Chapter 16
Height, Weight, and Body Mass Index in Salvadoran Schoolchildren from the Bajo Lempa Rural Region

Roberto Pedrero-Tomé, María Sánchez-Álvarez, Noemí López-Ejeda, and M. D. Marrodán-Serrano

16.1 Introduction

Anthropometry enables us to describe the biological process of human growth in a simple and reproducible manner. By measuring only height and weight, it is possible to determine the changes in size during the ontogenetic process. Addition of

R. Pedrero-Tomé (✉)
Teaching Unit of Physical Anthropology, Department of Biodiversity, Ecology, and Evolution, Faculty of Biological Sciences, Universidad Complutense de Madrid, Madrid, Spain

Research Institute Hospital 12 de Octubre (i+12), Madrid, Spain

Infanta Leonor Hospital Research and Innovation Foundation, Madrid, Spain

EPINUT Research Group (ref. 920325), Faculty of Medicine, Complutense University of Madrid, Madrid, Spain
e-mail: robertpe@ucm.es

M. Sánchez-Álvarez
EPINUT Research Group (ref. 920325), Faculty of Medicine, Complutense University of Madrid, Madrid, Spain

Faculty of Health Sciences of the International University Isabel I of Burgos, Burgos, Spain

Faculty of Humanities and Social Sciences of the International University Isabel I of Burgos, Burgos, Spain
e-mail: marisa06@ucm.es

N. López-Ejeda · M. D. Marrodán-Serrano
Teaching Unit of Physical Anthropology, Department of Biodiversity, Ecology, and Evolution, Faculty of Biological Sciences, Universidad Complutense de Madrid, Madrid, Spain

EPINUT Research Group (ref. 920325), Faculty of Medicine, Complutense University of Madrid, Madrid, Spain
e-mail: noemilop@ucm.es; marrodan@ucm.es

S. Datta Banik (ed.), *Human Growth and Nutrition in Latin American and Caribbean Countries*, https://doi.org/10.1007/978-3-031-27848-8_16

other dimensions such as perimeters, diameters, or subcutaneous adipose skinfolds broadens the knowledge about the developmental pattern of body shape and composition.

Growth monitoring is an excellent strategy to assess health and nutritional status. However, the basis of all clinical and epidemiological diagnoses is comparison with reference values. For this reason, it is necessary to have patterns that serve as a reference when establishing assessment criteria. Growth curves and tables make it possible to check whether a given individual is within the limits of variability that correspond to the population by age and sex. These curves and tables show graphically and numerically the anthropometric values that correspond to the normal ontogenetic variation. These patterns are usually called standards for children below 5 years of age and references for the higher age-groups; curves are constructed from cross-sectional, longitudinal or semi-longitudinal studies for the standards and from cross-sectional studies for the latter. As rightly explained by Khadilkar (2013), a standard must be constructed from a study elaborated with strict inclusion and exclusion criteria to ensure that it is a healthy sample. The growth model of a standard therefore, represents how children "should grow" in conditions that allow them to express their full genetic potential. Whereas a reference simply shows how children and adolescents of a sample representing a given population grow.

Considering the world's vast ethnic and population diversity, the controversy over which standards or references to use is still open (Cole, 2022). In the past, researchers such as Waterlow et al. (1977) and Johnston (1986) were in favor of universal use of growth charts and curves derived from the study conducted between 1971 and 1975 by the American National Center for Health Statistics -NCHS (Hamill et al., 1977). Those were widely used by the World Health Organization (WHO) from different countries' health and nutrition surveillance programs. In addition, data from the National Health and Nutrition Examination Survey (NHANES) have also been frequently used as an international reference (Frisancho, 1990).

Some specialists defend the "universality of growth potential" in all populations, which means that all children who grow in optimal environment conditions from health, and nutritional point of view, should grow in the same way and with the same speed at least during the first 5 years of life (Onyango & de Onís, 2008). Based on that premise, in 2006, WHO published the growth standards for children under 5 years of age, based on a sample of children from different continents: Pelotas (Brazil) and Davis (USA) in the Americas, Accra (Ghana) in Africa, Delhi (India) and Muscat (Oman) in Asia and Oslo (Norway) in Europe. That study had a semi-longitudinal design, and the selected children were born to non-smoking mothers and had been exclusively breastfed for a minimum of 4 months. These conditions would guarantee a suitable environment for achieving the maximum level of growth. Therefore, these standards have a "prescriptive" character showing how children should grow.

In 2007, WHO published the growth references for boys and girls between 5 and 19 years of age, but in this case, data come from the First National Health Survey of the United States, known as NHANES I, which was carried out in the 1970s. The mathematical methods applied to fit and model the curves were updated, but it is worth asking to what extent these tables represent the ontogenetic variability of the world population. As indicated in previous paragraphs, the Multicenter Growth Study that gave rise to the standards for children under 5 years of age, very strict criteria were applied for the selection of sample. The inclusion and exclusion criteria ensured that the participating children were healthy and could represent an optimal growth pattern or aspirational goal for our species. In contrast, for the elaboration of the WHO references between 5 and 19 years of age, previously published studies (mostly national surveys) were used as a starting point. The WHO 2007 growth reference did not select the samples with a clear criterion of healthy children. Environmental or nutritional conditions were not controlled for, so the references are "descriptive" in nature, i.e., they describe how subjects grow in the absence of disease and in an environment that is not overtly adverse.

Some countries have their national references. For example, Tanner (1966) published patterns for the British population and Roede (1985) for European Dutch children. Later, references were published for Spain (Hernández et al., 1988; Carrascosa et al., 2008), Italy (Cacciari et al., 2002), Norway (Júlíusson et al., 2009) Finlad (Saari et al., 2011) and Croatia (Juresa et al., 2012), among others. In Asia, growth charts for Iran (Hosseini et al., 1998), Saudi Arabia (El-Mouzzan et al., 2007), Japan (Suwa & Tachibana, 1993), China (Li et al., 2009), Taiwan (Chen et al., 2010), India (Khadilkar et al., 2015) and Korea (Kim et al., 2018) are worth mentioning. In Latin America, Faulhaber (1976) elaborated on growth patterns for the population of Mexico, Jordan (1979) for the Cuban population, and Lejarraga and Orfila (1987) for the Argentine population. More recently, Carmenate et al. (2015) published references for the Dominican Republic.

All the cited references, which reflect a greater or lesser extent the ethnic and population diversity of each country, may be more appropriate for the medical diagnosis of individuals. Nevertheless, from an epidemiological point of view, the application of WHO references may be more beneficial for the contrast between populations, socioeconomic groups, meta-analysis studies, or secular trend research (Garrido-Miguel et al., 2017).

At present, El Salvador has no national growth reference curves to evaluate physical growth and nutritional status of its children. The current protocol of the Ministry of Health for evaluating nutritional status in children and adolescents considers the reference values for anthropometric measurements proposed by the WHO (MINSAL, 2013).

In this background, objective of the present study was to characterize the expression of child and adolescent physical growth in the Salvadoran school population of the Bajo Lempa region and to compare the growth pattern both with WHO references and with those corresponding to another population located in Central America, such as the Dominican Republic.

16.2 Materials and Methods

16.2.1 Population and Scope of the Study

This research was carried out in the Bajo Lempa region of El Salvador. It is an impoverished and relatively young rural area since the current population, made up mainly of families of ex-combatants and displaced persons from the civil war that the country suffered between 1979 and 1992, settled after the signing of the Peace Accords in 1992.

This region is strongly threatened by climatic factors that endanger crops and food reserves, such as frequent flooding due to rainfall and overflowing rivers, especially between May and October (*Asociación-Fundación para la Cooperación y el Desarrollo Comunal de El Salvador,* 2017). Previous studies conducted by the authors detected a high percentage of food insecurity (58.7%) in a survey among 143 families in the same region. Furthermore, stunting (low height-for-age) affected almost 9% of the school population (Pedrero-Tomé et al., 2020).

16.2.2 Sample Composition and Anthropometry

A semi-longitudinal growth study was conducted among 948 Salvadoran schoolchildren (458 boys and 490 girls) aged 5–16 years, attending six public schools (Guajoyo, Granzazo, Caserío Rancho Grande, San Bartolo, Santa Marta, and Los Naranjos) located in the Bajo Lempa region (Municipality of Tecoluca, Department of San Vicente, El Salvador) (Fig. 16.1). Data were collected in August 2018, October 2019, and September 2021.

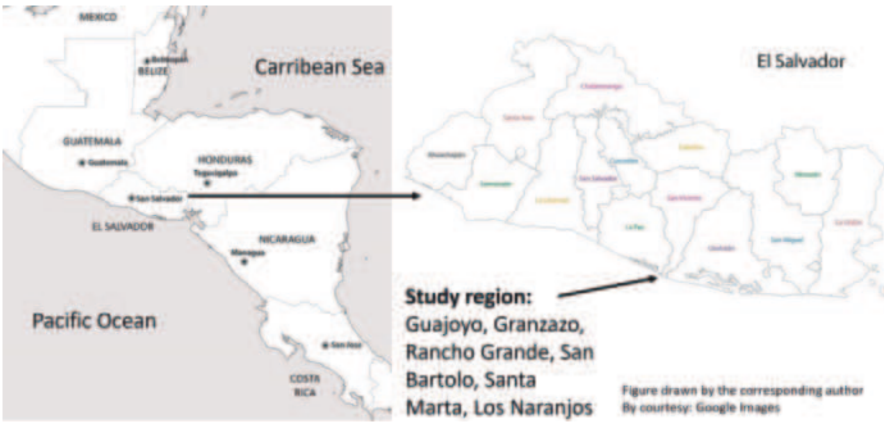

Fig. 16.1 Geographic location of the studied Salvadoran communities

Table 16.1 Distribution of the sample by sex and age

Age (years)	Male (n = 458)		Female (n = 490)	
	n	%	n	%
5	25	5.5	30	6.1
6	46	10.0	51	10.4
7	56	12.2	54	11.0
8	63	13.8	59	12.0
9	58	12.7	63	12.9
10	54	11.8	65	13.3
11	54	11.8	51	10.4
12	41	9.0	37	7.6
13	23	5.0	37	7.6
14	15	3.3	17	3.5
15	12	2.6	18	3.7
16	11	2.4	8	1.6

This research was conducted according to the ethical principles described by the World Medical Association (2013) and approved by the ethics committee of the Complutense University of Madrid and the National University of El Salvador. The objectives and procedures of the study were detailed in informal meetings at each school. The study included all the children who orally affirmed their collaboration and whose mothers, fathers, or legal guardians had previously signed the informed consent form (Table 16.1).

Anthropometric evaluations were performed by anthropometrists certified as level 1 by the International Society for the Advancement of Kinanthropometry (ISAK). The measurements were taken under the technical recommendations of the International Biological Program (IBP) (Weiner & Louire, 1981), with duly calibrated instruments before the commencement of each session. Three values were recorded for each variable. Weight (kg) was recorded using a TANITA digital scale with an accuracy of 100 grams, and height (cm) was taken using a SECA anthropometer with an accuracy of 1 mm. From these two anthropometric measurements, body mass index (BMI) was calculated using the formula [BMI = weight (kg)/height (m)^2].

16.2.3 Data Analysis

The LMS (lambda-mu-sigma) method was applied to model the growth curves for weight, height, and BMI of Salvadoran schoolchildren by age and sex. This technique transforms the anthropometric data using the Box-Cox method, adapting them to a normal distribution and significantly reducing the possible effects of asymmetry of the variables (Cole & Green, 1992); then models and combines three smoothed curves from which age- and sex-specific growth percentiles can be obtained (Cole, 1988; Cole & Green, 1992; Rigby & Stasinopoulos, 2005). These smoothed curves represent the parameters of the Box-Cox (Cole & Green, 1992). They are (1) the power needed to normalize data (lambda, L), (2) the median (mu, M), and (3) the coefficient of variation of the distribution for each age (sigma, S).

The results obtained were checked for compliance with the requirements of the LMS methodology, including that the percentile curves should grow (and not decrease) considering time, should change sufficiently with age, and should take into the account that growth pattern may be nonlinear (Muggeo et al., 2013; Ohuma & Altman, 2019).

The growth curves were created by calculating nine percentiles (3rd, 5th, 10th, 25th, 50th, 75th, 90th, 95th, and 97th) for each anthropometric variable. In addition, they were compared with the international growth reference of WHO (2007) and the Dominican Republic's national references (Carmenate et al., 2015). First, a graphical comparison was made by representing three centiles per group (3rd, 25th, and 97th). Secondly, the absolute differences between all possible combinations of the three references for the same centiles were plotted. Data processing was performed with the gamlss package of the R statistical analysis program R Core Team (2022).

16.3 Results

Tables 16.2, 16.3, 16.4, 16.5, 16.6 and 16.7 present the nine smoothed percentiles (3rd, 5th, 10th, 25th, 50th, 75th, 90th, 95th, and 97th) and the L, M, and S values for the variables weight (kg), height (cm), and BMI (kg/m^2) according to sex and age.

Figures 16.2, 16.3 and 16.4 illustrate the comparison of the 3rd, 50th, and 97th percentiles of the current Salvadoran sample's weight, height, and BMI references with the WHO international reference and the national reference of the Dominican Republic. Figure 16.2 shows the ontogenic evolution of weight in the different references. Very slight differences are detected for the 3rd and 50th percentiles. In contrast, for 97th percentile, both Central American series significantly exceed the values corresponding to the WHO references. This is the case for both boys and girls, especially in the Salvadoran sample.

Figure 16.3 shows height growth pattern. In general, growth of Salvadorans conforms reasonably close to the WHO curves up to prepubertal ages, being for all percentiles lower than that of Dominicans. However, the differences increase after 10 or 11 years, showing both Central American series clearly below the WHO values. This phenomenon is even more evident in the female series.

As shown in Fig. 16.4, and as expected, once the growth model for weight and height was known, the percentile values of BMI in Salvadoran children exceeded those corresponding to the WHO references. The distance between the curves is small for 3rd and 50th but very pronounced for 97th in both sexes.

Figures 16.5, 16.6 and 16.7 show the difference in absolute values for the 3rd, 50th, and 97th percentiles of weight, height, and BMI between the three references:

Table 16.2 Smoothed percentiles, and L, M, and S values for weight (kg) in boys

Age (years)	L	M	S	P3	P5	P10	P25	P50	P75	P90	P95	P97
5.0	1.00	18.52	0.23	14.62	14.97	15.57	16.77	18.52	21.01	24.47	27.61	30.42
5.5	1.00	19.72	0.20	15.42	15.81	16.47	17.79	19.72	22.48	26.30	29.78	32.90
6.0	1.00	20.97	0.20	16.25	16.67	17.40	18.85	20.97	24.00	28.22	32.05	35.48
6.5	1.00	22.26	0.21	17.08	17.55	18.34	19.93	22.26	25.59	30.21	34.39	38.13
7.0	1.00	23.59	0.23	17.94	18.45	19.31	21.05	23.59	27.23	32.25	36.79	40.82
7.5	1.00	24.97	0.24	18.82	19.37	20.32	22.21	24.97	28.92	34.35	39.21	43.51
8.0	1.00	26.41	0.24	19.73	20.33	21.35	23.40	26.41	30.67	36.49	41.66	46.19
8.5	1.00	27.89	0.23	20.66	21.31	22.42	24.64	27.89	32.47	38.69	44.14	48.87
9.0	1.00	29.42	0.23	21.62	22.32	23.52	25.92	29.42	34.34	40.94	46.66	51.56
9.5	1.00	31.01	0.23	22.61	23.37	24.66	27.25	31.01	36.27	43.24	49.21	54.26
10.0	1.00	32.66	0.24	23.62	24.44	25.84	28.62	32.66	38.25	45.59	51.78	56.93
10.5	1.00	34.36	0.25	24.68	25.56	27.06	30.05	34.36	40.29	47.96	54.32	59.55
11.0	1.00	36.12	0.26	25.78	26.73	28.34	31.54	36.12	42.38	50.35	56.84	62.10
11.5	1.00	37.95	0.26	26.94	27.95	29.68	33.09	37.95	44.51	52.74	59.32	64.57
12.0	1.00	39.85	0.25	28.15	29.24	31.08	34.71	39.85	46.69	55.14	61.78	66.98
12.5	1.00	41.81	0.24	29.43	30.59	32.55	36.40	41.81	48.93	57.56	64.22	69.36
13.0	1.00	43.84	0.23	30.77	32.00	34.09	38.16	43.84	51.21	60.01	66.67	71.75
13.5	1.00	45.94	0.21	32.16	33.48	35.69	40.00	45.94	53.57	62.51	69.17	74.17
14.0	1.00	48.11	0.19	33.61	35.01	37.36	41.90	48.11	55.99	65.07	71.73	76.67
14.5	1.00	50.36	0.19	35.12	36.60	39.09	43.88	50.36	58.49	67.71	74.37	79.26
15.0	1.00	52.69	0.19	36.67	38.24	40.88	45.92	52.69	61.08	70.45	77.12	81.97
15.5	1.00	55.11	0.17	38.27	39.94	42.72	48.03	55.11	63.75	73.28	79.98	84.80
16.0	1.00	57.60	0.16	39.90	41.68	44.63	50.22	57.60	66.53	76.23	82.97	87.78

Salvadorans children vs. WHO references (ES – WHO), Salvadorans vs. Dominicans children (ES – DR) and Dominicans children vs. WHO references (DR – WHO).

Figure 16.5 shows the absolute differences between the 3rd, 50th, and 97th percentiles for weight growth patterns among the three references. Practically in all cases, Salvadoran schoolchildren have higher weight values than Dominican schoolchildren. The most considerable differences are found while comparing the 97th percentile data of the Central American samples with the international reference. In the case of the 97th percentile, Salvadoran 5-year-old boys are already 6 kg heavier than their peers of the international reference, raising this value to 12 kg at the age of 10 years. The case of girls is quite similar, as they present 4 kg more at 5 years of age, reaching 14 kg more than the WHO reference.

It is important to note that the two Central American populations are below the international reference in height (Fig. 16.6). Regardless of the percentile or sex, the trend observed for the differences increases with age in both cases. Those differences are markedly high, so the Salvadorans are 5, 9, and 15 cm and Dominicans 15, 11, and 7 cm below the WHO reference for 3rd, 50th, and 97th percentiles, respectively. A more remarkable growth in height is reported in the Salvadoran sample

Table 16.3 Smoothed percentiles, and L, M, and S values for weight (kg) in girls

Age (years)	L	M	S	P3	P5	P10	P25	P50	P75	P90	P95	P97
5.0	1.00	18.11	0.21	14.18	14.55	15.17	16.38	18.11	20.46	23.47	25.96	28.02
5.5	1.00	19.18	0.21	14.94	15.32	15.97	17.27	19.18	21.80	25.07	27.74	29.91
6.0	1.00	20.38	0.20	15.77	16.16	16.85	18.25	20.38	23.32	26.92	29.76	32.03
6.5	1.00	21.70	0.20	16.66	17.08	17.79	19.30	21.70	25.04	29.01	32.04	34.41
7.0	1.00	23.13	0.20	17.62	18.04	18.79	20.42	23.13	26.96	31.36	34.61	37.07
7.5	1.00	24.67	0.22	18.62	19.06	19.84	21.60	24.67	29.10	34.01	37.49	40.05
8.0	1.00	26.33	0.25	19.65	20.10	20.93	22.85	26.33	31.41	36.92	40.69	43.40
8.5	1.00	28.08	0.26	20.70	21.18	22.07	24.17	28.08	33.86	40.04	44.18	47.12
9.0	1.00	29.94	0.25	21.77	22.3	23.27	25.59	29.94	36.40	43.31	47.93	51.19
9.5	1.00	31.90	0.26	22.86	23.45	24.55	27.13	31.90	38.98	46.64	51.84	55.55
10.0	1.00	33.95	0.27	23.96	24.66	25.91	28.79	33.95	41.52	49.91	55.79	60.07
10.5	1.00	36.06	0.27	25.08	25.9	27.37	30.60	36.06	43.92	52.96	59.58	64.54
11.0	1.00	38.17	0.28	26.19	27.18	28.91	32.53	38.17	46.08	55.64	63.00	68.71
11.5	1.00	40.23	0.29	27.29	28.48	30.51	34.53	40.23	47.98	57.85	65.84	72.23
12.0	1.00	42.18	0.29	28.37	29.78	32.12	36.51	42.18	49.61	59.60	68.00	74.91
12.5	1.00	43.96	0.28	29.43	31.05	33.67	38.40	43.96	51.04	60.95	69.51	76.65
13.0	1.00	45.58	0.27	30.49	32.28	35.16	40.13	45.58	52.33	62.02	70.48	77.56
13.5	1.00	47.05	0.26	31.55	33.49	36.55	41.70	47.05	53.52	62.90	71.06	77.84
14.0	1.00	48.43	0.24	32.64	34.70	37.90	43.16	48.43	54.66	63.66	71.40	77.76
14.5	1.00	49.76	0.21	33.79	35.94	39.26	44.59	49.76	55.75	64.35	71.65	77.57
15.0	1.00	51.09	0.18	34.98	37.26	40.72	46.11	51.09	56.76	64.96	71.89	77.48
15.5	1.00	52.47	0.16	36.22	38.70	42.38	47.84	52.47	57.62	65.40	72.13	77.61
16.0	1.00	53.90	0.15	37.56	40.36	44.34	49.83	53.90	58.32	65.63	72.26	77.81

than in the Dominican sample, to the point that the difference in absolute values between the two countries is reversed.

Figure 16.7 shows the differences in absolute values for BMI among the three references mentioned. In general terms, the Dominicans present the lowest BMI values at all ages, followed by those of the WHO reference and the Bajo Lempa sample. The disproportionate changes of BMI of the Salvadoran sample for the 97th percentile compared with the Dominican and WHO references is very striking. It should be noted that, although the differences in absolute values tend to attenuate, an excessive growth is observed for this variable in Salvadoran boys and girls, reaching a peak at the age of 10–11 years.

16.4 Discussion

Physical growth pattern of Salvadoran schoolchildren in the Bajo Lempa region differs from the WHO reference. Although the distance between the curves is small at the initial ages, the differences increase at 10–11 years in the male series and

Table 16.4 Smoothed percentiles, and L, M, and S values for height (cm) in boys

Age (years)	L	M	S	P3	P5	P10	P25	P50	P75	P90	P95	P97
5.0	1.00	109.57	0.05	98.03	99.90	102.44	106.05	109.57	112.97	116.22	118.36	119.88
5.5	1.00	112.73	0.04	100.96	102.87	105.46	109.14	112.73	116.21	119.52	121.72	123.28
6.0	1.00	115.67	0.04	103.68	105.62	108.26	112.01	115.67	119.20	122.59	124.83	126.42
6.5	1.00	118.44	0.05	106.25	108.22	110.90	114.71	118.44	122.03	125.48	127.77	129.39
7.0	1.00	121.19	0.05	108.80	110.81	113.53	117.40	121.19	124.85	128.35	130.69	132.34
7.5	1.00	124.02	0.05	111.44	113.48	116.24	120.18	124.02	127.74	131.32	133.69	135.38
8.0	1.00	126.79	0.05	114.02	116.09	118.89	122.89	126.79	130.57	134.20	136.62	138.33
8.5	1.00	129.32	0.05	116.40	118.49	121.33	125.37	129.32	133.15	136.83	139.28	141.02
9.0	1.00	131.66	0.05	118.62	120.73	123.59	127.67	131.66	135.53	139.25	141.73	143.50
9.5	1.00	133.91	0.05	120.76	122.89	125.78	129.89	133.91	137.81	141.56	144.07	145.86
10.0	1.00	136.15	0.05	122.93	125.07	127.97	132.11	136.15	140.08	143.87	146.41	148.21
10.5	1.00	138.49	0.04	125.19	127.34	130.26	134.42	138.49	142.45	146.27	148.82	150.64
11.0	1.00	140.97	0.04	127.60	129.76	132.70	136.88	140.97	144.95	148.80	151.37	153.21
11.5	1.00	143.65	0.05	130.21	132.39	135.33	139.54	143.65	147.65	151.53	154.12	155.97
12.0	1.00	146.63	0.05	133.13	135.31	138.27	142.49	146.63	150.66	154.56	157.17	159.04
12.5	1.00	149.97	0.05	136.40	138.59	141.57	145.81	149.97	154.02	157.95	160.59	162.47
13.0	1.00	153.51	0.04	139.88	142.08	145.07	149.33	153.51	157.59	161.54	164.20	166.10
13.5	1.00	157.01	0.04	143.34	145.55	148.54	152.81	157.01	161.10	165.07	167.74	169.66
14.0	1.00	160.13	0.04	146.48	148.69	151.67	155.94	160.13	164.22	168.20	170.87	172.79
14.5	1.00	162.58	0.04	149.03	151.22	154.18	158.42	162.58	166.65	170.61	173.27	175.19
15.0	1.00	164.32	0.04	150.93	153.09	156.02	160.20	164.32	168.34	172.26	174.90	176.80
15.5	1.00	165.36	0.04	152.21	154.33	157.21	161.32	165.36	169.32	173.18	175.79	177.66
16.0	1.00	165.82	0.03	152.95	155.02	157.84	161.86	165.82	169.70	173.49	176.05	177.89

11–12 years in the female series. From these peripubertal ages, Salvadoran boys and girls present height, clearly below that described by WHO, as seen from the percentile values. However, the weight is closer to the WHO references, although it slightly exceeds the median value and, especially, the 97th percentile one. Consequently, a lower height and higher weight are reflected in the BMI distribution of Salvadoran children, which also presents figures more elevated than the WHO references at 50th percentile and even higher at 97th.

Physical growth is a biological process with a genetic predisposition influenced by epigenetic and environmental factors. Economic factors are essential because they determine other issues such as education, housing, health care, hygiene, and food. According to the most up-to-date view, optimal nutrition, absence of disease, healthy environment, and favourable economic circumstances guaranteeing essential family support are prerequisites for successful growth regulation in children (Bogin et al., 2018). It is complex to discern to what extent the genetic composition determines short stature of Salvadorans since the analyzed sample lives under environmental conditions that are far from optimal. The Salvadoran region of Bajo

Table 16.5 Smoothed percentiles, and L, M, and S values for height (cm) in girls

Age (years)	L	M	S	P3	P5	P10	P25	P50	P75	P90	P95	P97
5.0	1.00	108.59	0.05	98.68	99.98	101.95	105.15	108.59	111.92	114.82	116.53	117.62
5.5	1.00	111.36	0.05	101.36	102.64	104.59	107.82	111.36	114.85	117.96	119.80	120.99
6.0	1.00	114.52	0.05	104.43	105.69	107.63	110.88	114.52	118.17	121.47	123.45	124.74
6.5	1.00	117.66	0.05	107.46	108.71	110.65	113.94	117.66	121.45	124.93	127.05	128.43
7.0	1.00	120.73	0.04	110.38	111.63	113.58	116.92	120.73	124.67	128.31	130.54	132.01
7.5	1.00	123.79	0.05	113.18	114.46	116.45	119.86	123.79	127.87	131.67	134.00	135.55
8.0	1.00	126.85	0.05	115.91	117.22	119.27	122.79	126.85	131.07	135.00	137.43	139.03
8.5	1.00	129.92	0.05	118.59	119.95	122.08	125.73	129.92	134.27	138.32	140.81	142.45
9.0	1.00	133.05	0.05	121.31	122.73	124.94	128.73	133.05	137.51	141.63	144.15	145.81
9.5	1.00	136.26	0.05	124.11	125.59	127.90	131.82	136.26	140.79	144.94	147.46	149.12
10.0	1.00	139.47	0.05	126.99	128.54	130.93	134.96	139.47	144.02	148.16	150.65	152.27
10.5	1.00	142.59	0.05	129.92	131.52	133.97	138.06	142.59	147.11	151.17	153.60	155.17
11.0	1.00	145.52	0.05	132.82	134.44	136.92	141.03	145.52	149.95	153.89	156.22	157.73
11.5	1.00	148.16	0.04	135.59	137.22	139.7	143.75	148.16	152.45	156.23	158.46	159.89
12.0	1.00	150.42	0.04	138.12	139.74	142.18	146.15	150.42	154.55	158.15	160.26	161.61
12.5	1.00	152.24	0.03	140.31	141.89	144.28	148.13	152.24	156.18	159.60	161.59	162.86
13.0	1.00	153.54	0.03	142.03	143.57	145.89	149.61	153.54	157.28	160.51	162.38	163.58
13.5	1.00	154.26	0.03	143.23	144.72	146.95	150.52	154.26	157.81	160.85	162.61	163.73
14.0	1.00	154.54	0.03	144.00	145.43	147.58	150.98	154.54	157.90	160.76	162.42	163.47
14.5	1.00	154.54	0.03	144.49	145.87	147.92	151.16	154.54	157.71	160.41	161.96	162.94
15.0	1.00	154.40	0.03	144.83	146.15	148.11	151.20	154.40	157.39	159.93	161.39	162.31
15.5	1.00	154.24	0.03	145.14	146.40	148.27	151.20	154.24	157.07	159.46	160.83	161.70
16.0	1.00	154.13	0.03	145.48	146.68	148.46	151.25	154.13	156.81	159.07	160.36	161.18

Lempa is recognized as a critical area in terms of environmental threat, risk and vulnerability, an aspect that negatively conditions health and food security of its inhabitants (Pedrero-Tomé et al., 2022).

Human body size shows a considerable ethnic and population variation that partly responds to the genetic component and partly to the environmental settings in which the individual grows (Roser et al., 2013). Biological anthropologists have been trying for decades to unravel the contribution of each of these components at each stage of ontogeny. This considerable variation in size supports the idea that genetic factors are involved. However, at the same time, in many cases, the tallest human groups are also the ones that enjoy the best economic conditions, while the shortest people being the poorest. Specific studies of family correlations between parent-children or twins have shown that the heritability of height and other longitudinal dimensions is significantly higher than the heritability of weight or BMI; phenotypes where the environmental component contributes to a greater extent (Jalenovic & Rebato, 2012; Poveda et al., 2012; Segal et al., 2009;). This implies that the contribution of the genetic factor is not the same for all body tissues; compared to bone tissue, more sensitive to environmental changes are muscle and fat

Table 16.6 Smoothed percentiles, and L, M, and S values for BMI (kg/m^2) in boys

Age (years)	L	M	S	P3	P5	P10	P25	P50	P75	P90	P95	P97
5.0	1.00	15.30	0.17	12.92	13.15	13.53	14.27	15.30	16.70	18.52	20.09	21.43
5.5	1.00	15.62	0.16	13.08	13.32	13.73	14.51	15.62	17.12	19.08	20.77	22.22
6.0	1.00	15.91	0.15	13.22	13.47	13.90	14.74	15.91	17.51	19.61	21.42	22.96
6.5	1.00	16.19	0.14	13.34	13.61	14.06	14.94	16.19	17.88	20.12	22.03	23.68
7.0	1.00	16.45	0.15	13.45	13.74	14.21	15.14	16.45	18.24	20.60	22.63	24.37
7.5	1.00	16.69	0.16	13.55	13.85	14.34	15.32	16.69	18.59	21.08	23.22	25.05
8.0	1.00	16.93	0.17	13.64	13.95	14.46	15.48	16.93	18.92	21.53	23.79	25.71
8.5	1.00	17.15	0.17	13.72	14.04	14.58	15.64	17.15	19.23	21.97	24.33	26.34
9.0	1.00	17.37	0.17	13.79	14.12	14.69	15.79	17.37	19.53	22.38	24.83	26.92
9.5	1.00	17.57	0.17	13.87	14.21	14.79	15.94	17.57	19.81	22.76	25.27	27.41
10.0	1.00	17.77	0.18	13.95	14.30	14.90	16.08	17.77	20.07	23.08	25.64	27.80
10.5	1.00	17.96	0.19	14.04	14.41	15.02	16.23	17.96	20.31	23.36	25.92	28.07
11.0	1.00	18.14	0.20	14.14	14.52	15.15	16.38	18.14	20.52	23.57	26.11	28.21
11.5	1.00	18.32	0.20	14.26	14.64	15.28	16.54	18.32	20.70	23.73	26.22	28.25
12.0	1.00	18.49	0.20	14.39	14.77	15.43	16.70	18.49	20.87	23.85	26.25	28.19
12.5	1.00	18.65	0.19	14.53	14.92	15.58	16.86	18.65	21.01	23.92	26.24	28.07
13.0	1.00	18.81	0.19	14.67	15.07	15.73	17.02	18.81	21.14	23.97	26.18	27.91
13.5	1.00	18.96	0.17	14.83	15.23	15.90	17.19	18.96	21.26	24.00	26.11	27.74
14.0	1.00	19.12	0.16	14.99	15.39	16.06	17.35	19.12	21.36	24.02	26.02	27.55
14.5	1.00	19.26	0.15	15.15	15.56	16.23	17.52	19.26	21.47	24.03	25.94	27.38
15.0	1.00	19.40	0.14	15.32	15.72	16.40	17.68	19.40	21.56	24.04	25.86	27.22
15.5	1.00	19.54	0.13	15.48	15.89	16.56	17.84	19.54	21.65	24.05	25.78	27.07
16.0	1.00	19.68	0.12	15.64	16.05	16.72	17.99	19.68	21.75	24.06	25.72	26.94

tissues that are influenced by diet and exercise habits, factors that can generate size differences even with a similar genetic structure (López-Ejeda et al., 2020).

Low height-for-age in childhood, also known as chronic malnutrition or stunting, has been recurrently used as an indicator of poor socioeconomic background. WHO considers that a country with a prevalence of stunting above 30% is in a very high severity situation, and it should be a priority for humanitarian action (de Onis et al., 2018). However, there are countries where these figures are markedly exceeded in almost the entire territory, as is the case of Guatemala, with a national prevalence of 46.5%, with figures reaching 70% in some regions of the country (SIINSAN, 2016).

In general, larger body size requires more energy for maintenance, and more susceptible in the contexts of deprivation due to lack of food or excess energy expenditure, as occurs when exposed to recurrent infectious diseases (Diez-Navarro et al., 2017; Solomons, 2019). After studying height of human remains from archaeological sites and historical series, Scheffler and Hermanussen (2022) found high prevalences of stunting in poor contexts as well as privileged social strata. Therefore, they propose that stunting would be the natural condition of the human species, the most adaptive response for most of our evolutionary history. Therefore, in contexts where the availability of resources and the epidemiological situation have remained stable until recent history, population selection for "small size genes" could be

Table 16.7 Smoothed percentiles, and L, M, and S values for BMI (kg/m^2) in girls

Age (years)	L	M	S	P3	P5	P10	P25	P50	P75	P90	P95	P97
5.0	1.00	15.17	0.15	12.84	13.12	13.54	14.26	15.17	16.48	18.36	20.04	21.43
5.5	1.00	15.33	0.15	12.98	13.25	13.66	14.38	15.33	16.70	18.70	20.48	21.96
6.0	1.00	15.49	0.14	13.11	13.37	13.77	14.49	15.49	16.94	19.07	20.97	22.54
6.5	1.00	15.64	0.13	13.21	13.46	13.86	14.60	15.64	17.19	19.47	21.50	23.19
7.0	1.00	15.79	0.13	13.28	13.53	13.94	14.70	15.79	17.45	19.89	22.08	23.90
7.5	1.00	15.95	0.16	13.34	13.59	14.00	14.79	15.95	17.72	20.36	22.73	24.70
8.0	1.00	16.13	0.20	13.41	13.66	14.08	14.90	16.13	18.03	20.88	23.45	25.61
8.5	1.00	16.35	0.21	13.50	13.76	14.19	15.05	16.35	18.39	21.47	24.28	26.65
9.0	1.00	16.63	0.21	13.63	13.90	14.35	15.25	16.63	18.81	22.16	25.23	27.85
9.5	1.00	16.98	0.21	13.82	14.10	14.57	15.51	16.98	19.31	22.92	26.30	29.21
10.0	1.00	17.38	0.21	14.07	14.35	14.84	15.84	17.38	19.85	23.74	27.44	30.69
10.5	1.00	17.82	0.21	14.34	14.64	15.15	16.19	17.82	20.42	24.55	28.57	32.16
11.0	1.00	18.26	0.21	14.61	14.92	15.46	16.56	18.26	20.96	25.29	29.61	33.54
11.5	1.00	18.68	0.22	14.83	15.16	15.73	16.89	18.68	21.49	25.99	30.55	34.81
12.0	1.00	19.08	0.23	14.98	15.33	15.94	17.18	19.08	22.03	26.70	31.47	36.02
12.5	1.00	19.47	0.23	15.05	15.43	16.09	17.43	19.47	22.59	27.43	32.35	37.10
13.0	1.00	19.86	0.24	15.09	15.51	16.23	17.68	19.86	23.11	27.96	32.73	37.26
13.5	1.00	20.25	0.24	15.17	15.63	16.41	17.97	20.25	23.49	27.97	32.02	35.62
14.0	1.00	20.63	0.22	15.37	15.87	16.70	18.33	20.63	23.68	27.50	30.57	33.02
14.5	1.00	21.01	0.19	15.75	16.27	17.14	18.80	21.01	23.76	26.87	29.12	30.79
15.0	1.00	21.41	0.17	16.24	16.79	17.68	19.32	21.41	23.84	26.37	28.09	29.29
15.5	1.00	21.82	0.14	16.74	17.30	18.22	19.85	21.82	24.00	26.15	27.54	28.47
16.0	1.00	22.25	0.12	17.17	17.77	18.71	20.35	22.25	24.26	26.16	27.33	28.11

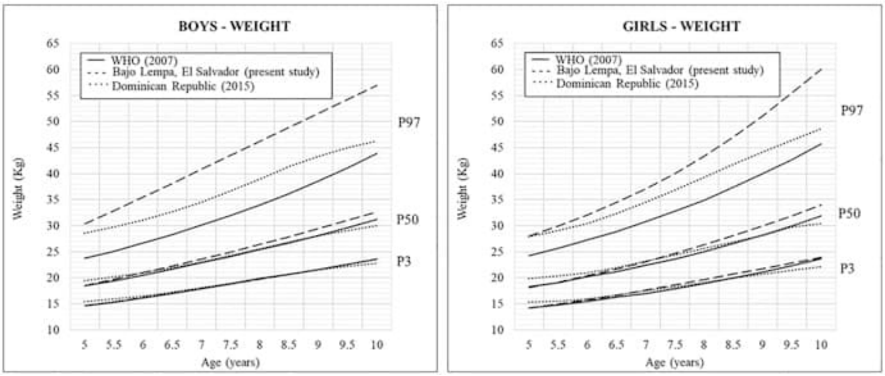

Fig. 16.2 Normalized weight (kg) of boys and girls from El Salvador and comparison with WHO growth reference and data from Dominican Republic

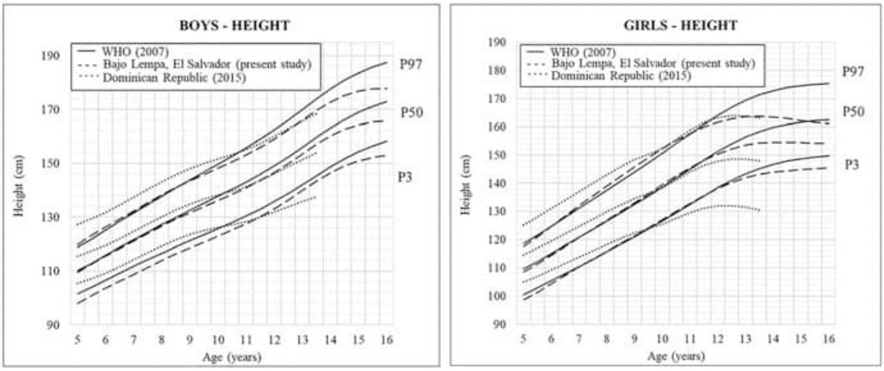

Fig. 16.3 Normalized height (cm) of boys and girls from El Salvador and comparison with WHO growth reference and data from Dominican Republic

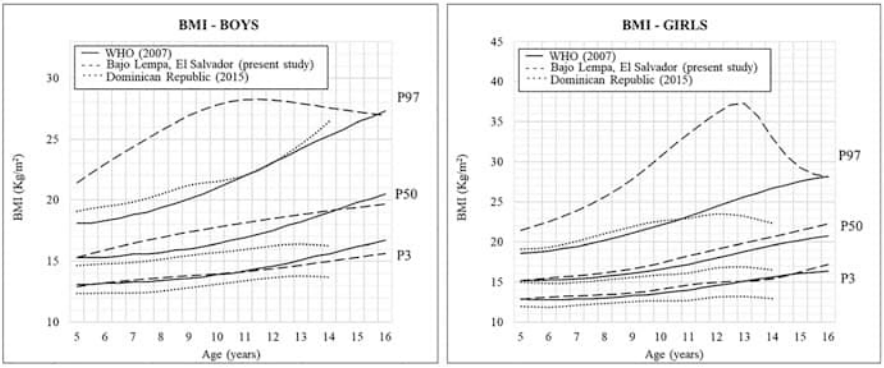

Fig. 16.4 Normalized BMI (kg/m^2) of boys and girls from El Salvador and comparison with WHO growth reference and data from Dominican Republic

considered a resource-adaptive phenomenon and not necessarily an anthropometric failure. In this context, international references are not useful for diagnosing chronic malnutrition, and the development of a specific reference would be required.

To date, Genome-Wide Association Studies have identified more than 200 Single Nucleotide Polymorphisms (SNPs) associated with height in adults with different frequencies in European, Asian, and African populations (Lango et al., 2010; Du et al., 2014; He et al., 2015). The number of SNPs associated with weight or BMI in adults, children, and adolescents is also very high and has an unequal frequency in different populations (Yilmaz, 2020; Czerwinski & Choh, 2022).

In any case, these genetic variants would explain only 10–20% of the variability in height, which, as secular studies have amply demonstrated, is a sensitive indicator of living conditions. As mentioned, social and political conditions are associated with the average height of children and adults worldwide (Bogin & Loucky, 1997; Candela-Martínez et al., 2022; Martínez-Carrión et al., 2022). In 100 years (from

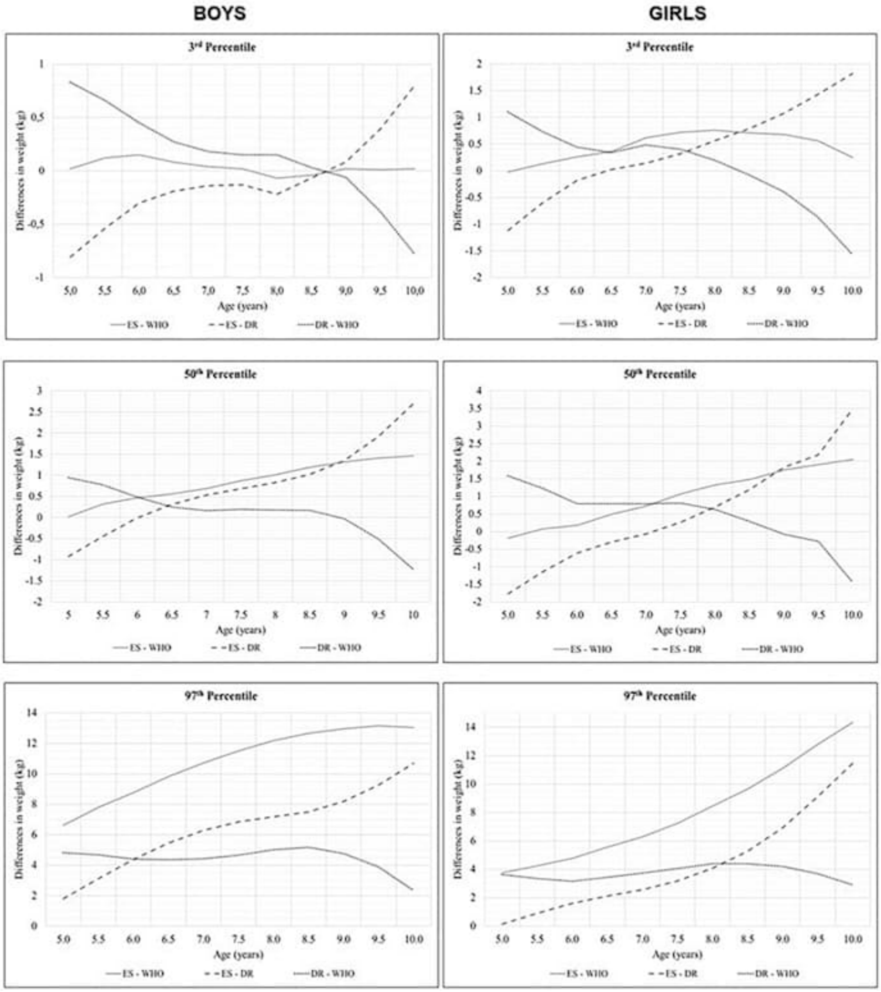

Fig. 16.5 Weight (kg) by percentile of boys and girls from El Salvador and comparison with WHO growth reference and data from Dominican Republic

1914 to 2014), height has increased up to 20 cm in specific human groups that have experienced increased social welfare (NCD Risk Factor Collaboration, 2016).

Studies of migrant populations moving to more favorable environments have demonstrated growth plasticity. Examples include Guatemalan children migrated to the United States or Bangladeshi children born and raised in London, among other cases reported by Bogin et al. (2018). Interestingly, along with this trend of height increase, a tendency of obesity is perceived in migrant children, also detected in the Tarahumara ethnic group of Mexico displaced from rural settlements to the city of Chihuahua (Benítez-Hernández et al., 2017) or Latino adolescents who migrated to Spain (Santos et al., 2009).

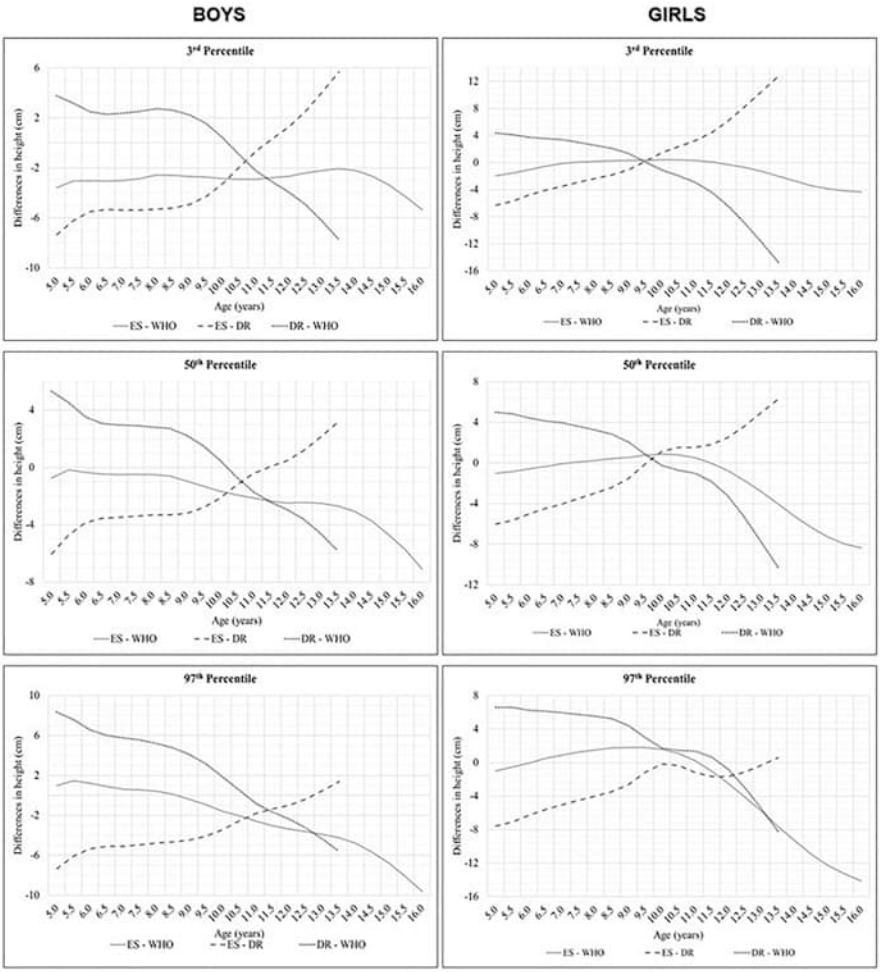

Fig. 16.6 Height (cm) by percentile of boys and girls from El Salvador and comparison with WHO growth reference and data from Dominican Republic

Dietary changes and more sedentary lifestyle that affect these transition populations negatively, influence weight gain and increase of BMI. In addition, the most satiating and inexpensive foods are usually calorie-dense but not necessarily of more excellent nutritional value. As indicated above, surveys conducted in the Bajo Lempa area by this same research team have shown that food insecurity was high, affecting almost 60% of the households (Pedrero-Tomé et al., 2022).

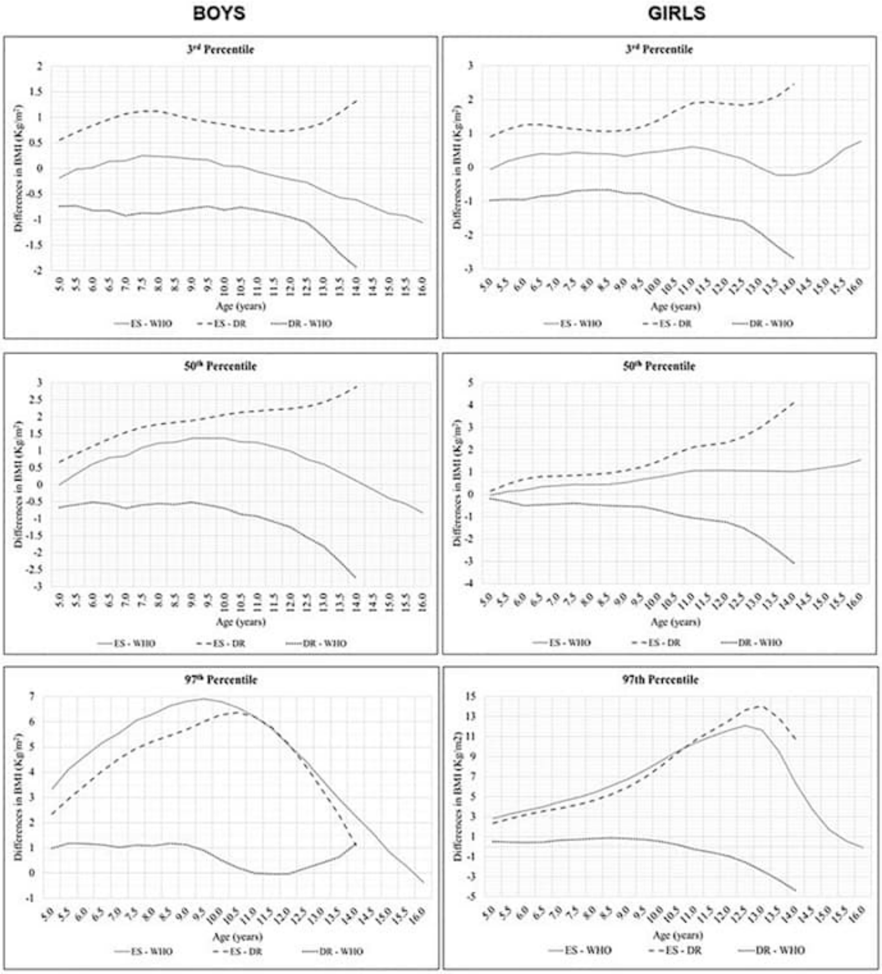

Fig. 16.7 BMI (kg/m^2) by percentile of boys and girls from El Salvador and comparison with WHO growth reference and data from Dominican Republic

16.5 Conclusions

The shorter stature of Salvadoran schoolchildren with respect to the international references, which becomes evident only after pubertal age, should not necessarily be interpreted as a problem of chronic malnutrition or generalized stunting since it is after puberty when growth curves begin to diverge from the reference, but not before. It is possible that the genetic component of the population partly limits the potential for longitudinal growth. However, the conditions of vulnerability and food insecurity that are typical of the region of study may be the factors that negatively affect height growth and favors obesity.

However, the marked predisposition to overweight reflected in the curves defining the 97th percentile for weight and BMI reveal a tendency towards obesity that may undermine the future health of these children. Follow-up studies monitoring physical growth of children and adolescents in these same communities, where a program of education, school gardens, and school canteens is now starting, will reveal the adaptive response to the expected changes.

Acknowledgments The authors would like to thank the Complutense University of Madrid for the funding received to carry out this study (Ref. 19/2017; Ref. 11/2018; Ref. 05/2021; Ref. 17/2022). We also thank the National University of El Salvador and the Asociación-Fundación para la Cooperación y el Desarrollo Comunitario de El Salvador (CORDES), Spanish Society of Dietetics and Food Science (*Sociedad Española de Dietética y Ciencias de la Alimentación, SEDCA*) and of course, the communities and all the people who participated in the study.

References

Asociación-Fundación para la Cooperación y el Desarrollo Comunal de El Salvador. (2017). Diagnóstico participativo. In *Área de desarrollo territorial*. CORDES.

Benítez-Hernández, M. L., de la Torre-Díaz, M., Cervantes-Borunda, M., Hernández-Torres, P., Cabañas, M. D., López-Ejeda, N., & Marrodán, M. D. (2017). Migration and nutritional status of Tarahumara schoolchildren from Chihuahua State (México). *American Journal of Human Biology, 29*, e2292. https://doi.org/10.1002/ajhb.22927

Bogin, B., & Loucky, J. (1997). Plasticity, political economy, and physical growth status of Guatemala Maya children living in the United States. *American Journal of Physical Anthropology, 102*, 17–32. https://doi.org/10.1002/(SICI)1096-8644(199701)102:1<17::AID-AJPA3>3.0.CO;2-A

Bogin, B., Hermanussen, M., & Scheffler, C. (2018). As tall as my peers – Similarity in body height between migrants and hosts. *Anthropologischer Anzeiger, 74/5*(Supplement), 63–374. https://doi.org/10.1127/anthranz/2018/0828

Cacciari, E., Milani, S., Balsamo, A., Dammacco, F., De Luca, F., Chiarelli, F., & Vanelli, M. (2002). Italian cross-sectional growth charts for height, weight and BMI (6-20y). *European Journal of Clinical Nutrition, 56*(2), 171–180. https://doi.org/10.1038/sj.ejcn.1601314

Candela-Martínez, B., Cámara, A. D., López-Falcón, D., & Martínez-Carrión, J. M. (2022). Growing taller unequally? Adult height and socioeconomic status in Spain (Cohorts 1940-1994). *SSM – Population Health, 101126*. https://doi.org/10.1016/j.ssmph.2022.101126

Carmenate, M., Gómez Valenzuela, V., & Prado, C. (2015). *Evaluación del estado nutricional de niños y niñas del primer ciclo de la educación básica del sistema de educación pública de la República Dominicana*. MINERD. IDEICE. Santo Domingo, D. N. República Dominicana.

Carrascosa, A., Fernandez, J. M., Fernandez, C., Ferrandez, A., Lopez-Siguero, J. P., Sanchez, E., et al. (2008). Spanish cross-sectional growth study 2008. Part II. Height, weight and body mass index values in 32,064 subjects (16,607 males and 15,457 females) from birth to adulthood. *Anales de Pediatría (Barc), 68*(6), 552–569. https://doi.org/10.1157/13123287

Chen, W., & Chang, M. H. (2010). New growth charts for Taiwanese children and adolescents based on World Health Organization standards and health-related physical fitness. *Pediatrics & Neonatology, 51*(2), 69–79. https://doi.org/10.1016/S1875-9572(10)60014-9

Cole, T. (1988). Fitting smoothed centile curves to reference data. *Journal of the Royal Statistical Society A, 151*, 385–418. https://doi.org/10.2307/2982992

Cole, T. (2022). Chapter 14: Growth references and standards. In N. Cameron & L. M. Schell (Eds.), *Human growth and development* (3rd ed., pp. 391–422). Academic Press. https://doi.org/10.1016/B978-0-12-822652-0.00012-2

Cole, T., & Green, P. (1992). Smoothing reference centile curves: The LMS method and penalized likelihood. *Statistics in Medicine, 11*, 1305–1319. https://doi.org/10.1002/sim.4780111005

Czerwinski, S., & Choh, A. C. (2022). Chapter 8: The genetic epidemiology of growth and development. In N. Cameron & L. M. Schell (Eds.), *Human growth and development* (3rd ed., pp. 203–244). Academic Press. https://doi.org/10.1016/B978-0-12-822652-0.00001-8

De Onis, M., Borghi, E., Arimond, M., Webb, P., Croft, T., Saha, K., De-Regil, L. M., Thuita, F., Heidkamp, R., Krasevec, J., Hayashi, C., & Flores-Ayala, R. (2018). Prevalence thresholds for wasting, overweight and stunting in children under 5 years. *Public Health Nutrition, 22*(1), 175–179. https://doi.org/10.1017/S1368980018002434

Diez-Navarro, A., Marrodán, M. D., Gómez, A., Rivero, E., Vargas, A., Pacheco, J. L., Sánchez-Álvarez, M., López-Ejeda, N., Moreno-Romero, S., Prado, C., Cabañas, M. D., & Martínez-Álvarez, J. R. (2017). Female eco-stability and severe malnutrition in children: Evidence from humanitarian aid interventions of Action Against Hunger in African, Asian and Latin American countries. *Nutricion Clinica y Dietética Hospitalaria, 37*(4), 127–134. https://doi.org/10.12873/374dnavarro

Du, M., Auer, P. L., Jiao, S., Haessler, J., Altshuler, D., Boerwinkle, E., et al. (2014). Whole-exome imputation of sequence variants identified two novel alleles associated with adult body height in African Americans. *Human Molecular Genetics, 15;23*(24), 6607–6615. https://doi.org/10.1093/hmg/ddu361

El-Mouzan, M. I., Al-Herbish, A. S., Al-Salloum, A. A., Qurachi, M. M., & Al-Omar, A. A. (2007). Growth charts for Saudi children and adolescents. *Saudi Medical Journal, 28*(10), 1555. https://doi.org/10.4103/0256-4947.51726

Faulhaber J (1976) *Investigación longitudinal del crecimiento.* Col. Científica. n° 26. Instituto Nacional de Antropologia e Historia. México.

Frisancho, A. R. (1990). *Anthropometric standards for the assessment of growth and nutritional status*. University of Michigan Press. https://doi.org/10.3998/mpub.12198

Garrido-Miguel, M., Cavero-Redondo, I., Álvarez-Bueno, C., Rodríguez-Artalejo, F., Moreno-Aznar, L., Ruiz, J. R., & Martínez-Vizcaíno, V. (2017). Prevalence and trends of thinness, overweight and Obesity among children and adolescents aged 3-18 years across Europe: A protocol for a systematic review and meta-analysis. *British Medical Journal, 7*, e018241. https://doi.org/10.1136/bmjopen-2017-018241

Hamill, P. V., Driz, T., Johnson, C. L., Reed, R. B., & Roche, A. F. (1977). *NCHS growth curves for children, birth-18 years United States*. Public National Center for Health Statistics. https://doi.org/10.1037/e405052004-001

He, M., Xu, M., Zhang, B., Liang, J., Chen, P., Lee, J. Y., et al. (2015). Meta-analysis of genome-wide association studies of adult height in East Asians identifies 17 novel loci. *Human Molecular Genetics, 15;24*(6), 1791–1800. https://doi.org/10.1093/hmg/ddu583

Hernández, M., Castellet, J., Narvaiza, J. L., Rincón, J. M., Ruiz, I., Sánchez, E., Sobradillo, B., & Zurimendi, A. (1988). *Curvas y tablas de crecimiento (0-18 años)*. Instituto de Investigación sobre Crecimiento y Desarrollo. Fundación Faustino Orbegozo, Bilbao. ISBN: 84-7391-177-6 1-32.

Hosseini, M., Carpenter, R. G., & Mohammad, K. (1998). Growth charts for Iran. *Annals of human biology, 25*(3), 237–247. https://doi.org/10.1080/03014469800005602

Jelenkovic, A., & Rebato, E. (2012). Association among obesity-related anthropometric phenotypes: Analyzing genetic and environmental contribution. *Human Biology, 2*, 127–137. https://doi.org/10.3378/027.084.0202

Johnston FE (1986) Reference data for physical growth in nutritional anthropology. In: Quandt SA, Ritenbaugh C (Editors) Training Manual in Nutritional Anthropology. Washington, D.C. pp. 60-65.

Jordan. (1979). *Desarrollo humano en Cuba*. Editorial Científico Médica.

Júlíusson, P. B., Roelants, M., Eide, G. E., Moster, D., Juul, A., Hauspie, R., Waaler, P. E., & Bjerknes, R. (2009). Vekstkurver for norske barn [Growth references for Norwegian children]. *Tidsskrift for den Norske Laegeforening, 12;129(4):281-6*. https://doi.org/10.4045/tidsskr.09.32473

Jureša, V., Musil, V., & Kujundžić, T. M. (2012). Growth charts for Croatian school children and secular trends in past twenty years. *Collegium Antropologicum, 36*(1), 47–57. https://doi.org/10.5671/ca.2012361s.47

Khadilkar, V. (2013). The growing controversy about growth charts: WHO or regional? International. *Journal of Pediatric Endocrinology*, (Suppl 1), O6. https://doi.org/10.1186/1687-9856-2013-S1-O6

Khadilkar, V., Yadav, S., Agrawal, K. K., et al. (2015). Revised IAP growth charts for height, weight and body mass index for 5- to 18-year-old Indian children. *Indian Pediatrics, 52*, 47–55. https://doi.org/10.1007/s13312-015-0566-5

Kim, J. H., Yun, S., Hwang, S. S., Shim, J. O., Chae, H. W., Lee, Y. J., Lee, J. H., Kim, S. C., Lim, D., Yang, S. W., Oh, K., Moon, J. S., & Committee for the Development of Growth Standards for Korean Children and Adolescents; Committee for School Health and Public Health Statistics, the Korean Pediatric Society; Division of Health and Nutrition Survey, Korea Centers for Disease Control and Prevention. (2018). The 2017 Korean National Growth Charts for children and adolescents: development, improvement, and prospects. *Korean Journal Pediatrics, 61*(5), 135–149. https://doi.org/10.3345/kjp.2018.61.5.135

Lango Allen, H., Estrada, K., Lettre, G., Berndt, S. I., Weedon, M. N., Rivadeneira, F., Willer, C. J., Jackson, A. U., Vedantam, S., & Raychaudhuri, S. (2010). Hundreds of variants clustered in genomic loci and biological pathways affect human height. *Nature, 467*, 832–838. https://doi.org/10.1038/nature09410

Lejarraga, H., & Orfila, G. (1987). Estándares de peso y estatura para niñas y niños argentinos desde el nacimiento hasta la madurez. *Archivos Argentinos de Pediatría, 85*, 209–222.

Li, H., Ji, C. Y., Zong, X. N., & Zhang, Y. Q. (2009). Height and weight standardized growth charts for Chinese children and adolescents aged 0 to 18. *Chinese Journal of Pediatrics, 47*(7), 487–492.

López-Ejeda, N., Martínez, J. R., Villarino, A., Cabañas, M. D., González Montero de Espinosa, M., López Mojares, L. M., Romero Collazos, J. F., Prado, C., Alaminos, A., & Marrodán, M. D. (2020). Physical Activity Protects Genetically Predisposed Schoolchildren from Obesity. *Kronos, 19*(2).

Martínez-Carrión, J. M., Varea, C., & Salvatore, R. (2020–2022). Biological living standards and nutritional health inequality in transition to the developed world. *International Journal of Environmental Research and Public Health*, Special Issue.

MINSAL – Ministerio de Salud de El Salvador. (2013). *Lineamientos técnicos para la evaluación del estado nutricional en el ciclo de vida y desarrollo en la niñez y adolescencia.* http://asp.salud.gob.sv/regulacion/pdf/lineamientos/lineamientos_estado_nutricional_ciclo_vida_29112013.pdf

Muggeo, V. M. R., Sciandra, M., Tomasello, A., & Calvo, S. (2013). Estimating growth charts via nonparametric quantile regression: A practical framework with application in ecology. *Environmental and Ecological Statistics, 20*(4), 519–531. https://doi.org/10.1007/s10651-012-0232-1

NCD Risk Factor Collaboration (NCD-RisC). (2016). A century of trends in adult human height. Elife 5: e13410. https://doi.org/10.7554/eLife.13410

Ohuma, E. O., & Altman, D. G. (2019). Statistical methodology for constructing gestational age-related charts using cross-sectional and longitudinal data: The INTERGROWTH-21st project as a case study. *Statistics in Medicine, 38*(19), 3507–3526. https://doi.org/10.1002/sim.8018

Onyango, A. W., & de Onís, M. (2008). *WHO child growth standards: training course on child growth assessment*. Department of Nutrition for Health and Development WHO Press. https://doi.org/10.1016/S0140-6736(08)60131-2

Pedrero-Tomé, R., Sánchez Álvarez, M., López-Ejeda, N., Herrero-Jaúregui, C., Acosta Gallo, B., & Dolores Marrodán, M. (2020). Development Cooperation in Bajo Lempa (El Salvador): Perception of the Health and Nutritional Condition. *Revista Agunkuyâa, 10*(1), 15–23.

Pedrero-Tomé, R., López-Ejeda, N., Sánchez Álvarez, M., Herrero-Jaúregui, C., Acosta Gallo, B., & Dolores Marrodán, M. (2022). Household food insecurity and nutritional status of schoolchildren in rural regions of Bajo Lampa, El Salvador (2018–2019). *Ecology of Food and Nutrition, 61*(2), 128–143. https://doi.org/10.1080/03670244.2021.1968851

Poveda, A., Jelenkovic, A., Salces, I., Ibanez, M. E., & Rebato, E. (2012). Heritability variations of body linearity and obesity indicators during growth. *Homo, 63*(4), 301–310. https://doi.org/10.1016/j.jchb.2012.03.006

R Core Team. (2022). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Rigby, R. A., & Stasinopoulos, D. M. (2005). Generalized additive models for location, scale and shape. *Journal of the Royal Statistical Society Series C (Applied Statistics), 54*(3), 507–554. https://doi.org/10.1111/j.1467-9876.2005.00510.x

Roede, M. J., & Vieringen, V. (1985). Growth diagrams 1980. Netherlands Third Nationwide Survey. *Tijdschrift voor GezondheidsRecht, 63*(suppl), 1–34.

Roser, M., Cameron, A., & Ritchie, A. (2013). *Human height*. Published online at OurWorldInData.org. Retrieved from https://ourworldindata.org/human-height

Saari, A., Sankilampi, U., Hannila, M. L., Kiviniemi, V., Kesseli, K., & Dunkel, L. (2011). New Finnish growth references for children and adolescents aged 0 to 20 years: Length/height-for-age, weight-for-length/height, and body mass index-for-age. *Annals of Medicine, 43*(3), 235–248. https://doi.org/10.3109/07853890.2010.515603

Santos, M. G., Fernández-del Olmo, R., Prado, C., Roville-Sausse, F., Marrodán, M. D., & Carmenate, M. (2009). Composition corporelle des adolescents de la région de Madrid selon leur origine géographique. *Biométrie Humaine et Anthropologie, 27*(1-2), 37–42.

Scheffler, C., & Hermanussen, M. (2022). Stunting is the natural condition of human height. *American Journal of Human Biology, 34*(5), e23693. https://doi.org/10.1002/ajhb.23693

Segal, N. L., Feng, R., McGuire, S. A., Allison, D. B., & Miller, S. (2009). Genetic and environmental contributions to body mass index: comparative analysis of monozygotic twins, dizygotic twins and same-age unrelated siblings. *International Journal of Obesity, 33*(1), 37–41. https://doi.org/10.1038/ijo.2008.228

SIINSAN (Sistema de Información Nacional de seguridad Alimentaria y Nutricional) de Guatemala. (2016). *Encuesta Nacional de Salud Materno Infantil 2014-2015*. From https://portal.siinsan.gob.gt/ensmi/. Retreived on August 9, 2022.

Solomons, N. W. (2019). Vision of research on human linear growth. *Food and Nutrition Bulletin, 40*(4), 416–431. https://doi.org/10.1177/0379572119885475

Suwa, S., & Tachibana, K. (1993). Standard growth charts for height and weight of Japanese children from birth to 17 years based on a cross-sectional survey of national data. *Clinical Pediatric Endocrinology, 2*(2), 87–97. https://doi.org/10.1297/cpe.2.87

Waterlow, J. C., Buzina, R., Keller, W., Lane, J. M., Nichaman, M. Z., & Tanner, J. M. (1977). The presentation and use of height and weight data for comparing the nutritional status of groups of children under the age of 10 years. *Bulletin of the world Health Organization, 55*(4), 489.

Weiner, J. S., & Lourie, J. A. (1981). *Practical human biology*. Academic Press.

World Health Organization. (2006). *World Health Organization Multicentre Growth Reference Study Group. WHO Child Growth Standards: Length/height-for-age, weight-for-age, weight-forlength, weight-for-height and body mass index-for-age: Methods and development* (pp. 1–312). World Health Organization.

World Health Organization (2007) *Growtth refrence data for 5 to 19 years*. Ginebra. https://www.who.int/tools/growth-reference-data-for-5to19-years

World Medical Association. (2013). *64th general assembly. Declaration of Helsinki. Ethical principles for medical research in humans*. In 64th WMA General Assambley, Fortaleza, Brasil.

Yilmaz, B., & Gezmen, K. M. (2020). The current review of adolescent obesity: the role of genetic factors. *Journal of Pediatric Endocrinology and Metabolism, 16;34*(2), 151–162. https://doi.org/10.1515/jpem-2020-0480