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ORIGINAL ARTICLE

A new examination of the determinants of weight in early childhood

Una nueva mirada a los determinantes del peso infantil en la primera infancia

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What do we know about the subject matter of this study?

In Chile, childhood obesity is not uniformly distributed and there is a greater concentration of overweight children in sectors with lower socioeconomic status.

What does this study contribute to what is already known?

Maternal income and schooling have heterogeneous effects on child weight according to age and nutritional status. In children 5-6 years old, higher income is associated with greater obesity if mothers have low schooling. The opposite occurs if mothers have high schooling.

Abstract

In the last decades, Chile has experienced a triple transition regarding demographic, nutritional, and economic issues. **Objective:** To explore the relationship between childhood weight and two dimensions of socioeconomic status, family income, and maternal educational level, analyzing the effect of each one by itself and how they operate together to determine childhood weight and comparing their effect on obese and non-obese children. **Subjects and Method:** Study based on data from the 2012 *Encuesta Longitudinal de Primera Infancia* (Early Childhood Longitudinal Survey), evaluating children between 2 and 6 years old (n=11,399). We estimated multivariate quantile regression models for the z-score of the body mass index (BMI-z). **Results:** We found that in children aged 2-3 years, income and weight had a positive association, while maternal educational level and weight had a negative one. In children aged 4-6 years, income and weight were negatively associated among children whose mothers have a higher educational level but positive among those with lower educational levels. **Conclusion:** Family income and maternal educational level have opposite effects on childhood weight. The positive effect of income on BMI-z is diminished when mothers have high educational levels. We recommend studying the effects of income and education on child weight separately and exploring the causal mechanisms that explain the relations between socioeconomic determinants and childhood weight.

Keywords:
Body Weight;
Socioeconomic Status;
Child Obesity;
Chile;
Body Mass Index

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Introduction

From the mid-20th century to the present, Chile has experienced a threefold demographic, nutritional, and economic transition. Childhood malnutrition went from 37% in 1960 to be virtually eradicated[1]. By 2018, 50.9% of all children measured by the JUNAEB nutritional map presented malnutrition due to excess (overweight and obese)[2]. Infant mortality decreased from 241 per thousand live births in 1939 to 6.6 in 2017[3]. The country experienced rapid economic growth, from underdevelopment to joining the Organization for Economic Cooperation and Development in 2010. Food environments also changed, with improvements in food safety and increased availability and consumption of processed foods (high in calories and deficient in nutrients)[4, 5]. Overall, these modernizing changes lead us to the stage in the nutritional transition when undernutrition is overcome and obesity-related degenerative diseases appear[3, 6-12].

In Chile, childhood obesity is not uniformly distributed and there is a greater concentration of overweight and obesity in sectors with lower socioeconomic status (SES)[13-14]. Although we can confirm this correlation, there is no certainty about the mechanisms under which SES influences child obesity. There is also no evidence about whether the determinants of childhood obesity behave in the same way in boys and girls, among weight categories, nor is there any history of studies that apply a disaggregated analysis across the BMI spectrum during early childhood in Chile. In this article, we explore the determinants of weight in early childhood in Chile, analyzing two aspects of the SES, family income, and mother's educational level, both disaggregated and combined, and comparing their effect on obese children and those of other weight categories.

Subjects and Method

This analysis is based on secondary sources using data collected in the Longitudinal Survey of Early Childhood (ELPI). This survey started in 2010, having as a sampling frame children born between January 1, 2006, and August 31, 2009. In the second stage, in 2012, a complimentary sample of children born between September 1, 2009, and December 31, 2011, was added.

The sampling frame for selecting the subjects was obtained from Civil Registry and Identification Service data. The sample design, in both stages, was stratified into a two-stage process. The strata were constructed by grouping communes of similar SES, using information from the Population and Housing Census 2002 and the National Socioeconomic Characterization (CASEN) Survey.

In the first stage, the municipalities with probability 1 (municipalities with more than 60,000 inhabitants and all those of Greater Santiago, due to the size of their population) were selected. In stage two, cases were selected through systematic random sampling. This two-stage sample design is usually used since it allows for obtaining a representative sample of the population in a short time and at a lower cost. The distribution of the sample was made in proportion to the population of each stratum, considering the 15 regions of the country[15].

The Survey has cross-sectional expansion factors, which combine the total probability of individual selection. This selection is defined by the sample design (considering the sampling type used and the selection method of the first and second stage units), with the expansion factor of each selected individual in each selected municipality (the reciprocal distribution of the total probability of individual selection), and an adjustment component (defined as the quotient between the target sample and the sample achieved in each stratum, considering that, as is typically the case in household surveys, fewer surveys were obtained in some strata than those determined in the original design)[15].

However, this research did not use such expansion factors, in other words, all analyses in this study are unweighted. Although using expansion factors would have provided similar-sized estimates of population size (which is the goal of using expansion factors), unweighted population parameter estimators are not only unbiased and consistent but are generally more efficient than their weighted counterparts[16-17].

In this research, we used only the data transversally collected in 2012. The main caregiver answered a questionnaire and psychological tests, and anthropometric measurements were applied to the selected children and their main caregiver. The institution that collected the data obtained signed informed consent from the main caregiver. Following World Health Organization (WHO) recommendations that body mass index (BMI) is not an adequate measure to determine nutritional status in infants[18], we excluded from this analysis children under two years of age.

With the anthropometric data of the children, we calculated the BMI z-score (ZBMI), using the WHO Anthro software for children up to 60 months of age and the WHO Anthro Plus, for children older than 60 months[19]. Subjects were classified according to their ZBMI following WHO criteria[18] (malnutrition, < -2; normal weight, = -2 and <1; overweight, = 1 and <2; and obesity, > = 2). The maternal BMI was calculated, differentiating obese mothers (BMI > = 30) from non-obese ones.

Two SES indicators were obtained from the questionnaire to the main caregiver, per capita household income, and mother's educational level. The latter indicator was used as a dichotomous variable, differentiating mothers with higher educational level (technical or university, complete and incomplete) from those with less education. Income was incorporated as a log of income, considering its non-normal distribution, since most of the sample has a rather low income, observed in the left part of the distribution, and only a small percentage has a high income, forming a long tail to the right.

In addition, we included in the multivariate analysis data on the sex of the child, age in months, rural or urban residence, and belonging to indigenous peoples (reported by the mother) as well as on maternal obesity (calculated based on mothers' self-reporting of weight and height and their respective BMI), breastfeeding practices (breastfed for more than six months), and healthy foods intake. For the latter, we followed the example of Marteleto et al.[20] by constructing an index that works as a consumption *proxy* based on questions about the child's intake frequency of different foods.

The index was constructed from a polychoric factor analysis due to the non-continuous nature of the item response categories. The items that were included in the factorial analysis were hotdogs, hamburgers, pizzas, French fries, etc.; meat or fish; legumes; bread, noodles, rice; chocolate, sweet juices or packaged drinks; chips, corn or cheesy puff snacks, or other packaged snacks; milk; water; cookies; fruits, and vegetables.

The variables with more weight in the analysis were milk, water, and fruits and vegetables, therefore the emergent factor is considered as an indicator of healthy food. After constructing the index, it was dichotomized, distinguishing children with a high intake of healthy food (25% higher than the index). The missing values (i.e., the cases in which respondents did not respond) were ZBMI (8.4%), maternal obesity (1%), maternal educational level (2.3%), healthy food intake (0.4%), and per capita household income (2.1%).

Full case analysis was conducted and we excluded cases where the primary caregiver was not the mother (1.7%). The final sample size was 11,339. Children aged 2 to 3 years (24 to 47 months) and 4 to 6 years (48 to 83 months) were analyzed separately. This stratification was made considering that a significant percentage of children enter the preschool system at the age of four, which can mean a change in physical activity and eating habits; therefore, it was considered an appropriate cut-off point.

A multivariate analysis with quantile regression models was carried out. Unlike linear regression, which estimates the effect of a series of predictors on the average of a dependent variable, quantile regression estimates the effect of predictors at different points in the distribution of the dependent variable[21]. This is relevant, because not only BMI has different meanings at different points of its distribution, but also because focusing on the average can lead to errors in societies going through a nutritional transition, where BMI values can change rapidly and the association between BMI and its predictors can be different across the BMI spectrum[11]. We used four percentiles (p) p5, p50, p85, and p95, which are the criteria used by the Centers for Disease Control and Prevention (CDC) to define underweight, normal weight, overweight, and childhood obesity in children over 2 years of age[22-23] and which have been used in previous Chilean research[13-14]. The models were also estimated using the p3 and p97 criteria. The results are generally consistent and are available upon request.

The first model included the two measures of SES, maternal obesity, healthy food intake, breastfeeding practices, sex, age, ethnic identification, and rural residence. The second model considered the same variables, but also included the interaction between family income and mother's educational level to assess differences in the effect of income between mothers with and without higher educational level and to better understand the effect of SES on child weight. We calculated the marginal effects of this model in order to better communicate the combined action of the mother's education and family income more clear. Marginal effects are a measure of the value predicted in the model for individuals who have certain characteristics. In this case, the predicted or expected value of the ZBMI was obtained for children of mothers with and without higher educational level and at different levels of family income. These expected values are graphed so that it can be seen how the ZBMI changes before different levels of family income in the case of children of mothers with and without higher educational level. The other variables in the model are left at their average value, that is, the values displayed describe average children.

Results

Table 1 shows the characteristics of the sample. Half of the children were overweight and only 1% were malnourished. The sample was balanced in terms of sex and 10% of the mothers reported their child as belonging to an indigenous group. Most of the children lived in urban areas. 18% of the mothers had post-secondary education and 30% of them presented some degree of obesity. The distribution of all variables was similar in both age groups.

Table 2 shows the multivariate analysis for all sub-

Table 1. Sample Description. Chilean Children. 2-6 years old, 2012

Variables	2 to 3	4 to 6	Total
N	4,492	6,847	11,339
Age (in months)	38.7 ± 6.4	63.4 ± 8.8	53.6 ± 14.5
Nutritional status (%)			
Underweight	1.3	0.8	1.0
Normal weight	44.8	47.4	46.3
Overweight	32.4	31.8	32.0
Obesity	21.7	20.1	20.7
Women (%)	48.8	51.2	50.3
Ethnicity (% indigenous)	9.6	9.9	9.8
Rural residence (%)	10.6	11.3	11.0
Mother with higher education (%)	18.2	18.5	18.4
Mean family income per capita (standard deviation)	118.4 (119.5)	115.8 (113.6)	116.8 (116.0)
Obese mother (%)	28.7	30.0	29.5
Breastfed for more than 6 moths (%)	66.8	68.0	67.5

Table 2. Synthesis of the Quantile Regression Analysis for Z-scores of the Body Mass Index. Chilean Children, 24 to 48 months (2-4 years old)

	q5 (underweight)	q50 (normal weight)	q85 (overweight)	q95 (obesity)
N	4,492	4,492	4,492	4,492
Mother with higher education	-0.06	-0.08	**-0.19*** **	**-0.20** **
	(0.15)	(0.06)	-0.07	(0.10)
Log per capita family income	0.10	**0.05***	**0.10** **	0.05
	(0.07)	(0.02)	(0.04)	(0.05)
Obese mother	0.23	**0.29*** **	**0.37*** **	**0.24** **
	(0.15)	(0.05)	(0.07)	(0.10)
High healthy foods intake	0.01	-0.06	-0.08	-0.03
	(0.07)	(0.04)	(0.06)	(0.07)
Breastfed for more than 6 moths	0.01	-0.03	0.06	-0.05
	(0.11)	(0.06)	(0.04)	(0.11)
Age (in months)	0.00	-0.02	-0.00	0.00
	(0.00)	(0.01)	(0.00)	(0.01)
Female	-0.01	-0.04	-0.05	**-0.14***
	(0.10)	(0.04)	(0.06)	(0.09)
Ethnicity (indigenous)	-0.13	0.01	0.08	0.11
	(0.19)	(0.08)	(0.10)	(0.15)
Rural residence	0.13	-0.03	-0.05	-0.24*
	(0.17)	(0.07)	(0.07)	(0.14)
Constant	**-2.12** **	0.59	**1.17** **	**2.44*** **
	(0.88)	(0.44)	(0.49)	(0.50)

Beta coefficients (unstandardized). Standard errors in paratheses. ***p < 0,01. **p < 0,05. *p < 0,1.

jects aged between 2 and 3 years. In this age group, the interaction between maternal education and the log of income (Model 2) was not significant; therefore, we only presented Model 1.

The two variables measuring SES were statistically significant, but the effect of maternal educational level was negative, and in contrast, the log of income was positive.

Regarding maternal education, the ZBMI was lower in children of mothers with higher educational level compared with those with a lower one. This effect was significant among overweight and obese children (p85 and p95), but not among those with normal or low weight.

The log of income had a positive effect on the ZBMI (higher family income is associated with higher ZBMI) among children of p50 and p85 (normal weight and overweight). The effect was not significant among obese and underweight children.

In relation to the other predictors, maternal obesity had a large positive effect (the largest of all the variables included in the models) in the ZBMI on almost the entire weight spectrum, except for p5 (underweight). Female sex and rural residence were associated with lower ZBMI among children on the obesity spectrum but had no significant effect at any other point in the child weight distribution.

Table 3 shows the multivariate results for subjects aged between 4 and 6 years. In this case, the interaction between the log of income and maternal educational level in Model 2 was significant at p50 (normal weight) and p95 (obesity). Figures 1 and 2 explain how these variables acted together.

In both cases, there was a crossover in the predicted values of the ZBMI, indicating that the effect of income was negative for children whose mothers have higher educational level and positive for children of mothers without higher education. Thus, in figure 1 (normal weight children), we see that in the group of children with mothers with low educational level, when moving from the lowest to the highest level of family income, the predicted value of the ZBMI changes from 0.69 to 1.28 (0.59 increase SD); while among those with mothers with higher levels of educational attainment, when moving from the lowest to the highest level of family income, the predicted value of the ZBMI changes from 1.38 to 0.95 (0.43 decrease SD).

Regarding the other predictors, maternal obesity, as in the previous age group, had a large positive effect on child weight, which is significant across the spectrum of the ZBMI. Child age had a negative and relatively small effect, not significant among normal-weight children (p50), but significant across the rest of the ZBMI spectrum. Female was also significantly associated with lower ZBMI, but the effect was not substantial since, at the percentiles that it was significant in Model 1 (p5, p85, and p95), it ceased to be so in Model 2, where the female sex effect was significant at p50. Only for normal-weight children, the indigenous or rural condition was associated with higher ZBMI. In Model 2 and p5, breastfeeding for more than six months had a significant but small effect on child weight, in other words, among underweight children prolonged breastfeeding was associated with slightly higher ZBMI.

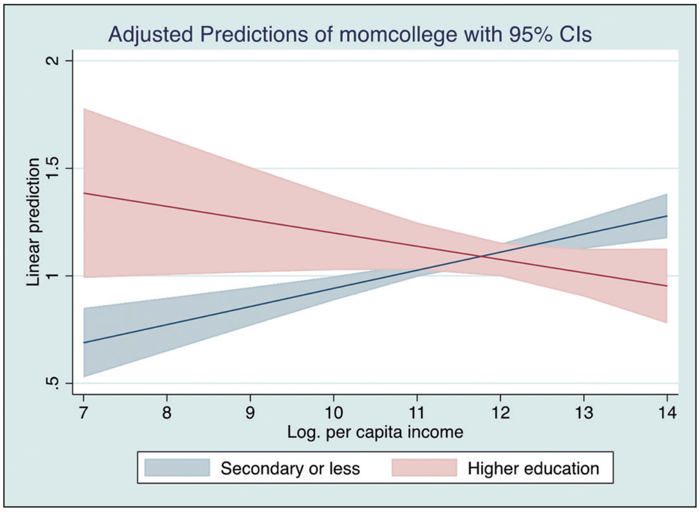

Figure 1. Predicted values for the effect of maternal education on ZBMI (adjusted), q50 (95% confidence intervals). ZIMC: Z score for BMI. The pesos value of the per capita log. income in the X axis are: 7 = $ 1,097; 8 = $ 2,981; 9 = $ 8,103; 10 = $ 22,026;11 = $ 59,874; 12 = $ 162,755; 13 = $ 442,413 y 14 = $ 1,202, 604.

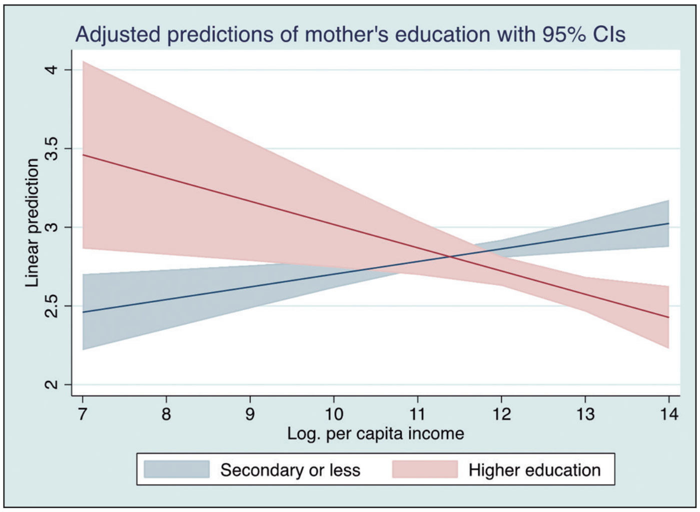

Figure 2. Predicted values for the effect of maternal education on ZBMI (adjusted), Q95 (95% confidence intervals). ZIMC: Z score for BMI. The pesos value of the per capita log. income in the X axis are: 7 = $ 1,097; 8 = $ 2,981; 9 = $ 8,103; 10 = $ 22,026; 11 = $ 59,874; 12 = $ 162,755; 13 = $ 442,413 y 14 = $1,202, 604.

Table 3. Synthesis of the Quantile Regression Analysis for Z-scores of the Body Mass Index. Chilean Children, 49 to 83 months (5-6 years old)

	Model 1				Model 2			
	q5 (underweight)	q50 (normal weight)	q85 (overweight)	q95 (obesity)	q5 (underweight)	q50 (normal weight)	q85 (overweight)	q95 (obesity)
N	6847	6847	6847	6847	6847	6847	6847	6847
Mother with higher education	-0.06	-0.00	**-0.14****	**-0.14****	1.27	**1.72*****	1.26	**2.60*****
	(0.10)	(0.044	(0.06)	(0.07)	(1.30)	(0.55)	(0.99)	(0.63)
Log per capita family income	0.05	**0.06****	**0.08****	0.04	0.08	**0.08*****	**0.10*****	**0.08*****
	(0.04)	(0.02)	(0.03)	(0.03)	(0.05)	(0.02)	(0.02)	(0.03)
Mother educ. * log. income					-0.11	**-0.15*****	-0.12	**-0.23*****
					(0.10)	(0.05)	(0.08)	(0.05)
Obese mother	**0.42*****	**0.34*****	**0.36*****	**0.15*****	**0.39*****	**0.35*****	**0.36*****	**0.17*****
	(0.07)	(0.03)	(0.04)	(0.03)	(0.09)	(0.05)	(0.04)	(0.05)
High healthy foods intake	-0.05	-0.02	-0.09*	-0.09	-0.03	-0.02	-0.10*	-0.07*
	(0.09)	(0.05)	(0.04)	(0.06)	(0.09)	(0.05)	(0.05)	(0.04)
Breastfed for more than 6 moths	0.06	0.00	-0.03	-0.02	0.07*	-0.01	-0.03	-0.02
	(0.07)	(0.03)	(0.05)	(0.05)	(0.04)	(0.03)	(0.03)	(0.03)
Age (in months)	**0.02*****	0.00	**-0.01****	**-0.02*****	**0.02*****	0.00	**-0.00****	**-0.02*****
	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Female	**-0.14****	**-0.09*****	-0.04	**-0.09****	**-0.14****	**-0.09*****	-0.04	-0.07
	(0.06)	(0.02)	(0.04)	(0.04)	(0.06)	(0.03)	(0.05)	(0.05)
Ethnicity (indigenous)	0.15	**0.15****	0.02	-0.03	0.16	**0.16*****	0.03	-0.04
	(0.15)	(0.07)	(0.06)	(0.07)	(0.15)	(0.06)	(0.05)	(0.09)
Rural residence	-0.01	**0.09****	-0.07	0.04	-0.01	**0.08***	-0.07	0.05
	(0.10)	(0.04)	(0.06)	(0.08)	(0.08)	(0.04)	(0.06)	(0.06)
Constant	**-2.43*****	0.27	**1.53*****	**3.27*****	**-2.74*****	-0.02	**1.27*****	**2.84*****
	(0.57)	(0.31)	(0.37)	(0.36)	(0.52)	(0.24)	(0.23)	(0.27)

Model 2 include the same variables as Model 1, and it adds the interaction term between mother's education and the logarithm of family per capita income. Beta coefficients (unstandardized). Standard errors in parentheses. ***p < 0,01. **p < 0,05. *p < 0.1

Discussion

In this article, we analyzed the determinants of ZBMI in obese and non-obese children, focusing on SES indicators, maternal educational level, and family income. In line with the worldwide literature, the effect with the greatest magnitude in the estimated models was maternal obesity[24-28].

Regarding socioeconomic determinants, previous research - in social sciences and health sciences - has tended to use family income and/or educational level as individually representative and substitutable indicators of SES[13]. However, some studies have begun to differentiate amongst these variables. For example, it has been observed that the effect of family income on childhood obesity can be both positive and negative. As Martin et al. proposed, when analyzing adolescent BMI, higher family income increased the probability of processed foods intake and video game use, as well as access to healthy foods, and paid physical activities[29].

In addition, the effect of SES on BMI depends on the phase in the nutritional transition[11, 12]. In undeveloped countries with high levels of malnutrition, obesity is more common in families with higher SES, in contrast, the relationship is inverse in developed countries[8-12]. In middle-income countries, there is evidence of a nonlinear effect of development level on obesity[9].

Considering the above, this study analyzed the effect that family income and maternal educational level individually have on childhood weight, and also their combined effect analyzed through their interaction. It examined not only average childhood weight but several weight percentiles, ranging from malnutrition to obesity.

The results showed that both income and education had significant effects but in opposite directions. Among children aged between 2 and 3 years, the association between ZBMI and maternal educational level was negative, while the association between ZBMI and family income was positive, and the two variables did not interact with each other. Among 5-6 year-old children, the two variables interacted significantly, among both normal-weight and obese children. Thus, among children of mothers with higher educational levels, higher income was associated with lower ZBMI, while among children of mothers with lower education it was associated with higher ZBMI.

This leads us to the debate about the effects of education on health. In those cases where it is observed that people with higher levels of education have general better health indicators, the discussion revolves around whether this is due to the higher income associated with higher education or to an educational effect.

Several authors have emphasized that education improves people's ability to seek and use health-related information efficiently. Mirowsky and Ross (2003) have proposed the concept of 'learned effectiveness' to refer to how by accumulating more education, people gain knowledge, skills, and resources that allow them to make better choices about healthy lifestyle behaviors[30].

Food preferences may also play a role. Families with recent social mobility -where income has grown, but educational levels can remain relatively low- may consume more processed foods as a status symbol[31], an idea that privileges the industrial over the home-made.

On another note, if mothers have more education, they are more likely to be in the labor market, contribute a wage to the family income, and thus have more power in making decisions about the use of those resources. There is ample evidence that women and men use family resources in different ways, where women allocate a greater percentage to the well-being of children[32]. This could be extrapolated to the purchase of healthier foods.

In the Chilean context, the demographic-nutritional transition occurred in parallel with rapid economic growth, and therefore, greater purchasing power, changes in the food environment (greater availability of processed foods at affordable prices), and in preparation and intake habits.

In conclusion, Chile is located at the stage in the nutritional transition that Popkin defines as a pattern where the so-called 'Western' diet causes degenerative diseases[10]. An adaptation involving a change in behavior towards healthy diets and habits and prevention of adverse effects is still pending.

This research makes several innovative contributions to the study of childhood weight: the analysis of weight determinants along the whole spectrum of BMI, which is an unprecedented exercise for the Chilean population; consideration of the effect of maternal education and family income, both separately and together, for the early childhood age segment.

As a conclusion, it is established that there is a need for further research on this topic, and we recommend disaggregating income and educational levels in the analysis, as well as research that investigates the mechanisms through which these two variables affect childhood weight.

Ethical Responsibilities

Human Beings and animals protection: Disclosure the authors state that the procedures were followed according to the Declaration of Helsinki and the World Medical Association regarding human experimentation developed for the medical community.

Data confidentiality: The authors state that they have followed the protocols of their Center and Local regulations on the publication of patient data.

Rights to privacy and informed consent: The authors have obtained the informed consent of the patients and/or subjects referred to in the article. This document is in the possession of the correspondence author.

Conflicts of Interest

Authors declare no conflict of interest regarding the present study.

Financial Disclosure

Authors state that no economic support has been associated with the present study.

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