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RESEARCH ARTICLE

Weight status prior to-, during- and post-school closures in the COVID-19 pandemic: A school-based cohort study in children aged 6 to 9 years

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Abstract

Background: School closures during the COVID-19 pandemic increased children's exposure to obesogenic behaviors, potentially affecting weight status. **Objective:** To report temporal trends in the weight status of children aged 6 to 9 years before, during, and after school closures in response to restrictions imposed by the COVID-19 pandemic, using a three-year school-based cohort design. **Method:** Weight status was analyzed using the body mass index and diagnostic criteria proposed by IOFT. Initial data collection took place in 2020 (pre-pandemic period), in 2021 and 2022 (pandemic period), and in 2023 (post-pandemic period), after the reopening of schools. **Results:** The data collected confirmed that restrictions imposed to mitigate the adverse impact of the COVID-19 pandemic, including the full or partial closure of schools, substantially increased children's weight above what would be expected for their sex and age. After two years of the pandemic period, 16% of children identified in the pre-pandemic period as with normal weight migrated to overweight, while 23% with overweight became obese. Data collected during the post-pandemic period showed signs of a reduction in excess weight accumulated during the pandemic; however, the prevalence rates of overweight and obesity remained at 14% and 26%, respectively, which were higher than in the pre-pandemic period. **Conclusion:** The findings suggest that the harmful effects contributing to greater weight gain during the COVID-19 pandemic were not spontaneously reversed. Therefore, specific actions to combat overweight and obesity are essential to avoid present and future adverse consequences in children's health.

Keywords: COVID-19; pediatric obesity; overweight; body mass index; schools.

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BACKGROUND

The new severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), the etiological agent of COVID-19, was initially identified in December 2019. Due to its transmission potential, population susceptibility, disease severity, and ability to affect all regions of the world, strongly impacting global public health, the WHO declared SARS-CoV-2 a Public Health Emergency of International Concern and subsequently classified it as a worldwide pandemic[1].

As a result, health authorities worldwide faced intense challenges in dealing with the crisis, leading to the implementation of social and public health measures, including social distancing, home isolation, restricted travel, and, at times, even lockdown, as a preventive action to contain the rate of community transmission of the virus. Thus, the inevitable consequence of self-confinement was a drastic, sudden change in the daily routines of a broad spectrum of people. In the case of children, schools were either fully or partially closed, leading to the interruption of face-to-face teaching activities.

According to UNESCO, Brazil was among the countries where schools remained closed for the longest period in response to the COVID-19 pandemic. Data showed that Brazilian schools remained closed for an average of 39 weeks from March 2020 to January 2022. If the partial school closure is also considered, the duration increases to 78 weeks. As a point of comparison, during the same period, schools in China and the United States remained entirely closed for no more than 12 weeks and partially closed for 27 and 58 weeks, respectively[2].

Although social and public health restrictions were necessary, one of the main adverse effects of total or partial school closures was increased exposure of children to obesogenic behaviors. Interrupting face-to-face teaching activities eliminated the need to carry out extracurricular tasks and reduced opportunities for active travel[3]. The closure of sports facilities, parks, and outdoor play areas further affected children's opportunities for physical activity[4, 5]. At the same time, due to increased time spent at home and limited active entertainment options, sedentary behavior, screen time, and sleep time increased dramatically[6]. Additionally, changes in eating habits were reported, including an increased intake of snacks and processed foods[7]. Furthermore, emotional stress contributed to potentiating events of psychological suffering and deterioration of mental health, often related to excess body weight[8, 9].

In this scenario, previous studies suggested that the COVID-19 pandemic exposed children to an increased risk of greater body weight accumulation; however, to date, the evidence found is limited to examining relatively short periods in children from Asian, European, or North American countries and, in most cases, using cross-sectional designs[10, 11], while studies with longitudinal designs are rare[12-14]. Studies with this purpose are still necessary and can help us to understand the harmful impact that occurred during the period, considering that excess body weight identified in childhood tends to track into adulthood[15] and is strongly associated with the current and future health of children[16] and the higher incidence of psychosocial events[17].

Therefore, the objective of the current study was to report temporal trends in the weight status of children aged 6 to 9 years before, during, and after school closures in response to COVID-19 pandemic restrictions, using a cohort design of a three-year school-based program (2020-2023).

METHODS

Study design

This is a three-year, longitudinal, school-based observational study involving children with an initial age of approximately 6 years enrolled in municipal public schools in Cambé, Paraná, Brazil.

The intervention protocols were approved by the Research Ethics Committee of the Local University (3.412.665/2019). The children's parents or guardians signed an Informed Consent Form, granting permission for the children to participate in the study. At the time of data collection, verbal consent was requested from the participants.

The city of Cambé is in the north-central region of Paraná State, Brazil, with a subtropical climate and a population of approximately 110,000. Its economy is based on agricultural activities, public services, and industry, and it is considered an important development hub in the southern region of the country[18]. According to the Human Development Atlas of Brazil, Cambé is a city with a high Average Human Development Index of 0.734[19]. Considering the infant mortality rate, another indicator classically used to assess the level of development of a region, the available information indicates 11 deaths per 1,000 live births.

Participants

The selection of participants for the study was carried out by inviting the entire universe of students enrolled at the beginning of the 2020 school year (pre-pandemic period, before the closure of schools) in the 1st year of elementary education at the 44 public schools existing in the urban region from Cambé, Paraná (N = 1,183). In this case, all parents or guardians of the students were contacted and informed about the nature and objectives of the project, as well as the principles of confidentiality and non-influence on academic performance. Authorization was requested so that the students could participate in data collection.

The following exclusion criteria were adopted: (a) lack of authorization from parents or guardians; (b) absence from school on the day scheduled for data collection; (c) any physical problem that precluded the anthropometric measurements; and (d) chronological age less than 5.5 years and more than 6.5 years. Therefore, the initial sample consisted of 876 participants, representing a recruitment success of 74%.

All participants selected for the initial sample were contacted during the same period in the subsequent three years: 2021 and 2022 (the pandemic period, with total or partial school closures) and 2023 (the post-pandemic period, 1 year after schools reopened) for anthropometric measurements. Participants diagnosed with SARS-CoV-2 or those with reports from parents or guardians of disease symptoms were excluded from the sample. Therefore, for data analysis, only the 797 participants (415 girls and 382 boys) who completed all four waves of follow-up were considered, resulting in a 9% loss from the beginning to the end of the follow-up. Figure 1 illustrates the student participation in the study.

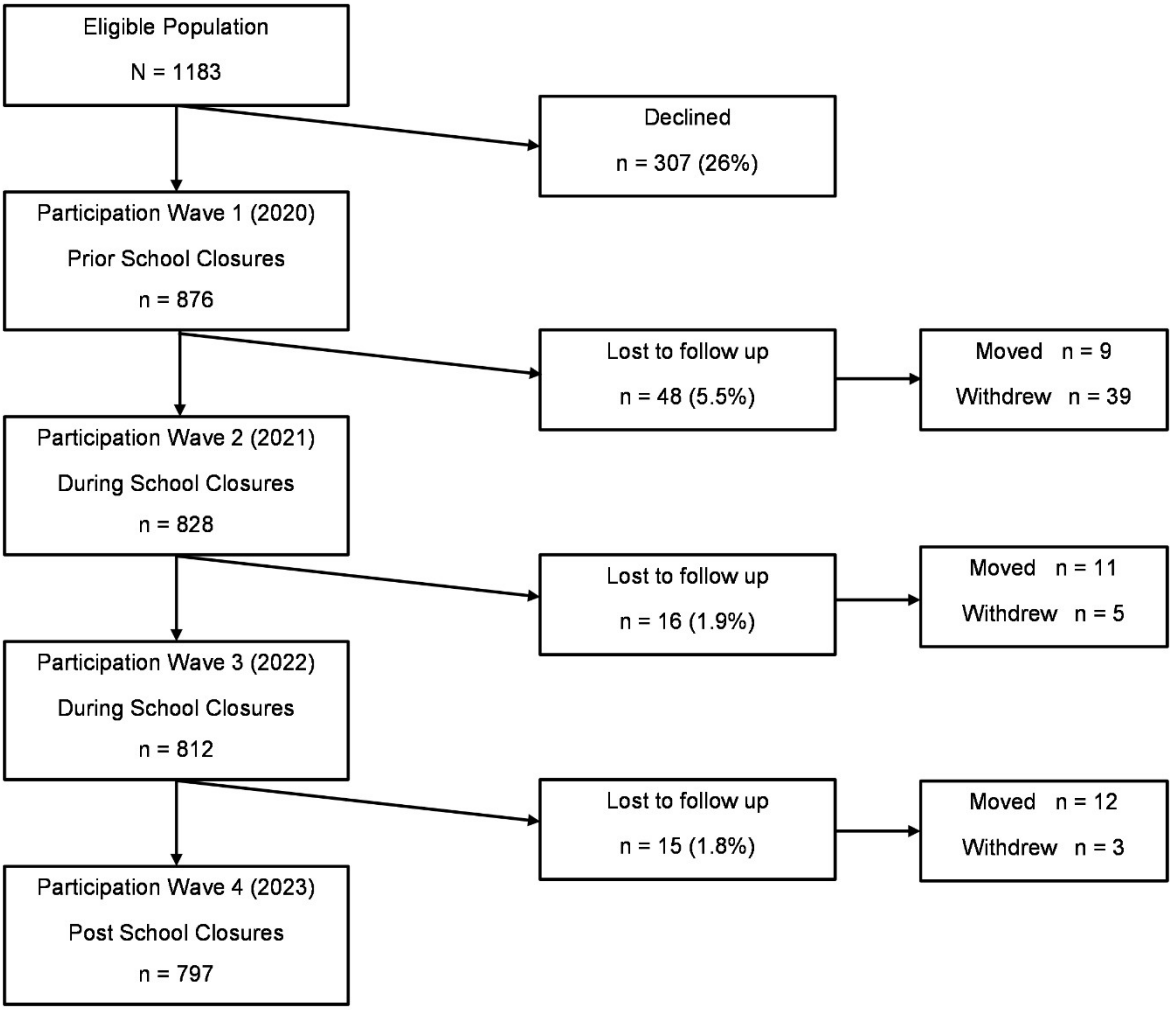

Figure 1. Flowchart of the study population and participants

Procedures

The initial data collection took place in February 2020 (the pre-pandemic period, before school closures), when the average age of the participants was 6.2 ± 0.2 years. The students were subsequently followed up annually through anthropometric measurements in February 2021 and 2022 (pandemic period, total or partial closure of schools) and 2023 (post-pandemic period, one year after reopening of schools), when the average ages of the students were 7.1 ± 0.2, 8.1 ± 0.2, and 9.0 ± 0.1 years, respectively.

The data collection procedure included identifying sex and age, and measuring height and body mass. The researchers comprised physical education teachers from schools that had previously been trained in measurement procedures. The anthropometric measurements (height and body mass) were conducted individually in a private location within the schools, adhering to anti-epidemic control procedures (social distancing, disinfection, and air ventilation), and using standardized and identical protocols across the four monitoring waves.

The participants' chronological age was determined in years and months by comparing the date of data collection with their date of birth. An aluminum stadiometer with a 1 mm scale (Seca, Hamburg, Germany, model 870) was used to measure height.

For body mass measurements, an anthropometric scale with a 10-gram setting, Seca brand (Hamburg, Germany, model 879), was used. The scale was calibrated after every ten measures, following procedures presented by the World Health Organization[20]. Replicas were made for every ten students to ensure data quality for height and body mass measurements. The magnitudes of the technical measurement error ranged between 1 mm and 4 mm for height measurements and 10 g and 40 g for body mass measurements.

The body mass index (BMI) was calculated using the ratio of body mass measurements, expressed in kilograms, to height, expressed in meters squared (kg/m^2). The diagnostic criteria suggested by the International Obesity Task Force (IOTF) were applied to classify the weight status (underweight, normal weight, overweight, and obesity) of participants[21].

Statistical analysis

The statistical analysis of the data was performed using the Statistical Package for the Social Sciences (SPSS, version 26.0). The anthropometric data were initially compared with the normal curve using the Kolmogorov-Smirnov test. Height and body mass measurements showed normal distributions. Descriptive statistics (mean and standard deviation) were used to characterize the sample, and covariance analysis with interactions involving two classification criteria (sex and age) was performed.

Regarding weight status, specific proportions and their respective 95% confidence intervals (95%CI) were identified and stratified by sex and follow-up period. Statistical differences were analyzed using contingency tables involving the non-parametric chi-square test ($\chi 2$) for linear trend. The chances of children having excess body weight (overweight + obesity) in the pandemic/2021, pandemic/2022, and post-pandemic/2023 monitoring periods, compared to the pre-pandemic/2020 period, were identified through the values of odds ratios accompanied by 95%CI, calculated using binary logistic regression analysis with adjustments for sex and age. Statistical significance was pre-established at $p < 0.05$.

RESULTS

Table 1 presents the participants' height, body mass, and body mass index measurements, categorized by sex and study period. Girls and boys showed statistically similar measurements; however, the values found in the three anthropometric outcomes indicated an increase with advancing age.

Table 1. Mean values, standard deviation, and "F" statistics equivalent to the height, body mass, and body mass index measurements of the participants (n = 797)

Waves	Age (years)	Stature (cm)		Weight (kg)		BMI (kg/m^2)	
		Girls	Boys	Girls	Boys	Girls	Boys
Prior to School Closures/ Pandemic/2020	6.2±0.2	116.5±4.9	117.0±5.2	22.5±4.0	23.0±3.8	15.9±2.0	16.1±2.1
During School Closures/ Pandemic/2021	7.1±0.2	121.2±5.6	121.6±5.2	25.1±4.4	25.5±4.3	16.8±2.1	17.3±2.3
During School Closures/ Pandemic/2022	8.1±0.2	126.7±5.9	127.4±6.1	27.5±5.1	28.1±4.8	17.1±2.3	17.6±2.3
After School Closures/ Pandemic/2023	9.0±0.1	133.1±6.3	133.9±6.5	30.6±5.6	30.9±5.7	17.4±2.5	17.9±2.4
F_{Age}:		147.825 (p < 0.001)		274.148 (p < 0.001)		4.481 (p < 0.016)	
F_{Sex}:		1.053 (p = 0.175)		2.983 (p = 0.043)		2.827 (p = 0.068)	
$F_{Interaction}$:		2.587 (p = 0.091)		2.353 (p = 0.105)		1.938 (p = 0.125)	

Regarding the weight status of the participants, using the specific cut-off points for sex and age proposed by IOFT, it was found that girls had lower rates of underweight prevalence and higher rates of overweight prevalence than boys ($\chi2 = 10.637$; $p < 0.001$). Specifically considering the study's follow-up waves, there was a significant tendency for both sexes to present increased prevalence rates of overweight and obesity in the pandemic periods, during which schools remained totally or partially closed, and post-pandemic, when schools had already been reopened for a year, compared to the pre-pandemic period, before the closure of schools (girls: $\chi2 = 8.328$; $p = 0.001$; boys: $\chi2 = 9.085$; $p < 0.001$) – Table 2.

Table 2. Prevalence rates (%) of weight status according to the International Obesity Task Force (IOFT) criteria

	Girls				Boys			
	Prior-school closures/ pandemic (2020)	During-school closures/pandemic (2021-2022)		Post-school closures/ pandemic (2023)	Prior-school closures/pan-demic (2020)	During-school closures/pandemic (2021-2022)		Post-school closures/pan-demic (2023)
	6 years	7 years	8 years	9 years	6 years	7 years	8 years	9 years
Low weight	3.9 (3.5-4.4)	2.5 (2.3-2.8)	2.4 (2.2-2.7)	3.4 (3.1-3.8)	5.4 (4.9-6.0)	3.7 (3.3-4.2)	3.5 (3.2-3.9)	4.5 (4.1-5.0)
Eu-trophic	71.8 (68.3-75.4)	66.3 (63.0-69.8)	63.1 (59.9-66.5)	68.1 (64.7-71.6)	72.7 (69.2-76.4)	67.7 (64.3-71.2)	64.3 (61.1-67.6)	69.5 (66.0-73.1)
Over-weight	17.4 (16.4-18.4)	22.1 (20.8-23.5)	24.3 (22.8-25.9)	19.6 (18.5-20.8)	14.5 (13.7-15.3)	18.9 (17.8-20.5)	21.5 (20.2-22.9)	16.9 (15.9-18.0)
Obesity	6.9 (6.4 - 7.4)	9.1 (8.3-10.0)	10.2 (9.4-11.1)	8.9 (8.1-9.8)	7.4 (6.9-7.9)	9.7 (8.9-10.6)	10.7 (9.9-11.6)	9.1 (8.4-9.9)
χ^2_{Wave}	8.328 ($p = 0.001$)				9.085 ($p < 0,001$)			
χ^2_{Sex}	10.637 ($p < 0.001$)							

Figure 2 presents the individual changes in the participants' weight status over the four monitoring waves. At the end of the pandemic period and school closures (2022), the number of children identified as overweight and obese in the pre-pandemic period (before school closures) increased from 128 to 183 and from 57 to 83, respectively. During the same period, only nine children who were identified as overweight in the pre-pandemic period transitioned to a normal weight status.

Of a group of 575 children initially identified as eutrophic, 90 accumulated enough body weight to be classified as overweight. In comparison, no more than six children moved to a low body weight at the end of the pandemic and school closures. Data equivalent to the post-pandemic period, when schools had already been reopened for a year, showed a tendency to a reduction in the greater accumulation of body weight achieved in pandemic periods when schools remained totally or partially closed; however, the rates of excess body weight were still above those identified in the pre-pandemic period, before the closure of schools. During this period, the reduction in body weight was more evident in children initially identified as eutrophic and overweight, in contrast to those identified as obese, who showed more subtle signs of reestablishing body weight.

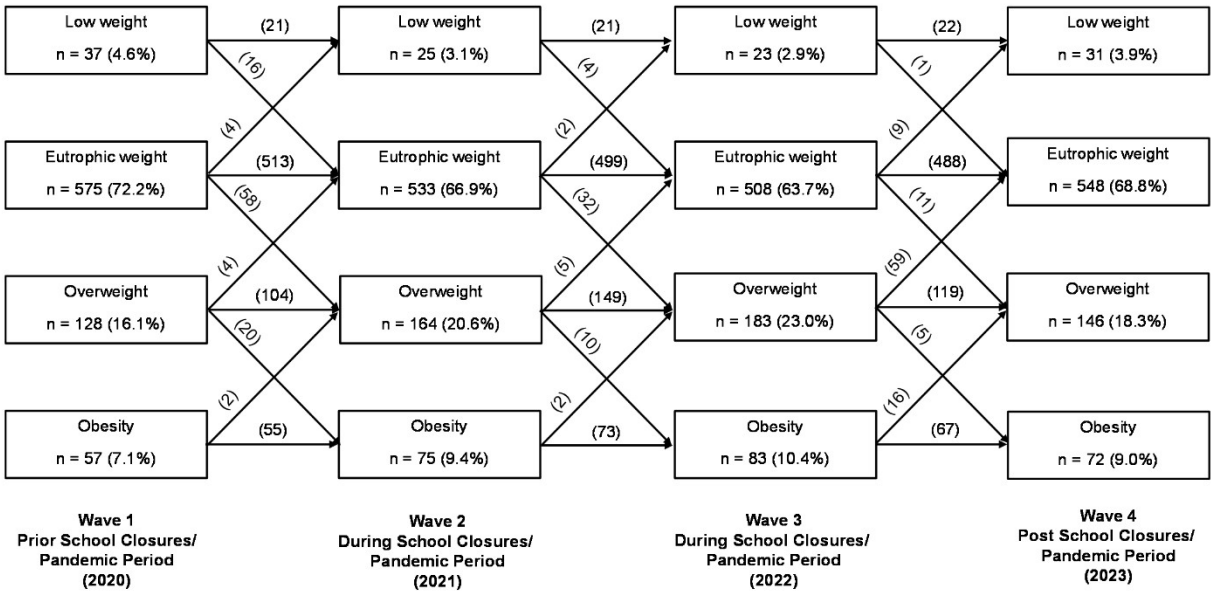

Figure 2. Individual changes in children's weight status throughout the four monitoring waves of the COVID-19 Pandemic

Table 3 presents binary logistic regression models indicating the risk of children having excess body weight (overweight + obesity) during pandemic periods, when schools remained totally or partially closed, and post-pandemic, when schools had already been reopened for one year. The odds ratio values adjusted for sex and age suggest that, in the first pandemic period/2021, children were 51% (OR = 1.51 [95%CI 1.19 – 2.47]; p = 0.019) more likely to have excess body weight than in the pre-pandemic period/2020, while in the second pandemic period/2022 exposure to excess body weight almost doubled (OR = 1.94 [95%CI 1.48 – 3.19]; $p < 0.001$).

In the follow-up wave, equivalent to the post-pandemic period in 2023, a declining trend in risk exposure for excess body weight was identified, although it remained statistically significant (OR = 1.35 [1.05–2.25]; $p = 0.039$).

Table 3. Chances of children having excess body weight (overweight + obesity) in the pandemic and post-pandemic periods compared to the pre-pandemic period

Waves	Prevalence Rate (CI95%)	OR (CI95%)	*p*-value
Prior-school closures/pandemic (2020)	23.1 (21.5 – 24.8)	Reference	
During-school closures/pandemic (2021)	29.9 (28.1 – 31.8)	1.51 (1.19 – 2.47)	0.019
During-school closures/pandemic (2022)	33.4 (31.5 – 35.4)	1.94 (1.48 – 3.19)	< 0.001
Post-school closures/pandemic (2023)	27.3 (25.6 – 29.1)	1.35 (1.05 – 2.25)	0.039

Note: Values adjusted for sex and age

DISCUSSION

The current study examined the impact of school closures as a measure to contain the COVID-19 pandemic on the weight status of children aged 6 to 9 years, using three-year (2020-2023) school-based cohort data. The main results showed a significant increase in the prevalence rates of excess body weight in the two years in which schools remained totally or partially closed (pandemic periods 2021 and 2022) compared to the pre-pandemic period/2020, before the closure of schools. Data equivalent to the post-pandemic period/2023, when schools had already been reopened for a year, showed a tendency to a reduction in the greater accumulation of body weight achieved in the pandemic periods 2021 and 2022, during which schools remained closed; however, the rates of excess body weight were still significantly above those identified in the pre-pandemic period.

These findings raise concerns for public health in the coming years, as the immediate and long-term consequences of excess body weight on children's health are widely recognized[22, 23]. Furthermore, a meta-analysis study found that children with excess body weight may be at a five times greater risk of becoming obese adults compared to their peers with normal body weight and, consequently, more exposed to associated comorbidities[24]. Regarding the increase in body weight above what would be expected for sex and age[21], specifically during the COVID-19 pandemic, our results align with those of other studies employing cross-sectional[25] and longitudinal[11] designs. These studies included children of different ages, ethnicities, economic levels, and cultural backgrounds and brought together samples from various geographic regions around the world, which may indicate a global representation of the effects of restrictions imposed to mitigate the adverse impact of COVID-19 on weight status.

To date, there is a lack of data on the long-term effects of the COVID-19 pandemic and subsequent periods on body weight variation in children. A study was conducted with Australian children for a period equivalent to 21 months after the start of the pandemic[26], and another with Austrian children between March/2020 and November/2022[27].

Similar to what was found in the present study, in both studies, the prevalence rates of overweight and obesity increased immediately after the start of pandemic restrictions; however, with lower rates. After these initial changes, from the second year of the pandemic onwards, the increase in body weight tended to stabilize.

Subsequently, the prevalence rates of overweight and obesity gradually returned to rates close to those found in the pre-pandemic period. In our study, a tendency towards body weight stabilization was also observed; however, the prevalence rates of overweight and obesity did not return to pre-pandemic levels (March 2020) by the end of the study (March 2023). It is also noteworthy that in the Australian and Austrian samples, the risk of disproportionate body weight gain during the pandemic period was greater in children with pre-existing overweight or obesity, a finding that was confirmed in the current study.

Interestingly, no differences were identified between the sexes in the trends toward increasing body weight induced by anti-epidemic measures. These findings differ from other studies that examined variations in body weight in response to the COVID-19 crisis using cross-sectional designs, which found more pronounced increases in girls than in boys[28, 29]. On the other hand, the data from the present study showed that in the post-pandemic period, the recovery of overweight and obesity prevalences to values close to the pre-pandemic period was lower in girls, suggesting more pronounced residual impacts on their body weight and leaving them with more visible pandemic effects even one year after schools reopened (2023). The reasons for this sex difference could not be analyzed in our study; however, according to findings from a previous study, it is speculated that this may be mainly due to the different inter-sex changes observed in obesogenic behaviors resulting from the restrictions imposed by the COVID-19 pandemic[30].

The weight status is influenced by the interaction of various lifestyle behaviors, including eating habits, physical activity, screen time, and sleep[31]. The restricted mobility, social distancing, and interruption of in-person school activities due to the isolation measures imposed to combat the COVID-19 pandemic resulted in profound changes in the lifestyle behaviors of families, particularly among children[32].

Regarding eating habits, mobility restrictions limited the frequency of purchases of foodstuffs and, consequently, tended to increase the consumption of processed and canned foods, which are easier to acquire and store and have a longer shelf life, which can directly impact children's nutrition[33]. Moreover, the interruption of face-to-face classes deprived children of consuming school meals prepared according to a planned and nutritionally balanced menu. In this scenario, several children who depended financially on school meals to complement the food offered at home had less availability of nutritious food[34]. A previous study found that changes in children's eating habits may have influenced the type of snack foods taken from home to school after the return of in-person classes, providing strong evidence that unhealthy eating behaviors acquired during the COVID-19 pandemic persist in the daily lives of families[35].

Two other lifestyle behaviors significantly impacted by the actions resulting from the COVID-19 pandemic are the reduction in physical activity and the increase in screen time[36]. Schools are an ideal environment to enhance children's physical activity. This scenario enables students to participate in physical education classes, engage in sports, play active games, and interact in groups, thereby reducing the likelihood of using screen-based equipment[37]. However, with the temporary closure of schools, children remained without this school support for an extended period. Further aggravating this situation, children demonstrated difficulty accessing public areas, parks, and clubs where they can play or engage in activities that would increase physical activity and reduce screen time.

Furthermore, the school environment can help define the routines and structures necessary for children's mealtimes, physical activity, sleeping periods, and lifestyle behaviors, thus implying a greater risk of overweight and obesity without these routines[28]. In this context, school vacation periods are usually associated with a greater increase in body weight due to the dysregulation of these three lifestyle behaviors[38], and the COVID-19 pandemic extraordinarily exacerbated this effect with the interruption of in-person school activities. A previous study, which investigated the perception of parents of children between four and 12 years old, pointed out that the children's daily screen time more than doubled, physical activity time decreased by half, and bedtime was postponed by around two hours during the period in which schools remained closed because of the COVID-19 pandemic[39].

The study has some strengths. It is a longitudinal design with anthropometric annual measurements that allow comprehensive conclusions about the short- and medium-term impact of the COVID-19 pandemic restrictions on children's weight status. A representative sample was recruited, encompassing the entire universe of students in the 1st year of primary education in public schools in the urban region of Cambé, Paraná, with an acceptable rate of refusal to participate in the study (9%), thereby ensuring greater reliability of the findings.

All anthropometric measurements were taken annually by trained personnel, increasing the data collection quality. Possible seasonal interferences in anthropometric measurements were eliminated, considering that data collection was carried out at the same time of year (February). Another strong point worth mentioning was the analysis of body weight in different weight status, which produced more detailed findings on the impact of the pandemic periods.

The limitations of the study must also be recognized. For one, as the study focuses on a specific population of children attending public elementary schools in Cambé, Paraná, the findings may have limitations in their generalizability to the child population of other Brazilian regions. However, due to the study design, the participant selection procedures, the large sample, and the methodological rigor used in collecting and processing the data, it is quite likely that the results found can describe, with satisfactory conditions, the short and medium-term impact of COVID-19 pandemic restrictions on the weight status of children in cities in the northern region of Paraná.

Furthermore, the analyses were adjusted for sex and age but not for other demographic data that could produce some residual confusion, such as the economic condition of the families. However, the financial condition of families can be estimated, as the selected students belong exclusively to public schools, although the collected data does not have the power to identify the economic status of the study participants. Moreover, the reasons for changes in body weight cannot be identified, as no data are available on potential mediators of lifestyle behaviors, including eating habits, physical activity, screen time, sleep, and psycho-emotional factors related to the pandemic. It is essential to consider that participation in the study was voluntary; therefore, possible selection bias cannot be ruled out.

CONCLUSION

Our results suggest that the restrictions imposed to mitigate the adverse impact of the COVID-19 pandemic, including the total or partial closure of schools, substantially increased the body weight of the children above what would be expected for sex and age. After two years of the pandemic period, 16% of children identified in the pre-pandemic period with normal body weight migrated to overweight, while 23% of overweight children became obese. Data equivalent to the post-pandemic period showed signs of a reduction in the excess body weight accumulated during the pandemic; however, the prevalence rates of overweight and obesity were still 14% and 26%, respectively, higher than in the pre-pandemic period.

Therefore, the study findings suggest that the harmful effects contributing to the greater accumulation of body weight during the COVID-19 pandemic were not reversed spontaneously, even three years after its onset. Thus, specific actions to prevent, combat, and control overweight and obesity are essential to avoid present and future adverse consequences for children's health.

Author Contributions: S.L.S. and D.P.G.: Contributed to the conception and design of the study; S.L.S., D.P.G., and A.S.R.: Contributed to data collection and methodological procedures; D.P.G. and L.S.: Contributed to statistical analysis and data interpretation; S.L.S. and L.S.: Contributed to manuscript drafting; L.S., R.A.C.A, and A.S.R.: Contributed to critical revision of the manuscript for important intellectual content; L.S., R.A.C.A, and A.S.R.: Contributed to study coordination and final approval of the version to be published. All authors read and approved the final manuscript and agree to be accountable for all aspects of the work.

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