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Growth Standards: Are we assessing correctly the growth of children in Portugal?

Joana Matos da Silva

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Candidate: Joana Matos da Silva

Supervisor: Professor Tiago Taveira-Gomes

(*)Written in British English

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Curvas de Crescimento: estamos a avaliar correctamente o crescimento das crianças em Portugal?

Joana Matos da Silva [a, b], Nuno Lourenço-Silva [c], Cristina Gavina[d, e, f], Tiago Taveira-Gomes[c, g, h] *

a USF Araceti - ACES Baixo-Mondego, ARS Centro, Portugal
b Faculty of Medicine, University of Porto, Porto, Portugal
c Department of Community Medicine, Health Information and Decision, Faculty of Medicine, University of Porto, Porto, Portugal
d Pedro Hispano Hospital - ULS Matosinhos, Matosinhos, Portugal
e Department of Medicine, Faculty of Medicine, University of Porto, Porto, Portugal
f UnIC, Faculty of Medicine, University of Porto, Porto, Portugal
g MTG Research and Development Lab, Porto, Portugal
h Faculty of Health Sciences, Fernando Pessoa University, Porto, Portugal

*Corresponding Author: Joana Matos da Silva
Telephone: +351932577177
Email: joanamatosdasilva@gmail.com

Abstract:

Background and objective:

Monitoring children's growth and development is fundamental for accessing quality healthcare. In 2004, the World Health Organization (WHO) developed healthy growth reference curves to be applied worldwide, establishing how children were expected to grow if ideal health and nutrition conditions were met. This study aims to evaluate the growth evolution of children in a Portuguese health unit, using anthropometric data records (weight, height and BMI) to create new growth curves representing Portuguese children. The results were compared with the WHO's curves to infer the appropriateness of their use in Portugal.

Methods

Retrospective cohort study, accessing electronic health records of children aged 0-5 years with follow-up at the Unidade Local de Saúde de Matosinhos, born from 01/01/2010 to 31/12/2019. Systematic collection and percentile curve distribution of the variables weight, height and Body Mass Index were registered at each surveillance appointment (0, 1, 2, 4, 6, 9, 12, 15, 18, 24 months and 3, 4 and 5 years). The study curves were compared with the WHO's standards, and differences and averages were calculated.

Results

The study had a total of 10 988 evaluations and showed differences between boys and girls in weight, height and BMI, with an average difference of 0.535 Kg, 1.46 cm and 0.27 Kg/m^2 less in girls. When comparing P50 of same-aged children in our study with WHO's standards, boys exhibit an average deficit of 0.772 Kg in weight and 3 cm reduction in height, while girls exhibit an average deficit of 0.806 Kg in weight and 3.15cm in height. There were no major differences found between P50 BMI in both studies, but our study's BMI overlaps the WHO's study at the age of 15 months in girls and 18 months in boys, being superior in about 4 Kg/m^2 in both genders in P95.

Conclusions

In this study, using large-scale national data we can infer that the WHO's curves are not representative of Portuguese children. Our study shows shorter, lighter but with higher BMI children who might have a compromised future health. Including all children in the study might bias the results as the WHO's study only focussed on full-term, breastfed and without significant morbidity children. Our results emphasise the importance of constructing national reference charts based on Portuguese children to further evaluate the need to adjust growth standard curves.

Keywords: Child Development, Child Growth, Child Nutrition, Anthropometry, Growth Charts, Growth Curves.

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1. Introduction

The assessment of child development has gained particular relevance in recent decades, with recognition of the role of growth monitoring and nutritional assessment as one of the main pillars of a child's health and healthy growth. A change in growth pattern may be indicative of disease, either of an infectious or genetic cause, or of disturbances in family dynamics (poverty, neglect, abuse), among others [1-3].

Analysing the impact of healthy growth on the long-term, many morbidity and mortality studies show that some factors in the early years of life (such as growth, nutrition, exposure to environmental factors) have a huge influence on the health of an individual in adulthood and on the development of many chronic diseases such as diabetes, dyslipidemia and cardiovascular diseases[1-5].

The World Health Organisation (WHO) plays a key role in monitoring global health, advocating measures to increase the health gains of populations. In their 2008 health report, they highlighted Portugal as an example of success regarding infant mortality indicators, having reduced the infant mortality rate from 77.5 to 3.6 ‰ between 1960 and 2009 [6].

This success is due not only to improvements in the socio-economic conditions of the population, but also to the implementation of nationwide health plans in the public healthcare system, "Sistema Nacional de Saúde" (SNS), which included the National Child and Youth Health Programme [7]. These programmes aim to standardise care according to the latest scientific evidence and promote the child's contact with health care starting at birth, with specific periodicity, and recommend the assessment of anthropometric parameters and physical and cognitive development at each contact.

There are many factors involved in the equation of child growth. Socio-cultural differences between and within countries dictate different eating habits and behaviours. Access to infrastructure and encouragement of physical activity varies from community to community. The influence of environmental exposure to harmful factors and some diseases also interfere with each child's growth pattern.

Thus, it has become imperative to standardise what can be considered "normal" and to create alerts for when this growth deviates from what is recommended for a child of a certain age in order to diagnose and manage these changes early. Monitoring children's growth and development based on anthropometric data provides objective indicators of their health and nutritional status, and standardised growth references help determine whether each child reaches optimal development at each growth stage.[8-9]

Focussing on preventive care in childhood and the assessment of height and weight status and nutritional development, the National Center for Health Statistics (USA) developed their growth charts in the 1970s, which were reviewed by the Centers for Disease Control and Prevention in 2000 and are in use until today, however, its worldwide applicability is compromised as they only studied the USA population [10].

The WHO reviewed the NCHS references and in the light of their limitations and methodological weaknesses, developed for several years (1997-2003) the study "The WHO Multicentre Growth Reference Study" [11-13], a longitudinal study in 6 countries, with approximately 8,500 children, based on subpopulations with favourable conditions for growth, of full-term births, breastfed and without significant morbidity. This study, published in 2004, provided expected growth curves, divided by percentiles.

It was intended to create healthy growth references that would be applied worldwide and would establish how children were expected to grow if ideal health and nutrition conditions were present.

In Portugal, the Portuguese Society of Paediatrics and the Direção Geral de Saúde (DGS) decided to adopt the WHO's growth curves in 2010, which remain as a reference in the Child and Youth Health Surveillance Programme until today [7].

Studies showing discrepancies between the WHO's growth curves and national registries have been carried out in countries such as Canada, Norway, Belgium, Poland, Germany, Turkey, South Korea and China, that question the applicability of the WHO's growth curves on a global scale [14-24]. Thus, it is worth questioning whether these curves are correctly categorising our children's growth as normal or abnormal.

Valerie Natale et al. demonstrated in a systematic review that concerning weight and height, the curves in 55 different countries are comparable/overlapping to those of the WHO, but in terms of cephalic perimeter, the findings in different countries and ethnic groups are very discrepant, which may lead to the misdiagnosis of macro or microcephaly of normal children for their population[17].

Almost 20 years after the WHO's standards publication and 13 years after its adoption in Portugal, it is of great importance to carry out a study of the growth of Portuguese children in order to verify the applicability of the WHO's curves and possibly alert to the need of changing the parameters of growth assessment of our infants.

The main objective of this study is to evaluate the growth evolution of children in a Portuguese health unit, using anthropometric data records (weight, height and BMI) and to create growth curves, establishing an empirical derivation for Portuguese children. The secondary objective is to compare the results with the WHO's curves and infer the appropriateness of their use in the Portuguese population.

2. Materials and Methods

Study design

This is a retrospective cohort study, with an assessment of the electronic health records of children born in the area of influence and with follow-up at the Unidade Local de Saúde de Matosinhos (ULSM), in Portugal in the period between 2010 and 2019. This unit aggregates 14 Primary Health Care units and one Secondary Healthcare unit (Hospital Pedro Hispano) and responds to a population of 176,845 patients[25].

The pre-index date was assumed as the date of implementation of the electronic healthcare software (around 2006 for most units) and the index date was defined as 01/01/2010.

The present study characterises the growth evolution of children aged zero to five years born in Portugal between 01/01/2010 and 31/12/2019 (population), and the study's sample is of all children with follow-up at the ULSM.

The study analyses a 10-year time window using electronic health records with systematic collection of the variables data weight, height and Body Mass Index (BMI) from all the surveillance visits each child had at the healthcare unit.

At each child health surveillance appointment, it is recommended (by the Portuguese Child and Youth Health Surveillance Programme) to evaluate and register the infant's anthropometric data in the Child and Youth Health bulletin (paper support) and in the electronic health record software (electronic support). The recommended surveillance appointments start at birth, being the first ideally before 21 days and the subsequent at the ages of 0, 1, 2, 4, 6, 9, 12, 15, 18 months and 2, 3, 4, 5, 6-7, 8, 10, 12-13, 15-18 years (table 1). Weight and height should be assessed from the child's first visit until 18 years of age.

The correct surveillance and the optimised registers are encouraged by the SNS quality programmes with constant supervision using the Index contractualized with the primary care health units [26]. These establish when and by whom children should be evaluated, defining as quality criteria that children should have six appointments in the first year and three in the second year.

Table 1. Chronology of surveillance appointments

	Age [1]
1st year	0M 1M 2M 4M 6M 9M 12M
]1-2] years	15M 18M 24M
[3-18] years	3Y 4Y 5Y 6-7Y 8Y 10Y 12-13Y 15-18Y

[1] Age in months (M) and years (Y).

Each consultation integrates both nursing and medical evaluation of the child. Anthropometric measurements are done mostly by nurses with posterior medical validation. The data registration is made by both in the electronic health record programme, which has proper fields to register each variable - height and weight, thus automatically calculating the variable BMI when introducing both height and weight.

Data from the electronic health record is available for consultation by the health team that evaluates the child and by all health professionals in the SNS through the national electronic health network ("RSE"). This guarantees the follow-up of the child in different levels of health care.

Variable definitions and eligibility criteria

Children aged 0 to 5 years were included in the study as long as they had follow-up at the ULSM and were born between 01 January 2010 to 31 December 2019. Timepoints defined for determining variables were 0, 1, 2, 4, 6, 9, 12, 15, 18, 24 months, 3, 4 and 5 years (assuming an interval of 15 days before and after the precise age).

No exclusion criteria were applied when selecting the sample for this study.

Variables under study: child's age (days/months/years); child's sex (masculine/boy and feminine/girl), weight (in Kg), height (in cm), Body Mass Index (BMI) calculated by dividing weight (Kg) by height in metres (m) squared (in Kg/m^2).

Data and statistical analysis

The study was submitted and had the approval of the Ethical Committee of the Institution (ULSM).

The analysis and treatment of data were carried out using analytical programmes developed for this study that were applied in the institution data centre.

The data was extracted from the institution's data centre by the ULSM IT Department and was anonymised according to the Health Insurance Portability and Accountability Act (*HIPAA) Safe Harbour* criteria [27]. All identifying codes were removed prior to running the analytical programmes and the investigators had no direct access to the data.

The investigators studied the characteristics of the sample distribution of the quantitative continuous variables weight, height and BMI in both genders, from 0 months to 5 years of age. The variables data were aggregated and distributed in percentile curves (P5, P10, P15, P25, P50, P75, P85 P90, P95), considering the ages of surveillance appointments (0, 1, 2, 4, 6, 9, 12, 15, 18, 24 months, 3, 4 and 5 years) extracting data 15 days before and 15 days after the precise age of the children under surveillance. The data outside percentiles 0.01 and 0.99 were not considered in the analysis.

The percentile curves of ULSM children were compared with the WHO's standards using the expanded tables available on the WHO's website [28]. In order to compare both curves, the variable age was converted in days, corresponding 1 month to 30.4375 days, as per the WHO's study. To compare them, differences in each percentile at each point of age were calculated, as well as the average of those differences.

The software used was Microsoft Excel® and IBM® Statistical Package for the Social Sciences (SPSS®), version 26.

3. Results

The study population has 10988 evaluations/measurements from 0 to 5 years old, with 5331 of the evaluations in the first year, 2827 in the second year and 2830 between 3 and 5 years old. The moment of 1 month (30 days) was the one with the most observations -1401, and the one with fewer observations was at 6 months (182 days) - 563. Overall, 51.5% of the children are boys.

Table 2. Data´s distribution by age and sex

	Age [(1)]	n	Boy	Girl
1st year	7	644	308	336
	30	1401	682	719
	60	793	362	431
	121	583	293	290
	182	563	280	283
	274	600	296	304
	365	747	376	371
]1-2] years	457	805	412	393
	548	1008	538	470
	730	1014	530	484
[3-5] years	1096	836	463	373
	1278	957	548	409
	1825	1037	570	467
Sum		10988	5658	5330

[1] Age in days.

The examination of the study's data reveals that, on average, girls in the study have a 0.535 Kg lower weight at P50 when compared to boys. Additionally, the P50 height measurement for girls is, on average, 1.462 cm less than that for boys, and girls BMI is, on average, 0.272 Kg/m² lower (see Table 3).

Table 3. Study P50 data and sex differences.

Age (days)*	Boy Weight P50	Girl Weight P50	Weight Dif Boy-Girl	Boy Height P50	Girl Height P50	Height Dif Boy-Girl	Boy BMI P50	Girl BMI P50	BMI Dif Boy-Girl
7 (0M)	3.290	3.130	0.160	50.00	49.00	1.000	13.02	13.11	-0.090
30 (1M)	3.390	3.270	0.120	52.00	51.00	1.000	13.02	12.91	0.110
60 (2M)	4.510	4.000	0.510	56.00	55.00	1.000	14.90	13.78	1.120
121 (4M)	6.000	5.360	0.640	61.00	60.00	1.000	16.57	15.59	0.980
182 (6M)	7.000	6.500	0.500	66.00	63.00	3.000	17.24	16.63	0.610
274 (9M)	8.000	7.000	1.000	69.00	67.00	2.000	17.30	16.69	0.610
365 (12M)	9.000	8.000	1.000	74.00	72.00	2.000	16.44	16.76	-0.320
457 (15M)	10.000	9.000	1.000	77.00	75.00	2.000	16.87	16.00	0.870
548 (18M)	10.000	10.000	0.000	80.00	79.00	1.000	16.36	16.36	0.000
730 (2Y)	11.030	11.000	0.030	85.00	83.00	2.000	16.36	16.22	0.140
1096 (3Y)	14.000	13.000	1.000	90.00	89.00	1.000	16.62	16.54	0.080
1278 (4Y)	15.000	14.000	1.000	95.00	94.00	1.000	16.19	16.57	-0.380
1825 (5Y)	17.000	17.000	0.000	104.00	103.00	1.000	16.00	16.19	-0.190
Average			0.535			1.462			0.272

* Age in days with correspondent conversion to months (M)/years (Y); Dif - difference.

Analysing the P50 and comparing same-aged children in our study with the WHO's standards (see table 4), boys in our study have an average of 0.772 Kg less and are 3 cm shorter and girls have an average 0.806 Kg less and are 3.15 cm shorter.

There were no significant differences found between P50 BMI in both studies (0.13 higher in boys in the WHO's study and 0.01 higher in girls in our study).

However, our study BMI is higher than the WHO's study at the age of 12 months to 5 years in girls, and at the ages of 9 months and 15 months to 5 years in boys. BMI in children older than 2 years has an average of 0.86 Kg/m^2 more in our boys and 1.11 Kg/m^2 more in our girls.

Table 4. P50 data analysis in study vs WHO's standards.

Age (days)*	Weight Dif WHO-study Boy	Weight Dif WHO-study Girl	Height Dif WHO-study Boy	Height Dif WHO-study Girl	BMI Dif WHO-study Boy	BMI Dif WHO-study Girl
7 (0M)	0.198	0.209	1.12	1.33	0.32	0.10
30 (1M)	1.063	0.902	2.67	2.63	1.89	1.63
60 (2M)	0.968	1.051	2.33	1.98	1.39	1.96
121 (4M)	0.951	1.016	2.83	2.04	0.58	1.08
182 (6M)	0.926	0.789	1.59	2.70	1.09	0.28
274 (9M)	0.902	1.226	2.97	3.15	-0.13	0.05
365 (12M)	0.646	0.946	1.74	2.01	0.36	-0.40
457 (15M)	0.314	0.604	2.16	2.53	-0.43	0.00
548 (18M)	0.939	0.232	2.26	1.71	-0.22	-0.63
730 (2Y)	1.118	0.474	2.80	3.40	-0.62	-0.82
1096 (3Y)	0.344	0.852	6.09	6.06	-1.02	-1.14
1278 (4Y)	0.347	0.970	4.84	5.04	-0.75	-1.26
1825 (5Y)	1.330	1.212	5.94	6.40	-0.81	-0.92
Average 0-5 years	0.773	0.806	3.03	3.15	0.13	-0.01
Average 2-5 years					-0.86	-1.11

* Age in days with correspondent conversion to months (M)/years (Y); Dif - difference.

In Figure 1 we can analyse the P50's distribution of each variable in both studies.

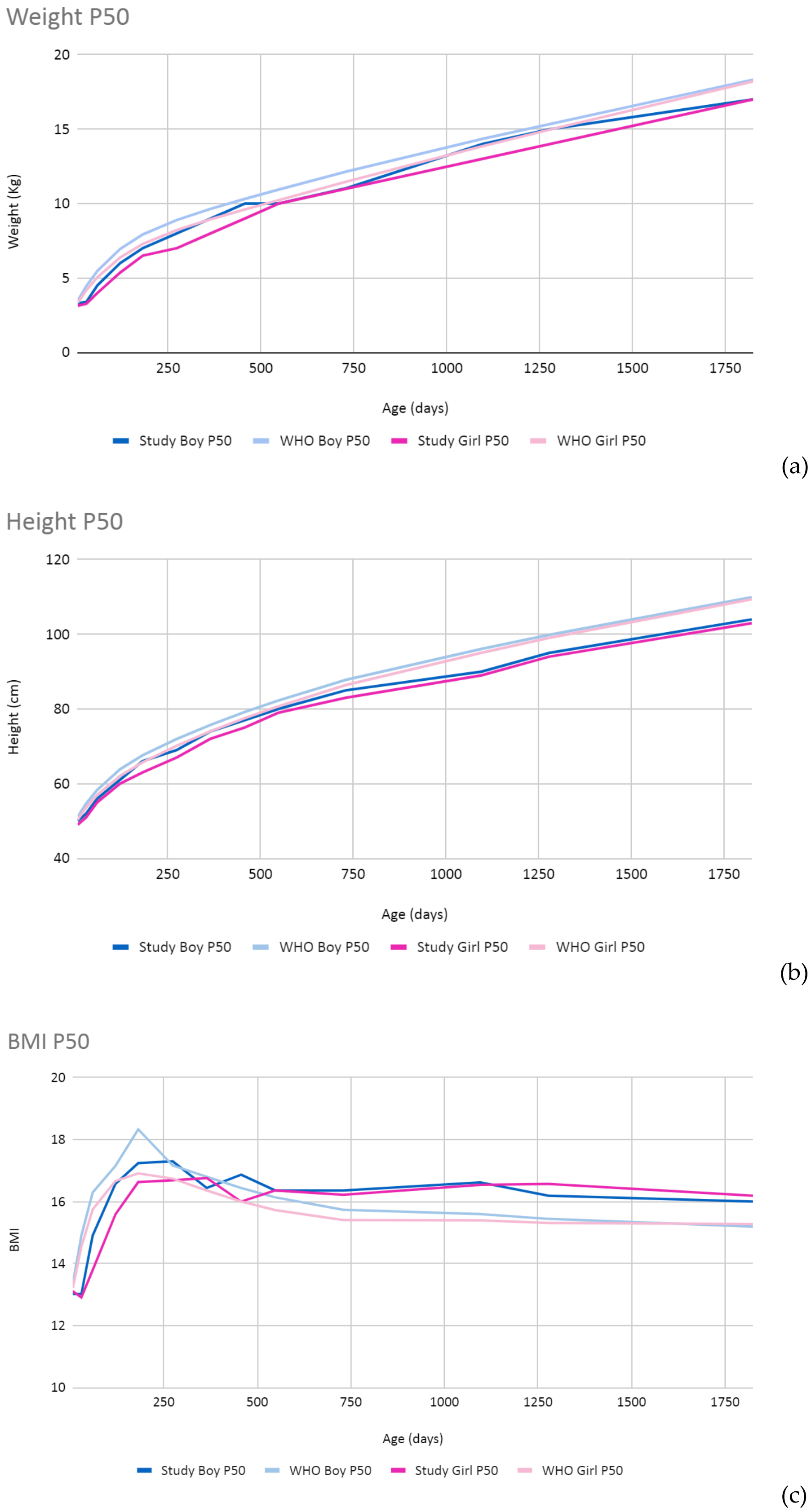
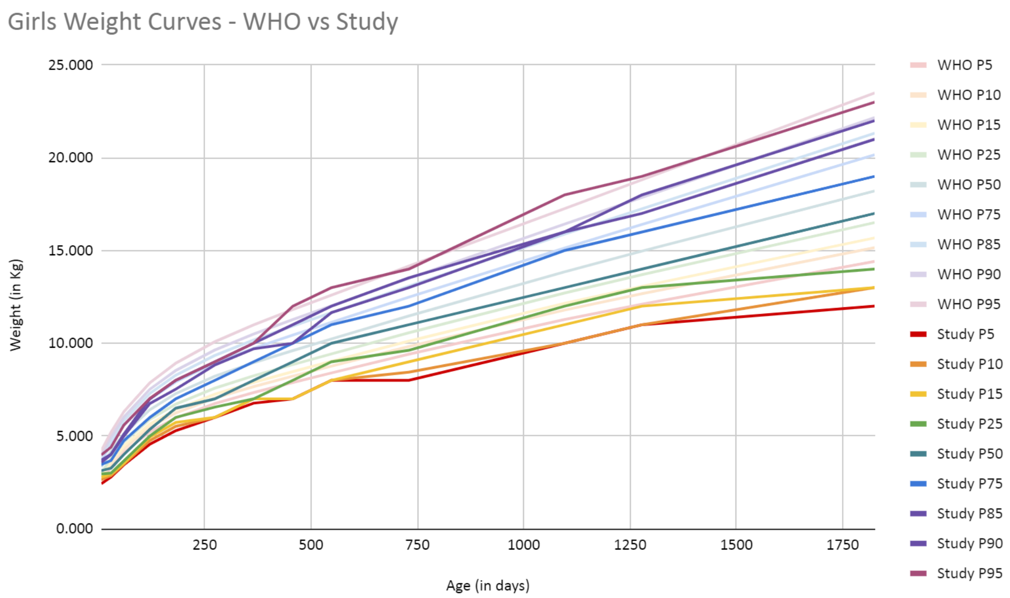


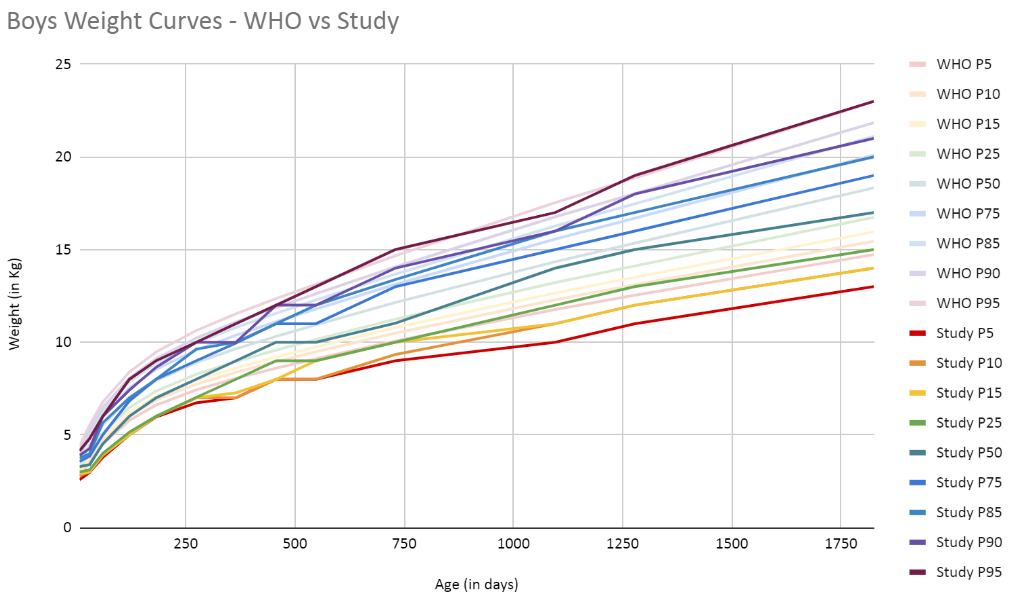
Figure 1. Study's P50 comparison with WHO's curves (**a**) Weight P50 in boys and girls; (**b**) Height P50 in boys and girls; (**c**) BMI P50 in boys and girls.

As seen in the graphics in Figure 1, the study's weight and height curves are always lower than the WHO's curves in both genders, but BMI overlaps the WHO's curves in girls older than 12 months and boys of 9 and older than 15 months.

When we expand the analysis to all percentile curves some differences can be detected. Regarding weight in the percentiles below P50, the study's curves tend to be lower than the WHO's study in both sexes and in percentiles above P50 the study's curves tend to overlap the WHO's curves, especially girls older than 1 year, regarding P90 and P95.

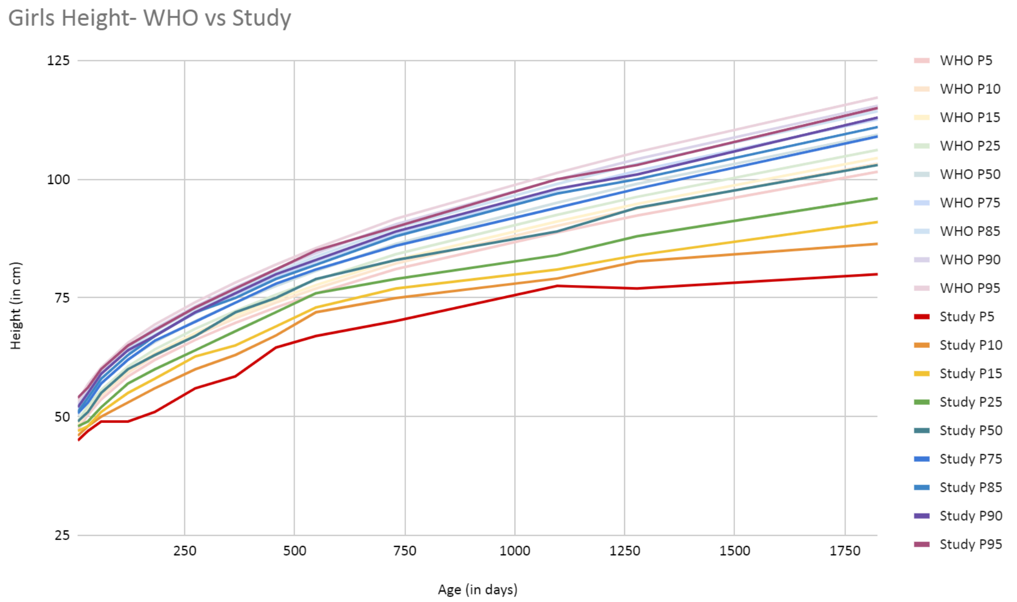


(a)

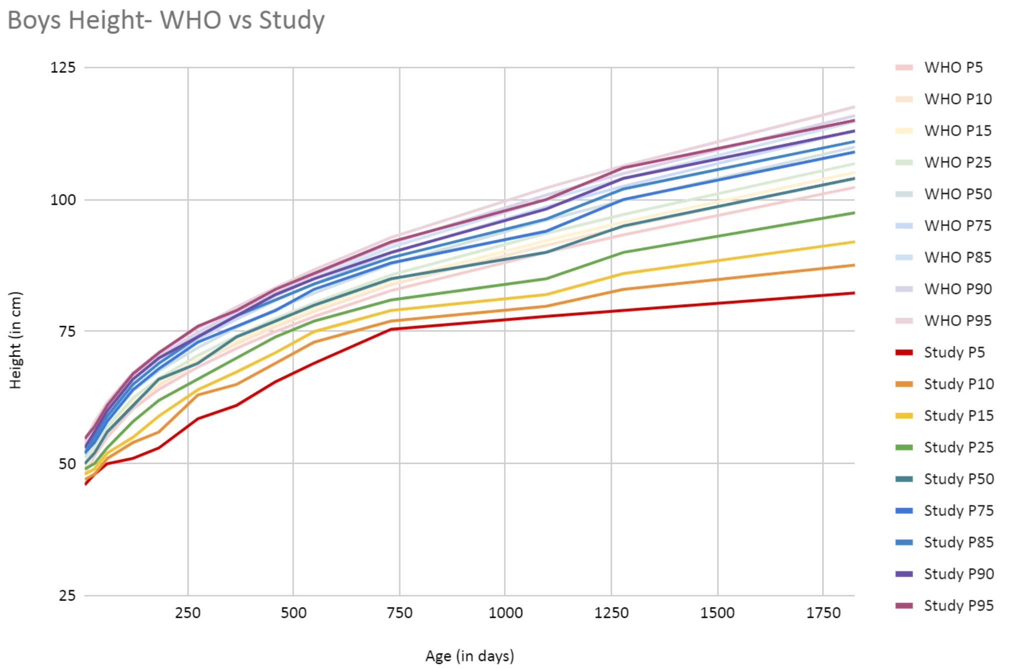


(b)

Figure 2. Weight Curves - WHO vs Study: (a) Girls Weight Curves; (**b**) Boys Weight Curves



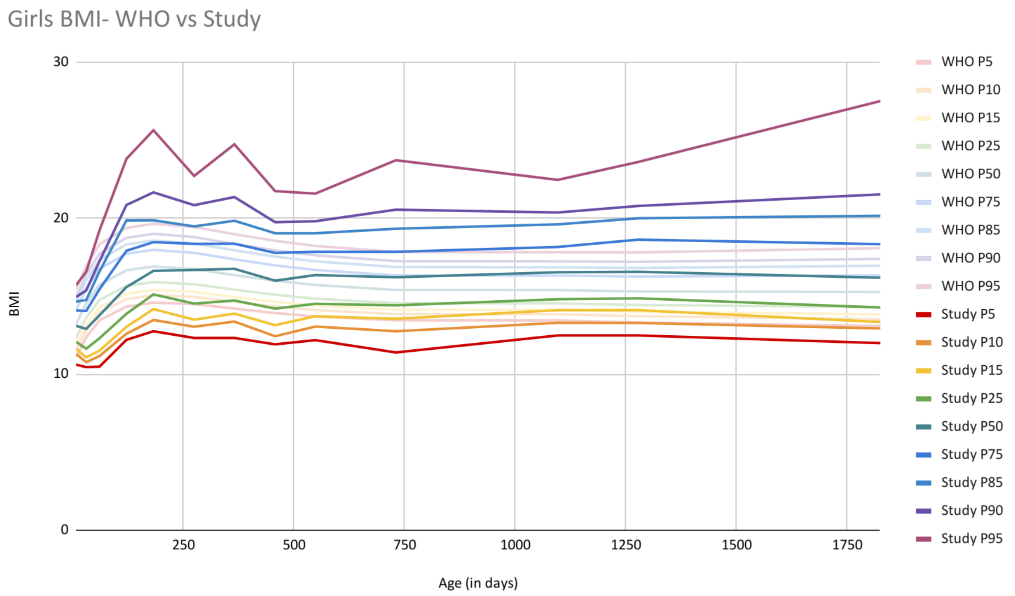
(a)



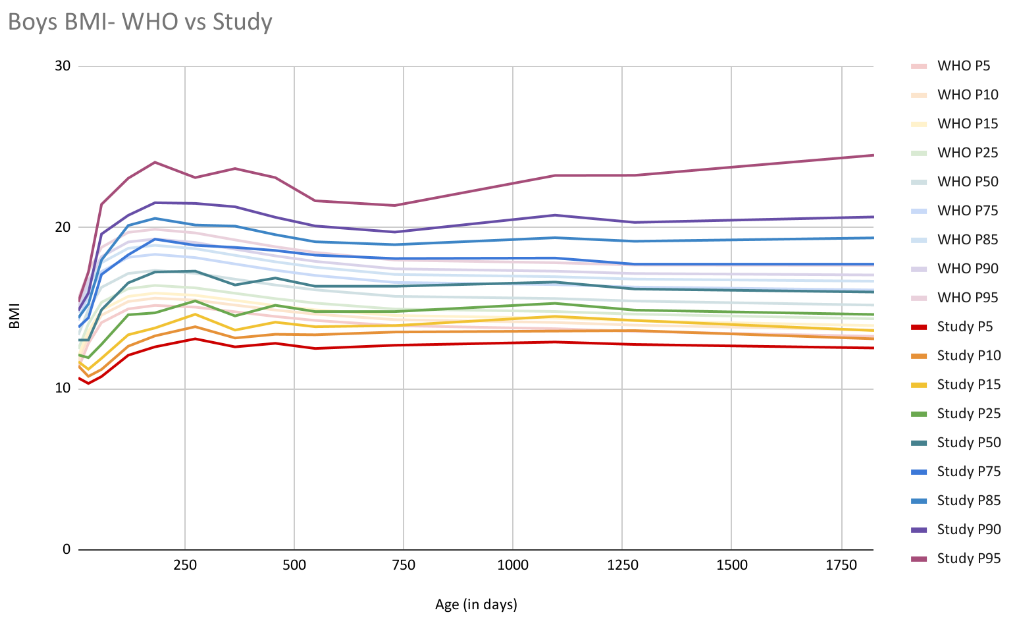
(b)

Figure 3. Height Curves - WHO vs Study: (a) Girls Height Curves; (b) Boys Height Curves

When analysing height, all study curves in all ages are lower than WHO's standards in both genders.



(a)



(b)

Figure 4. BMI Curves - WHO vs Study: (a) Girls BMI Curves; (b) Boys BMI Curves

BMI analysis shows that the curves in percentiles below P50 (P5-P25) are lower than WHO's study and the ones above (P75-P95) are superior in our study.

Table 5. BMI comparison for P05 and P95

	BMI P05						BMI P95					
	Girls			Boys			Girls			Boys		
Age	Study	WHO	Dif WHO-Study	Study	WHO	Dif WHO-Study	Study	WHO	Dif WHO-Study	Study	WHO	Dif WHO-Study
7	10.62	11.1	0.51	10.67	11.270	0.60	15.71	15.4	-0.29	15.39	15.580	0.19
30	10.46	12.4	1.91	10.33	12.815	2.49	16.57	16.9	0.38	17.24	17.253	0.01
60	10.49	13.5	2.98	10.76	14.108	3.35	19.22	18.3	-0.89	21.44	18.774	-2.67
121	12.21	14.3	2.13	12.08	14.954	2.87	23.81	19.4	-4.43	23.06	19.702	-3.36
182	12.76	14.6	1.84	12.6	15.171	2.57	25.64	19.6	-5.99	24.05	19.893	-4.16
274	12.33	14.5	2.17	13.1	15.065	1.97	22.71	19.4	-3.27	23.1	19.670	-3.43
365	12.33	14.2	1.88	12.6	14.777	2.18	24.74	19.0	-5.76	23.66	19.236	-4.42
457	11.92	13.9	2.01	12.82	14.486	1.67	21.74	18.6	-3.18	23.1	18.812	-4.29
548	12.19	13.7	1.52	12.5	14.241	1.74	21.58	18.2	-3.35	21.66	18.459	-3.20
730	11.4	13.5	2.06	12.7	13.917	1.22	23.72	17.8	-5.88	21.37	17.982	-3.39
1,096	12.49	13.5	0.96	12.9	13.726	0.83	22.46	17.8	-4.64	23.23	17.820	-5.41
1,278	12.49	13.3	0.83	12.75	13.559	0.81	23.61	17.8	-5.80	23.24	17.678	-5.56
1,825	12	13.1	1.09	12.53	13.254	0.72	27.51	18.1	-9.43	24.49	17.661	-6.83
Average			1.68			1.77			-4.04			-3.58

* Age in days with correspondent conversion to months (M)/years (Y).

As represented in table 5, differences in BMI are maximised in the extreme percentile. In girls, it has an average difference of 1.68 less and 4.04 more, and in boys it has a difference of 1.77 less and 3.58 more in this study.

4. Discussion

One previous study, of 2023, compared the height of Portuguese children with international standards and concluded that it had high agreement with the WHO's growth charts, especially for children under 5 years[29]. Another study, from 2015, developed references for height, weight, body mass index (BMI), waist circumference and body fat of rural Portuguese children and adolescents (7-17 years old), showing similarity between height but greater values of weight and BMI.[30]

To the best of our knowledge, our study's analysis is the first of its kind in Portugal, as it evaluates weight, height and BMI from birth to 5 years of age.

Regarding that the WHO's standards reflect a population of the late 90's is to be expected that with cumulative alterations in diet and nutrition conditioning different eating patterns, anthropometric measurements have also changed in recent years.

Our study analyses a younger population, born in 2010-2019 and includes children not represented in the WHO' standards, and therefore with different constitutional anthropometry.

As seen in the results, Portuguese children have slightly inferior weight curves than the WHO's standards and inferior height curves. This might be due to the Portuguese population being constitutionally shorter than the populations of the countries included in the WHO's standards and because our study included preterm births and children with morbidity which are expected to be smaller and grow slower.

The fact that height is inferior in our children translates into higher values of BMI early in the first months, both in boys and girls. The changing eating patterns, with more processed food and unbalanced diet might explain an increasing tendency to higher BMI in our children.

Higher BMI from so early ages might predict higher predisposition to weight related problems that should be corrected as soon as detected.

The main concern that this study reveals is that overweight and obesity might be underestimated in our children due to weight and height being inferior to the standards curves in use.

This study's biggest strength is that it uses data from a clinical registration software used in almost all Portuguese health units (hospitals and primary care), enabling the reproduction of this study in other health units and enlarging this study to the entire Portuguese population.

The main limitations of this study are that, as a retrospective observational study, the quality of the results depends on the quality of the data recorded on the health registration software. Also, by narrowing the study to a limited geographic area, the applicability of the conclusions to other regions or countries might be compromised. Both limitations have a small impact attending to the size of the sample.

Another limitation is that the WHO's study population featured breastfed and full-term births, and our study had no exclusion criteria for the population.

5. Conclusions

In this study, using large-scale national data we can infer that the WHO's curves are not representative of Portuguese children.

Both weight and height are inferior in our population in all the ages analysed and BMI being inferior in the first year, overlaps the WHO's standards in the second and subsequent years in both sexes for percentile above P50.

The present results point to a possible misdiagnosis of overweight and obesity in Portuguese children, which is known to be associated with increased morbidity and mortality.

Having no exclusion criteria in this study might bias the results as the WHO's standards only focused on full-term, breastfed, without significant morbidity children.

Nevertheless, the population excluded from the WHO's study are children with malnutrition, diseases, and poor socioeconomic conditions, which could lead to stunted growth, and our study results point in the opposite way.

Our study shows shorter, lighter but with higher BMI children who might have compromised future health.

Our results emphasise the importance of constructing national reference charts based on Portuguese children. Future nationwide studies should proceed to further evaluate the need to adjust growth standard curves and even create and adopt our own.

Author Contributions:

Joana Matos da Silva: Conceptualization, Methodology, Writing – original draft, Writing – review & editing, Formal analysis, Supervision.

Tiago Taveira-Gomes: Conceptualization, Methodology, Software, Validation, Formal analysis, Writing - review & editing, Supervision.

Nuno Lourenço-Silva: Writing – review & editing, Formal analysis, Supervision

Cristina Gavina: Conceptualization, Supervision.

All authors have read and agreed to the published version of the manuscript

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Institutional Review Board Statement
This study protocol was reviewed and approved by the Ethics Committee of the ULSM - Comissão de Ética da ULSM (reference number 90/CES/JAS —date 14 July 2023).

Informed Consent Statement:
Not applicable
This is a database study with an eligible population in the order of thousands, in which the application of informed consent is not practicable, concerning Article 9 point (i) and point (j) of the General Data Protection Regulation which refers to "ensuring a high level of quality and safety of health care and medicinal products or medical devices, based on Union or State law" and "scientific or historical research purposes or for statistical purposes" as valid reasons for the development of this study without the need for informed consent.

Data Availability Statement: All aggregate statistical results are incorporated into the article and its online Supplementary Materials. Patient-level data used in this study are not publicly available.

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