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Weight-for-length ratio or body mass index - which one is the best predictor of future overweight and obesity?

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Abstract
Anthropometric references play a central role in identifying children at risk of overweight and obesity. However, there is still no consensus on whether body mass index (BMI) or weight/length ratio (W/L ratio) serves as the superior predictor of obesity in early childhood. This study aims to determine which of these two measurements is the more reliable predictor of future obesity.
Retrospective and observational cohort study, that included children followed in consultation from a level II hospital, currently aged between 5 and 15 years. Inclusion criteria required children who had anthropometric records at 0, 2, and 5 years old, as well as at least one record at 6, 12, or 18 months. A correlation analysis was conducted between the BMI z-score (z-BMI) and the W/L ratio z-score (z-W/L). Logistic regression was employed to assess the association between z-BMI and z-W/L up to 2 years with the presence of overweight/obesity at 5/6 years.
The prevalence of overweight and obesity by 5/6 years old was 12% and 13%, respectively. There was a strong correlation between z-BMI and z-W/L (r = 0.908 - 0.997, $p<0.05$). In linear analysis, only z-BMI proved to be related to a higher z-BMI by the age of 5/6 years. In logistic regression, both z-BMI and z-W/L (at 6, 12 and 18 months) were significant predictors of overweight and obesity by 2 and 5/6 years old. Furthermore, z-BMI at 0 months proved to be associated with the primary outcome by 5/6 years old, but not z-W/L. Both parameters proved to be effective predictors of overweight/obesity by 2 and 5/6 years of age. However, the results suggest that BMI may have a stronger association with overweight and obesity, making it a potentially better indicator of future obesity risk in late childhood than W/L ratio.

Keywords: Overweight, obesity, childhood, anthropometric, world health organization

Introduction

Obesity (Ob) is a chronic, complex, multifactorial, and preventable disease characterized by the excessive accumulation of body fat. Over the past few decades, not only has the prevalence of obesity in pediatric populations increased, but its severity has also escalated, representing a major global public health concern. The early identification of children at risk of developing excess weight and obesity is imperative to address this pressing issue effectively.

Anthropometric references play a pivotal role in identifying children with, or at risk of, overweight (OW) and Ob. Consequently, growth assessment based on the interpretation of anthropometric indices has emerged as the most widely accepted technique for identifying growth-related issues and even estimating childhood growth trajectories. [1, 2, 3, 4, 5, 6, 7, 8].

The American Academy of Pediatrics (AAP) recommends the use of weight-for-length ratio (W/L) for assessing weight in children under 2 years of age and body mass index (BMI) for children older than 2 years. However, the clinical implications of using W/L or BMI in children under 2 years as indicators of obesity and future cardiometabolic risk remain poorly studied. Due to the absence of a consensus definition in this age group, identifying children at greater risk of obesity presents a significant challenge. For both anthropometric measures (W/L and BMI), the World Health Organization (WHO) provides reference curves [9, 10]. representing the international growth prototype.

WHO BMI curves have been integrated into the health bulletin of childhood and youth in Portugal since 2013 for assessing children aged 0 to 18 years and are now widely used in clinical practice. Conflictingly, W/L curves are not included in health bulletin in Portugal, even thought, W/L ratio continues to be frequently used in assessing obesity or obesity risk in children up to 2 years old.

Studies conducted worldwide have attempted to determine the superior predictor - W/L ratio or BMI - of early childhood obesity to establish anthropometric standardization below 2 years of age. Some of these studies have revealed that BMI (versus W/L) in early childhood exhibits a higher positive predictive value for future obesity, with BMI and W/L values only becoming more concordant after 6 months of age [3, 4, 8]. On the other hand, other study [7] has shown overlapping BMI and W/L in estimating adiposity and metabolic risk in early adolescence. Given the lack of national studies evaluating this relationship, the limited evidence from international research and the absence of consensus in the few existing studies, there is a need to determine the superior predictor of future BMI.

By this mean, the main objectives of this study, were to 1) evaluate which of the anthropometric parameters (BMI vs. W/L) in early childhood is the better predictor of future OW and Ob at 2 years and at 5/6 years old; 2) to examine the correlation between the two anthropometric parameters throughout the follow-up period.

Materials and Methods

Study design

Retrospective cohort observational study, with consultation of all the clinical files of children followed in General Pediatrics/Obesity consultation at a level II hospital, currently aged between 5 and 15 years (born between 2008 and 2018). Inclusion criteria required children to have anthropometric records at 0, 2, and 5/6 years, as well as at least one record at 6, 12, or 18 months. Children who did not met this inclusion criteria were excluded.

Data collection

Anthropometric data: weight and length at 0, 2, 4, 6, 12, 18 and 24 months; weight and height at 3 years, 4 years, 5/6 years and 10/11 years. Regarding the time of measurement, we considered approximations of ± 2 weeks for ages 0, 2 and 4 months; ± 4 weeks for ages 6 months; ± 6 weeks for ages 12 and 18 months; ± 8 weeks for ages 24 months and, finally, ± 4 months for ages 3 years, 4 years, 5/6 years and 10/11 years. [8] BMI was calculated as the relationship between weight and length squared (kg/m2). The z-score for weight, length, head circumference, BMI and W/L ratio was defined according to the WHO curves, using the *AnthroPlus* application. Below 5 years of age, we defined OW if BMI z-score (z-BMI) or W/L Ratio z-score (z-W/L) were > 2. We defined obesity if z-BMI or z-W/L were >3. For children with 5 years old or more, we considered OW if z-BMI > 1 but < 2, obesity if z-BMI was >2 and severe obesity z-BMI was >3 [1, 2, 9].

Sociodemographic data: Race/ethnicity, gender, presence of OW and Ob, other chronic comorbidities, age of parents/caregivers, parents/caregivers' occupation, type of birth, gestational age, maternal complications during pregnancy (Gestational diabetes, hypertension, pre-eclampsia, eclampsia, thyroid pathology), and duration of exclusive and non-exclusive breastfeeding.

Statistical analysis plan

Assessment of the distribution of continuous variables with graphical methods combined with the Shapiro-Wilks and Kolmogorov-Smirnov (if >30 observations) tests. Continuous variables with normal distribution were presented as mean ± standard deviation, and analyzed with the T-Student test. Given our large sample size, continuous variables with non-normal distribution were also presented as mean ± standard deviation, rather than median plus interquartile range. Non-continuous variables were analyzed using Pearson's chi-square test and Fisher's exact test when appropriate. Spearman correlation analysis was used to evaluate the correlations between the 2 parameters (z-BMI and z-W/L) at each age. A linear regression was carried out to evaluate if our independent variables, meaning z-BMI and z-W/L before 2 years, were useful in predicting z-BMI by 2 and at 5/6 years (our dependent variables). A logistic regression was carried out to evaluate the association between OW/Ob by 2 years and 5/6 years, with the z-BMI and z-W/L ratio before 2 years. The models were adjusted for clinically or statistically significant variables in the univariate analysis, considering possible confounders.

An analysis of the receiver operator characteristic curve (ROC) was made in the logistic regression to estimate the sensitivity and specificity in diagnosing OW/Ob at 2 years and 5/6 years of age, comparing both z-BMI and z-W/L under 2 years, with calculation of AUC and 95% confidence interval. The cutoff was selected as the value that maximizes the sum of sensitivity and specificity. Values of $p<0.05$ were considered statistically significant. Statistical analysis was carried out using the IBM SPSS Statistics 29.

This study protocol was submitted and approved by the local Ethics Committee and the Data Protection Officer, in accordance with the Declaration of Helsinki. Data were collected by the investigators and remained anonymous and confidential.

Results

A total of 853 children (57% male) were included in the study.

The median gestational age was 39 weeks. Most mothers accomplished an eutocic delivery (54%) and 11% had pregnancy complications. The majority of the newborns had a normal birth weight (2500 - 4000g). The median duration of exclusive breastfeeding was 4 months. The prevalence of OW and Ob by 2 years was 4% (n=38) and 1% (n=11), correspondingly. By 5 years this prevalence was 13% (n=112) and 14% (n=118), respectively. All the characteristics of study population can be checked below, at table 1.

Table 1: General Characteristics of Study Population

Variable	Population, n (%)
Total	853 (100%)
Male	482 (57%)
Female	371 (43%)
Chronic Disease	
Yes	179 (21%)
No	667 (78%)
Mother´s Age	
Median	31 years
Mother´s Education	
1 - Elementary school	12 (3%)
2 - Basic Education	42 (11%)
3 - Upper Secondary School	79 (21%)
4 - Graduation	75 (20%)
5 - Master's degree	16 (4%)
6 - PhD	1 (0.3%)
Father´s Age	
Median	34 years
Father´s Education	
1 - Elementary school	29 (6%)
2 - Basic Education	57 (12%)
3 - Upper Secondary School	61 (13%)
4 - Graduation	46 (10%)
5 - Master's degree	5 (1%)
6 - PhD	0
Type of birth	
Eutocic	460 (54%)
Dystocic by suction cup	109 (13%)
Dystocic by caesarean	279 (33%)
Gestational age	
Median	39 weeks
Maternal complications during pregnancy	
Gestational diabetes	57 (7%)
Hypertension	16 (2%)
Pre-eclampsia	5 (1%)
Eclampsia Thyroid pathology	0 8 (1%)
Duration of exclusive breastfeeding (months)	
Median	4 months
Missing values	698 (82%)
Birth weight	
Macrosomia (> 4000g)	14 (1.6%)
Normal birth weight (2500 - 4000g)	838 (98%)
Low birth weight (<2500g)	2 (0.2%)
Very low birth weight (<1500 g)	0
Extremely low birth weight (<1000g)	0
Overweight and Obesity at 2y	
Overweight (z-BMI and/or z-W/L >2)	38 (4%)
Obesity (z-BMI and/or z-W/L >3)	11 (1%)
Overweight and Obesity at 5/6y	
Overweight (1< z-BMI <2)	112 (13%)
Obesity (z-BMI >2)	118 (14%)

Continuous variables with a normal distribution included z-BMI and z-W/L ratio at 2 months, 4 months, 6 months and 4 years, for which mean and standard deviation (SD) were calculated. Continuous variables with a non-normal distribution included z-BMI and z-W/L ratio for 0, 12, 18, 24 months and 3 years, as well as z-BMI for 5/6 and 10/11 years. Given our sample size, we preferred to use mean and standard deviation for variables with a non-normal distribution, rather than median and interquartile variance range (IQR). The results are shown in table 2. Note that the "n" does not take into account the omitted cases, but the valid ones, considerate in this calculus.

Table 2: Mean and Standard Deviation for z-BMI and z-W/L Ratio (boys and girls)

z-BMI	**Boys**			**Girls**		
Age	**n**	**Mean**	**SD**	**n**	**Mean**	**SD**
0 months	479	-0.18	+1.07	368	-0.25	+1.03
2 months	24	-0.29	+1.21	21	-0.07	+1.67
4 months	36	-0.32	+1.14	28	-0.52	+1.43
6 months	125	-0.31	+0.94	90	-0.39	+1.07
12 months	342	+0.31	+1.29	269	+0.25	+1.11
18 months	299	+0.39	+1.39	229	+0.43	+1.18
24 months	474	+0.30	+1.40	370	+0.35	+1.39
3 years	230	+0.23	+1.19	172	+0.22	+1.45
4 years	202	+0.26	+1.28	154	-0.03	+1.23
5/6 years	482	+0.41	+1.80	370	+0.59	+1.99
10 years	111	+1.38	+3.57	101	+1.06	+2.32
z-W/L Ratio	**Boys**			**Girls**		
0 months	464	+0.16	+1.03	344	+0.06	+0.94
2 months	24	+0.05	+1.17	21	+0.55	+1.64
4 months	36	-0.19	+1.21	28	-0.16	+1.66
6 months	128	-0.20	+0.93	90	-0.26	+1.06
12 months	348	+0.25	+1.50	272	+0.17	+1.11
18 months	304	+0.33	+1.52	231	+0.32	+1.17
24 months	481	+0.22	+1.41	368	+0.21	+1.18
3 years	234	+0.23	+1.17	171	+0.17	+1.35
4 years	206	+0.25	+1.25	154	+0.01	+1.24

When accessing Spearman analysis (if both variables do not follow a normal distribution) and Pearson analysis, if otherwise, to evaluate correlations between the 2 parameters (z-BMI and z-W/L) at each age, we concluded that there was a strong correlation coefficient between z-BMI and z-W/L ratio (r = 0.908 - 0.997, p<0.05), as we can see on table 3, with a more strong correlation by ages 6 months and 4 years (r = 0.995 and 0.997, p<0.05, respectively), and with BMI and W/L most discordant at age 0 months (r=0.908, p<0.05).

Table 3: Spearman and Pearson analysis to evaluate the correlations between z-BMI and z-W/L at each age

Spearman Correlation	Non-normal distribution	**Pearson** Correlation	Normal distribution
z-BMI vs z-W/L - 0 months	R = 0,908 n = 808	z-BMI vs z-W/L - 2 months	R = 0,914 n = 45
z-BMI vs z-W/L - 12 months	R = 0,969 n = 611	z-BMI vs z-W/L - 4 months	R = 0,973 n = 64
z-BMI vs z-W/L - 18 months	R = 0,973 n = 528	z-BMI vs z-W/L - 6 months	R = 0,995 n = 215
z-BMI vs z-W/L - 24 months	R = 0,990 n = 841	z-BMI vs z-W/L - 4 years	R = 0,997 n = 356
z-BMI vs z-W/L - 3 years	R = 0,991 n = 401		
BMI vs z-W/L - 5 years	--------------------------------	z-BMI vs z-W/L - 5 years	----------------------------
z-BMI vs z-W/L - 10 years	--------------------------------	z-BMI vs z-W/L - 10 years	----------------------------

Table 4: Logistic regression analysis results, for both z-BMI at z-W/L ratio at 0, 6, 12 and 18 months, with dependent variable being OW/Ob at 2 years; E - specificity; S - sensitivity

Age	**z-BMI (boys)**	**z-W/L (boys)**	**z-BMI (girls)**	**z-W/L (girls)**
0 months	R^2 0.05	R^2 0.03	R^2 0.12	R^2 0.09
	E 99.7% / S 0.9%	E 99.7% / S 0%	E 98.9% / S 9.5%	E 98% / S 7.6%
	AUC 0.62	AUC 0.60	AUC 0.68	AUC 0.66
	CI 95% 0.56-0.68	CI 95% 0.54-0.66	CI 95% 0.62-0.74	CI 95% 0.59-0.72
	p<0,05	p<0,05	p<0,05	p<0,05
6 months	R^2 0.09	R^2 0.10	R^2 0.31	R^2 0.21
	E 99% / S 0%	E 99% / S 0%	E 89.4% / S 50%	E 90.9% / S 50%
	AUC 0.68	AUC 0.69	AUC 0.79	AUC 0.79
	CI 95% 0.56-0.79	CI 95% 0.56-0.81	CI 95% 0.69-0.90	CI 95% 0.69-0.90
	p<0,05	p<0,05	p<0,05	p<0,05
12 months	R^2 0.23	R^2 0.21	R^2 0.29	R^2 0.32
	E 97% / S 21.8%	E 97.3% / S 19.3%	E 95.4% / S 43.1%	E 94% / S 49.3%
	AUC 0.85	AUC 0.85	AUC 0.83	AUC 0.84
	CI 95% 0.79-0.89	CI 95% 0.81-0.90	CI 95% 0.77-0.88	CI 95% 0.78-0.89
	p<0,05	p<0,05	p<0,05	p<0,05
18 months	R^2 0.31	R^2 0.29	R^2 0.50	R^2 0.50
	E 96.4% / S 41.9%	E 96.9% / S 45.9%	E 94.2% / S 58.6%	E 94.2% / S 56.7%
	AUC 0.87	AUC 0.89	AUC 0.88	AUC 0.88
	CI 95% 0.83-0.92	CI 95% 0.85-0.93	CI 95% 0.83-0.94	CI 95% 0.88-0.93
	p<0,05	p<0,05	p<0,05	p<0,05

*values highlighted in yellow demonstrate witch variables had R^2 ≥0.2 and AUC ≥0.7 (acceptable model fit; reasonable performance and moderate differentiation ability)

A linear regression was performed to evaluate the association between z-BMI and z-W/L ratio up to 2 years, with the presence of a higher z-BMI score by the age of 2 years and 5/6 years. In other words, we wanted to access the possibility of predicting z-BMI values at 2 years and 5/6 years, using z-BMI or z-W/L ratio, before the age of 2 years. In this analysis, it was possible to adjust models with more than one independent variable for some dependent variables. After fitting several linear models, the model with the highest coefficient of determination (R^2) was considered to be the most explanatory model and the best fit for the data.

What emerged as significant predictors of a higher z-BMI by 2 years of age were z-BMI at 12 months for both boys and girls (Boys: R^2 0.630, 95% CI 0.331-1.236, p-value=0.004; Girls: R^2 0.960, 95% CI 0.403-1.322, p-value=0.009), z-W/L ratio at 2 months for boys (R^2 0.650, 95% IC 0.256-0.890, p-value=0.003) and, lastly, z-W/L ratio at 12 months for girls (R^2 0.947, 95% IC 0.449-1.141, p-value=0.005).

By 5/6 years of age, the significant predictors of a higher z-BMI were as follows: z-BMI at 0 months and 6 months for boys (R^2 0.497, 95% CI 0.160-0.905, p-value = 0.008), and z-BMI at 6 months for girls (R^2 0.435, 95% CI 0.169-2.231, p-value=0.027). Notably, the variable z-W/L ratio did not exhibit significance as a predictor in this context.

A logistic regression analysis was carried out to evaluate the association between the presence of OW/Ob by 2 years and 5/6 years of age, with the z-BMI and z-W/L ratio before 2 years old. In other words, weighing the influence of the independent variables on the probability of OW and Ob by 2 years of age. It was only possible to adjust models with one independent variable, due to the existence of multicollinearity between the independent variables.

With this analysis, we observed that both z-BMI and z-W/L ratio at 0 months, 6 months, 12 months and 18 months were significant predictors of OW and Ob at 2 years of age.

When comparing these variables (z-BMI and z-W/L) in male *versus* female children, we realize that the values globally overlap. The maximum correlation, with the highest R^2 and AUC values, was seen for girl´s z-BMI and z-W/L by 18 months (see table 6), with a $R^2 \geq 0.4$ and AUC $\geq$ 0.8 (R^2 0.50, 94% specificity, 57-59% sensibility and AUC 0.88, $p<0.05$).

Based on the results of logistic regression, we also accessed the odds ratio (OR) values for both independent variables (z-BMI and z-W/L) at each age (0, 6, 12 and 18 months) considered to be a significant predictor of OW/Ob by 24 months. We realize that results are very similar for z-BMI and z-W/L variables, with the odds of the event happening, ranging from 2 to 7. Also, we realize that this ratio increases as the time passes through. A similar trend is seen with beta coefficient, in both males and females, at each time age - consult the results of the OR and beta coefficient at table 5.

Table 5: Odds Ratio and *Beta coefficient* for z-BMI and z-W/L at 0, 6, 12 and 18 months in predicting Ow/Ob at 2years

Independent Variable (z-BMI)	**Odds Ratio - Male**	**p**	**Odds Ratio - Female**	**p**
z-BMI at 0 months	1,6	<0,05	2,1	<0,05
z-BMI at 6 months	2,0	<0,05	3,9	<0,05
z-BMI at 12 months	3,3	<0,05	3,6	<0,05
z-BMI at 18 months	3,6	<0,05	7,3	<0,05
Independent Variable (z-w/L)	Odds Ratio - Male	p	Odds Ratio - Female	p
z-w/L at 0 months	1,5	<0,05	1,9	<0,05
z-w/L at 6 months	2,1	<0,05	3,9	<0,05
z-w/L at 12 months	2,9	<0,05	3,9	<0,05
z-w/L at 18 months	3,5	<0,05	7,2	<0,05
Independent Variable (z-BMI)	ß-Coefficient Male	p	ß-Coefficient Female	p
z-BMI at 0 months	0,4	<0,05	0,7	<0,05
z-BMI at 6 months	0,7	<0,05	1,4	<0,05
z-BMI at 12 months	1,2	<0,05	1,3	<0,05
z-BMI at 18 months	1,3	<0,05	2,0	<0,05
Independent Variable (z-W/L)	ß-Coefficient Male	p	ß-Coefficient Female	p
z-w/L at 0 months	0,4	<0,05	0,7	<0,05
z-w/L at 6 months	0,7	<0,05	1,4	<0,05
z-w/L at 12 months	1,1	<0,05	1,4	<0,05
z-w/L at 18 months	1,3	<0,05	2,0	<0,05

When evaluating for significant predictors of OW and Ob by 5/6 years of age, our analysis yielded that, once again, both z-BMI and z-W/L at 6 months (girls only), 12 months and 18 months (boys and girls), were significant in predicting this outcome. For newborns at 0 months, however, only z-BMI (boys and girls) showed to be associated with the primary outcome, but not z-W/L ratio - see table 6.

Table 6: Logistic regression analysis results, for both z-BMI at z-W/L ratio at 0, 6, 12 and 18 months, with dependent variable being OW/Ob at 5/6 years; E - specificity; S - sensitivity

Age	**z-BMI (boys)**	**z-W/L (boys)**	**z-BMI (girls)**	**z-W/L (girls)**
0 months	R^2 0.02	------ not statistically relevant ---------------	R^2 0.03	------ not statistically relevant -------------
	E 100% / S 0%		E 100% / S 0%	
	AUC 0.57		AUC 0.59	
	CI 95% 0.52-0.63		CI 95% 0.52-0.66	
	p<0,05		*p*<0,05	
6 months	------ not statistically relevant ---	------ not statistically relevant -	R^2 0.20	R^2 0.20
			E 97% / S 21.7%	E 97% / S 21.7%

	----------	--------------	AUC 0.73	AUC 0.73
			CI 95% 0.62-0.84	CI 95% 0.62-0.84
			p<0,05	*p*<0,05
12 months	R² 0.10	R² 0.07	R² 0.29	R² 0.26
	E 99.8% / S 6.0%	E 99.6% / S 1.2%	E 92.7% / S 31.6%	E 91.8% / S 40.3%
	AUC 0.73	AUC 0.73	AUC 0.78	AUC 0.78
	CI 95% 0.67-0.79	CI 95% 0.66-0.79	CI 95% 0.71-0.84	CI 95% 0.72-0.84
	p<0,05	*p*<0,05	*p*<0,05	*p*<0,05
18 months	R² 0.20	R² 0.20	R² 0.20	R² 0.21
	E 96% / S 15.8%	E 96.5% / S 19.7%	E 92.4% / S 29.6%	E 92.5% / S 35.2%
	AUC 0.72	AUC 0.73	AUC 0.74	AUC 0.76
	CI 95% 0.66-0.79	CI 95% 0.67-0.79	CI 95% 0.67-0.81	CI 95% 0.69-0.83
	p<0,05	*p*<0,05	*p*<0,05	*p*<0,05

*values highlighted in yellow demonstrate witch variables had $R^2 \geq 0.2$ and AUC ≥0.7 (acceptable model fit; reasonable performance and moderate differentiation ability)

The OR and beta coefficient values for the independent variables at each age - 0, 6, 12 and 18 months - taking into account the significant predictors of OW and Ob by 5/6 years - are shown in table 7. Once again, values are very similar for z-BMI and z-W/L variables, in male and female children. The OR as the probability in discriminating Ob at 5/6 years of age, for both sexes, vary from 1 to 3, and the beta coefficient from 0.1 to 2.0, and they equally tend to increase as the time goes by.

Table 7: Odds Ratio and *Beta coefficient* for z-BMI and z-W/L at 0, 6, 12 and 18 months in predicting OW/Ob at 5/6 years

Independent Variable (z-BMI)	***Odds Ratio* - Male**	**p**	***Odds Ratio* - Female**	**p**
z-BMI at 0 months	1,3	<0,05	1,4	<0,05
z-BMI at 6 months	1,1	0,70	2,7	<0,05
z-BMI at 12 months	1,9	<0,05	2,9	<0,05
z-BMI at 18 months	2,3	<0,05	2,2	<0,05
Independent Variable (z-W/L)	***Odds Ratio* - Male**	**p**	***Odds Ratio* - Female**	**p**
z-w/L at 0 months	1,2	0,19	1,2	0,13
z-w/L at 6 months	1,1	0,61	2,7	<0,05
z-w/L at 12 months	1,7	<0,05	3,1	<0,05
z-w/L at 18 months	2,5	<0,05	2,4	<0,05
Independent Variable (z-BMI)	**ß-Coefficient Male**	**p**	**ß-Coefficient Female**	**p**
z-BMI at 0 months	0,3	<0,05	0,4	<0,05
z-BMI at 6 months	0,9	0,70	1,0	<0,05
z-BMI at 12 months	0,6	<0,05	2,0	<0,05
z-BMI at 18 months	0,8	<0,05	0,8	<0,05
Independent Variable (z-W/L)	**ß-Coefficient Male**	**p**	**ß-Coefficient Female**	**p**
z-w/L at 0 months	0,1	0,19	0,2	0,13
z-w/L at 6 months	0,1	0,61	1,0	<0,05
z-w/L at 12 months	0,5	<0,05	1,1	<0,05
z-w/L at 18 months	0,9	<0,05	0,9	<0,05

Discussion

OW and Ob are very frequent in the overall pediatric population, with an estimated frequency of 12% and 13% at 5/6 years age, correspondingly, in our study. In the United States, the prevalence of OW and Ob in school-aged children (6 to 11 years), varies from 15% to 19%, respectively. (11) Childhood Obesity Surveillance Initiative (COSI) in Portugal, which is integrated into the WHO/Europe's COSI and aims, monitors childhood obesity every 3 years. Last 2022 national results showed that the prevalence of childhood OW and Ob, in Portuguese children between 6 and 9 years old, was 18, 4% and 13.5%, correspondingly. By this means, results from our study correlate with the national data [12].

Both parameters (z-BMI and z-W/L) shared a strong correlation coefficient at each age, with a stronger correlation at 6 months and 4 years and a more discordant correlation when born, at 0 months, which is concordant with literature [3, 8].

In the context of linear analysis, only the z-BMI variable (0 months-boys; 6 months-girls) showed to be a significant predictor of a higher z-BMI by the age of 5/6 years, whereas the z-W/L variable did not reveal any positive predictability with this outcome. Other studies support these findings, meaning that BMI-for-age can be more strongly associated with early childhood obesity than a higher W/L ratio, however this correlation is best described when referring to the first 2 years of life, rather than 5/6 years or early adolescence [3, 4, 8].

In the logistic regression analysis, when analyzing the pseudo-R^2 (Nagelkerke R^2) and AUC, and considering a $R^2 \geq 0.2$ for an acceptable model fit, as well as an AUC ≥ 0.7 for a model with reasonable performance and moderate differentiation ability (13), we concluded that z-BMI and z-W/L ratio by 6 months (for girls), 12 and 18 months (for both boys and girls) were predictable of OW/Ob by 2 years of age.

When comparing z-BMI and z-W/L ratio according to gender, we realize that R^2 and AUC values globally overlap, meaning that both, z-BMI and z-W/L, seem to be good predictors of OW/Ob by 2 years of age. We also recognize that these values increase in both genders, as getting older, meaning that a higher z-BMI or z-W/L at 12 or 18 months, for example, is more predictable of OW/Ob by 2 years old, rather than a higher z-BMI or z-W/L at 0 or 6 months, as it would be expected, and according to what was described above. The highest correlation was seen for z-W/L and z-BMI in girls at 18 months, with a $R^2 \geq 0.4$ and AUC ≥ 0.8, meaning that the model has a good performance, with high differentiation capacity. Once again, a higher odds ratio is also seen in girls within this age range, meaning that z-BMI and z-W/L in 18 months girls could have a higher differentiation capacity in predicting Ow/Ob at 2 years old, other than boys or boys and girls at any other age. This tendency of gender was not found to be described in previous studies.

Reiteratively, when analyzing the pseudo-R^2 and the AUC for each independent variable, that could predict OW/Ob at 5/6 years of age, and again considering a $R^2 \geq 0.2$ for an acceptable model fit, as well as an AUC ≥ 0.7 for a model with reasonable performance and moderate differentiation ability, we realize that, one more time, both z-BMI and z-W/L ratio for 6 months (girls), 12 months (girls) and 18 months (boys and girls) also were predictors of OW/Ob. When comparing between these two variables, both z-BMI and z-W/L ratio did not present any significant difference. Some studies also support this evidence, finding no substantially different associations across WFL and BMI cut points, with the higher likelihood of adverse cardiometabolic risk markers or even a stronger probability of developing obesity, during early adolescence. [7, 14].

For newborns, however, only z-BMI (for both boys and girls) was associated with the primary outcome, but not z-W/L ratio.

When looking more closely and comparing gender, girls once again, rather than boys, seem be more suitable in predicting our primary outcome.

An identical trend is shown when consulting the OR for each - z-BMI and z-W/L - independent variable in the logistic regression. We conclude that a one-unit increase in z-BMI and z-W/L at 0, 6, 12 and 18 months, is associated with an approximately 2 to 7 times and a 1 to 3 times increase, respectively, in the odds of the child being classified as overweight or obese by 2 years and 5/6 years of age, rather than non-obese, with this ratio being superior as the child gets older. A similar tendency is seen with the beta coefficient, in both genders, as time goes by.

By this way, in logistic regression, both z-BMI and z-W/L at 6, 12 and 18 months were significant predictors of OW/Ob by 2 and 5/6 years of age, and both seem to be more accurate as the time goes by. Even so, only z-BMI at birth showed to have an association with the presence of OW/Ob by 5/6 years. Still, girls seem to more reliable predict our primary outcome, rather than boys.

Despite these results, it is always important be aware of the possibility that other factors not considered in the model may be associated with OW and Ob.

The difference in our results, comprising linear and logistic regression, can be attributed to the nature of the dependent variable. In other words, the difference in our results suggests that the relationship between the independent variables (z-BMI and z-W/L at different ages, before 2 years) and the dependent variables (z-BMI and the presence of OW/Ob above 2 years) may not be strictly linear, especially when considering the nature binary of the dependent variable. In this case, logistic regression (and not linear regression) is used.

A great strength of our study is the inclusion of anthropometric records at different ages, allowing for a thorough examination of the correlation between BMI and W/L ratio as well as their predictive ability for future OW/Ob in early childhood. Other positive points include a large sample size, the lack of similar studies made in Portugal, as the scarcity at a global level.

Nonetheless, this study also has some limitations, such as the retrospective and observational design of the study, which may have introduced biases. Additionally, the study population consisted of children followed in consultation at a single hospital, which may limit the generalizability of our findings to other populations. Finally, we examined the association between BMI and W/L ratio but did not account for some potential risk factor for OW/Ob, such as environmental and lifestyle behaviors. Future research should consider these limitations and attempt to address them in order to provide a more comprehensive understanding of the predictors and risk factors for OW/Ob in early and late childhood.

Conclusion

Despite the limitations, our results seem to indicate that both z-BMI and z-W/L are good predictors of the risk of developing OW and Ob in early and late childhood. In Both z-BMI and z-W/L ratio at 18 months showed a good performance to predict future OW/Ob by 2 years, as well as z-BMI and z-W/L at 12 and 18 months for predicting future OW/Ob at 5/6 years.

However, when considering late childhood (5/6 years), the results seem to indicate that z-BMI may be a better predictor of OW/Ob, possibly considering it a better indicator of future risk of Ob than z-W/L ratio.

Nonetheless, the inclusion of z-W/L in the analysis may provide additional insight and complement the predictive ability of z-BMI, particularly in the earlier years of a child's development. It is also important to note that these conclusions are specific to this study and may not apply to other populations or situations.

Keypoints

- This study is the first report in our country and, to the best of our knowledge, one of the few international essays, that compares z-W/L and z-BMI in a longitudinal study with a diverse cohort, to determine whether they differ in identifying children at risk for childhood overweight and obesity;
- Our results indicate that both parameters (z-BMI and z-W/L) share a strong correlation coefficient through all ages, with a stronger correlation at 6 months and 4 years and a weaker correlation at 0 months;
- z-BMI, however, seems to be a better indicator of future risk of obesity than z-W/L ratio, in late childhood.

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