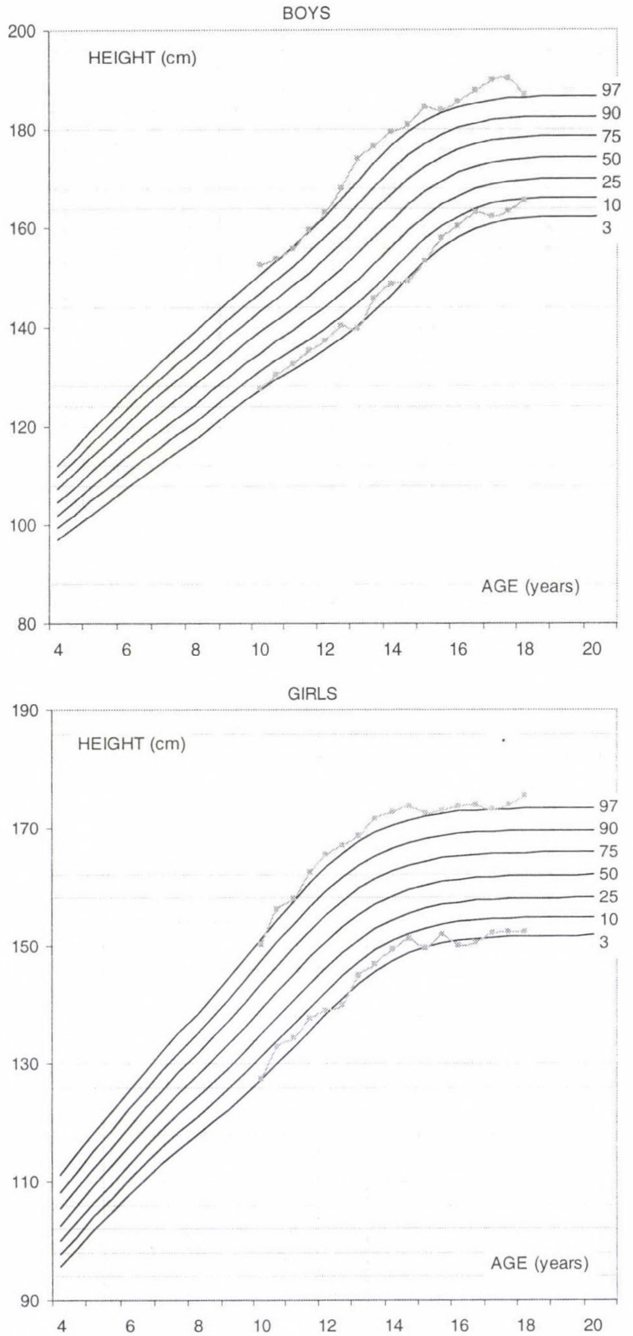

Figure 1: Growth charts for height by age in boys and girls from 4 to 21 years of age. The seven centiles 3rd, 10th, 25th, 50th, 75th, 90th, 97th were smoothed by means of the application of the LMS method. The upper and lower centiles (97th and 3rd) of the unsmoothed reference of Sobradillo et al. (2004) are also shown (marked lines) in the age range of 10 to 18 years.

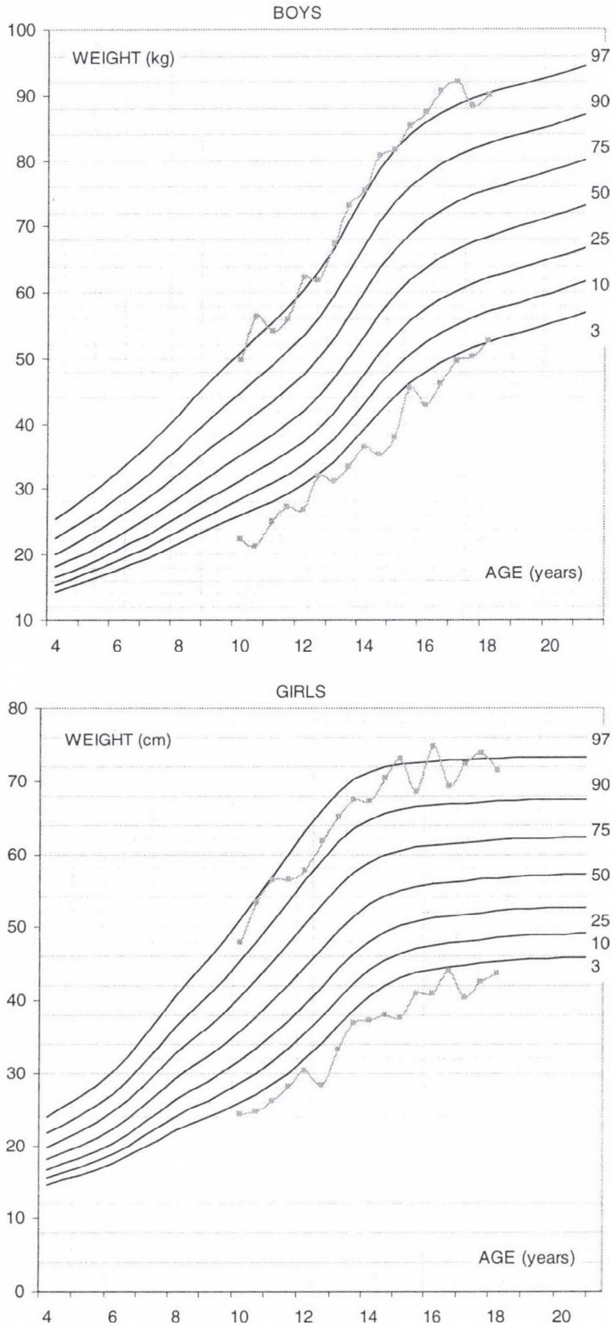

Figure 2: Growth charts for weight by age in boys and girls from 4 to 21 years of age. The seven centiles 3rd, 10th, 25th, 50th, 75th, 90th, 97th were smoothed by means of the application of the LMS method. The upper and lower centiles (97th and 3rd) of the unsmoothed reference of Sobradillo et al. (2004) are also shown (marked lines) in the age range of 10 to 18 years.

In weight by age charts, the proportion of low weight at adolescence, regardless of sex, ranged from 2.6 to 3.1% (below 3rd percentile) or from 1.6 to 2.3% (below 2SDS). Low weight did not show significant differences by reference, whatever the sex or the cut-off line considered. Overweight at adolescence ranged from 3.2 to 5.7% (above 97th percentile) or from 2.7 to 5.1% (above +2SDS). Significant differences between proportions of overweight among references were found only when classifying females above +2SDS (χ^2(1df)=4.77, p<0.05), due to the more frequent identification of heavy subjects by Sobradillo et al. (2004) with respect to the new reference (present study). Both references show the greater proportion of overweight in females with respect to males.

Table 5. Comparison of the proportion of subjects below or above the specific cut-off lines of height by age showed by the references of Sobradillo et al. (2004) and those of the present study (New reference).

Growth chart	Cut-off lines	Males				Females			
		Sobradillo et al. (2004)		New reference		Sobradillo et al. (2004)		New reference	
		n	%	n	%	n	%	n	%
Height by age	3rd percentile	62	4.8	54	4.2	64	4.4	62	4.2
	–2SDS	52	4.1	45	3.5	53	3.6	50	3.4
	97th percentile[1]	25	2.0	56	4.4	43	2.9	65	4.4
	+2SDS[2]	20	1.6	42	3.3	33	2.3	45	3.1
Weight by age	3rd percentile	33	2.6	33	2.6	34	2.3	46	3.1
	–2SDS	30	2.3	28	2.2	24	1.6	34	2.3
	97th percentile	41	3.2	53	4.1	83	5.7	65	4.4
	+2SDS[3]	34	2.7	42	3.3	75	5.1	51	3.5

[1]significant differences found when classifying subjects in 97th percentile, ($\chi^2_{(1df)}$=12.25, p<0.001 in males and $\chi^2_{(1df)}$=4.653, p<0.05 in females)
[2]significant differences only found when classifying males above 2SDS, ($\chi^2_{(1df)}$=8.00, p<0.01)
[3]significant differences found when classifying females above 2SDS, ($\chi^2_{(1df)}$=4.77, p<0.05)

Discussion

New height by age growth charts

Whatever the cut-off point used to classify subjects with short stature in both sexes, this study showed no differences between the cross-sectional references compared. In consequence, the new reference could be used with a screening power similar to the reference of Sobradillo et al. (2004) in paediatric practice or in screening undernutrition in public health. For clinical purposes, other researches have used a more restrictive definition of short stature, i.e., height SDS≤–2.5 (Attie 2000) or even below the 1st centile (Werther 1996). However a less restrictive definition in population screenings is preferred by most scientists, as in present study, i.e., below SDS≤–2.5 (=2.5th centile), or 3.0th centile (Lindsay et al. 1994). Paediatricians, in Europe, use frequently the assessment of child height below 3.0th centile and a growth rate below 25th centile of the velocity growth curve following the child data during 6 months prior to the application of hormone therapy (Evans and Gregory 2004).

The differences found in performance of the references compared in this study, when classifying subjects of high stature, were due probably to differences in height variance caused by sample origin. The reference of Sobradillo et al. (2004) is based on an urban survey including taller adolescent subjects than the new reference with urban and rural subjects pooled. The disagreement found does not have much diagnostic effects in the highest centiles, because the lower centiles are of much larger interest for paediatricians and nutritionists. A greater proportion of taller subjects is more frequent in urban populations and the environmental improvement found in cities should affect more boys than girls, therefore the differences found in this research can be viewed as a result of the ecological differences, hence socio-economics, of the samples.

Mean adult height in the new charts (Tables 1–2) approached to the recent data of mean height of Basque university students (175.6 cm in boys and 162.2 cm in girls: data afforded by Rebato in 2007 unpublished). However, at 18.0 years of age, mean adult height in Basque people (new reference and in Basque university students) was, in both sexes, lower than mean adult height of the cross-sectional reference of Sobradillo et al. (2004), proposed as a reference to be used for Spain. These differences can confirm the ecological effect found here when comparing both references, taking into account that Basque university students are a sample of wide origin, from all around the Basque Country and does not come solely from urban settlements.

New weight by age growth charts

The performance of the new weight by age reference is rather similar to the reference of Sobradillo et al. (2004) in males when classifying either low weight adolescents either overweight adolescents, whatever the cut-off line considered in the charts. However, the differences found when classifying overweight females are probably due to the origin of the sample. The urban survey of Sobradillo et al. (2004) included less overweight subjects than rural surveys. Mean adult weights at 18.0 years of age of the reference of Sobradillo et al. (2004) are lower in both sexes than mean adult weights of the new reference (Tables 3–4) and also with respect to other urban samples (i.e., Basque university students of 22 years old: 73.79 kg in boys and 58.31 kg in girls, Rebato 2007, unpublished data). These differences can confirm the ecological effects observed when comparing references.

Below/above specific cut-off line prevalences at adolescence

In general, in Biscayan adolescents of both sexes, the prevalence of subjects with short stature was slightly higher than the prevalence of tall subjects in both references. However, the definition of tallness in this paper was more restrictive than the usual definition (above 1SDS) in public health studies (OMS 1983). Although low weight screened by a cut-off line below 2SDS can afford the prevalence of mild or severe risk of global undernutrition at adolescence (OMS 1983), a low BMI (below 15th centile) during growth period adapts better to the individual diagnosis. The same can be said about the risk of overweight at adolescence screened by a weight above the cut-off line of +2SDS of the weight by age chart, with respect to consider the frequencies by high BMI (above 85th percentile).

The differences found in weight charts are probably also related with differences in the origin of the samples used to construct references. The sample used to construct the reference of Sobradillo et al. (2004) included both taller and thinner subjects with respect to the new reference sample. These differences could be interpreted as a tendency in urban Basque morphology, that deserve future research, because the reference comparison showed in this study points out a greater proportion of urban females with a leaner phenotype with respect to rural Biscay, and a greater proportion of urban males with a taller phenotype than in rural Biscay.

Basque growth references for Biscay

Johnston (1986) recommended the use of a unique international standard. In that sense, researchers and health practitioners have used the NCHS growth standard developed in USA (Hamill et al. 1977, 1979). However, the tendencies of some countries have been to develop National standards because a better performance in local populations, as in Netherlands (Roede and van Wieringen 1985), Germany (Brandt 1980), Norway (Waaler 1983), UK (Rona and Chinn 1984), Belgium (Vercauteren 1984), etc. In Spain most paediatricians used the references of Hernández et al. (1988) updated by Sobradillo et al. (2004) and proposed those references for National use in spite of the origin of the sample. However, the assumption of those references in Basque population has drawbacks because they were drawn from an urban sample and does not cover the variability related to geography and ecology of the Basque Country. Moreover, the external validity of the references depends on the possible changes of centile positions due to secular trend or due to the design of adequate sampling sizes.

Secular trend in height has been documented in Spanish urban and rural populations (Rebato 1998), although from the last two decades it has been demonstrated that mean height in Basque Country has not suffered important changes (Bilbao et al. 2003/2004). In consequence, it is not necessary to take into account the effect of secular trend when pooling samples to design new Basque references for Biscay and it is more useful to consider the effect of pooling samples as a proxy method of including a wider geographic and ecological variability, hence socio-economic variability.

Cameron (2002) found external validity of references when samples involved in their design, against new samples, have morphological similarity, and the sample size is enough to describe accurate population parameters (extreme centiles). Accuracy of extreme centiles is good enough in both references compared because they accounted for 0.5% of the census of 2006 in the new reference and 0.6% for the reference of Sobradillo et al. (2004). Therefore, the new growth references of height and weight for Biscay proposed in this research can be recommended to be used in screening health status and nutritional status of Basque people because they describe a great proportion of the total population and represent better than other references the geographic and ecological variability of this region.

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*

This article is devoted to Professor Éva B. Bodzsár, scientist and friendly college, in the celebration of her 60th anniversary. We want to express our congratulations to her and also remember her invaluable contributions to issues of our interest in the field of population research on growth and maturation of adolescents. We also remember her remarkable work as organizer of magnificent Hungarian academic meetings, particularly the recent 15th Congress of the European Anthropological Association hold in Budapest in 2006, and as an editor of unforgettable books published by Eötvös University Press.

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