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# Effects of school closure on lifestyle behaviours and health outcomes in children during the COVID-19 pandemic in Chile: A time-matched analysis

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## Summary

**Background:** The COVID-19 pandemic led to school closures, potentially impairing children's behaviours and health. We aimed to explore the effects of school closure on lifestyle behaviours (dietary habits, physical activity) and health outcomes (adiposity, fitness, self-esteem, self-concept) in children.

**Methods:** We measured 247 children before school closure (October–November 2019) and after school reopening (October–November 2021) (COVID-19 group). To distinguish the changes due to school closure from changes due to growth, we included 655 age-matched children with cross-sectional measurements in October–November 2019 (control group). The response of this group (i.e., differences between children with 2 years of difference) was considered the expected response to growth. Two-way ANOVA was used to test age-by-group interactions, indicating an effect of school closure.

**Results:** In 7-to-9-year-old children, the COVID-19 group had larger-than-expected decreases in physical activity (by 0.4 points), resulting in higher physical inactivity prevalence (by 19 percent points) at 9 years. This was accompanied by larger-than-expected increases in fat percentage (by 6.1 percent point). In 8-to-10-year-old children, the COVID-19 group had higher physical inactivity prevalence at 10 years (by 20 percent points). This was accompanied by larger-than-expected increases in fat percentage (by 8.3 percent points), z-score BMI (by 0.90 units), and waist circumference (by 6.1 cm). In 9-to-11-year-old children, the COVID-19 group had larger-than-expected decreases in physical activity (by 0.3 points) and increases in self-concept (by 0.2 points). The response in dietary habits, fitness, or self-esteem was not different between groups.

**Conclusion:** Overall, school closure negatively impacted physical activity and adiposity, particularly in the youngest children.

KEYWORDS
childhood obesity, health behaviours, schoolchildren

## 1 | INTRODUCTION

The Coronavirus Disease 2019 (COVID-19) was declared a pandemic by the World Health Organization in March 2020. To mitigate the virus spread, authorities worldwide implemented several measures including school closures. In Chile, schools closed in March 2020[1] and remained closed throughout 2020, with the classes being held virtually. Moreover, there were several restrictions on outdoor activities, including designated times for physical activities, the closure of sports and recreational facilities and the inability to use playgrounds.[2] These mobility restrictions inevitably changed children's routines, which could have disrupted their habits and potentially harmed their health. After intermittent closing/reopening cycles, the definitive school reopening occurred in September 2021.[1] Data from before the pandemic showed that when children were out of school the risk of obesity increased (e.g., during summer vacations), probably due to changes in lifestyle behaviours. Nevertheless, whether the increased obesity risk results from changes in sleep patterns, energy intake, physical activity or a combination of them is unknown.[3] Therefore, a great interest emerged in assessing the effects of the school closure during the pandemic on lifestyle behaviours and health outcomes in this population.

Several studies collected retrospective data in which parents reported the change in the lifestyle habits of their children during the pandemic. Using this design, several studies showed increases in the intake of unhealthy foods,[4,5] with some reports indicating a twofold and sixfold increase in the consumption of sugary drinks and potato chips, respectively.[5] These results were consistent with the stressful experience that the pandemic represented, as stress has been associated with increased consumption of 'comfort foods' high in sugar and fat.[6] Reports on healthy food consumption during the pandemic are mixed. One study reported improvements, with a 50%–80% increase in the consumption of fruits, vegetables and milk.[7] In contrast, another study reported that only 23% of children and adolescents engaged in healthy eating habits.[8] Regarding changes in physical activity, studies reported that between 36% and 64% of parents indicated that their children were less active during the pandemic compared with before the pandemic.[9–12] When physical activity was measured objectively, the decrease in physical activity ranged from 45 to 90 min per day.[9–12] These observations probably result from the cancellation of organized and free physical activities inside and outside school, along with the closure of parks and other spaces, which reduced the possibilities for children to engage in physical activity.[13] In Chile, as schools started to reopen, the government issued guidelines on physical distancing inside the school. These guidelines included alternating schoolyard use during breaks, holding physical education classes in open spaces, avoiding shared equipment and minimizing physical contact among students.[14] This situation potentially worsened the high prevalence of physical inactivity among children[15] and may have also impaired physical fitness, at least during the more critical period of the pandemic.[16]

The changes in lifestyle behaviours during the pandemic could impair relevant health outcomes. Accordingly, during the early stage of the pandemic, several studies worldwide reported an increase in body weight and BMI in children and adolescents. A systematic review with meta-analysis found an average weight increase of 2.67 kg and a BMI increase of 0.77 kg/m$^2$.[17] The emotional well-being of children also seemed affected as reported in another systematic review with meta-analysis that showed that parents reported high rates of anxiety (34.5%) and depression (41.7%) in their children.[18] Such psychological alterations have been associated with lower self-esteem and other self-outcomes.[19] This could further impair the physical health of children, as psychosocial factors are associated with the risk of obesity.[20]

All this evidence suggested an impairment in lifestyle behaviours and health outcomes during the pandemic because of the closure of schools. Nevertheless, the retrospective design of those studies is an important limitation. Self-report methods have inherent limitations[21] that may be amplified if individuals try recalling events that occurred long before and compare them with a stressful time point such as the pandemic. Importantly, some studies were able to collect objective measurements before and during the pandemic.[22,23] In those cases, however, the changes due to school closure cannot be distinguished from the expected changes due to growth and development during childhood. A control group unexposed to the school closure is required for that purpose, which was not possible.

As an alternative to a control group unexposed to school closure, herein, we used a time-matched control group composed of age-matched children. Thus, we aimed to explore the effects of the school closure on lifestyle behaviours (dietary patterns and physical activity) and health outcomes (adiposity, physical fitness, and psychological variables) of children during the pandemic in Chile. Measurements were conducted before the school closure due to the pandemic and after the definitive reopening. Data collected before the pandemic from age-matched children were used to distinguish the expected changes induced by growth and development (i.e., age) from those induced by the school closure.

## 2 | METHODS

### 2.1 | Design, setting and participants

The data for the current report is from a project initially intended to build an integrated model for a healthy school environment in public schools in Santiago, Chile (FONDEF IT 18I0018). The original project considered measuring lifestyle behaviours including dietary habits and physical activity, and health outcomes including adiposity measures, fitness and psychological variables at baseline in 2019, and after a 24-month intervention. The baseline measurements were conducted in October–November 2019. Nevertheless, the intervention was not implemented because of the confinement enforced by the COVID-19 pandemic. We then focused on determining the effects of 2 years of school closure on lifestyle behaviours and health outcomes. We thus remeasured all the variables in October–November 2021. Only some of the children measured in 2019 were available for measurement in

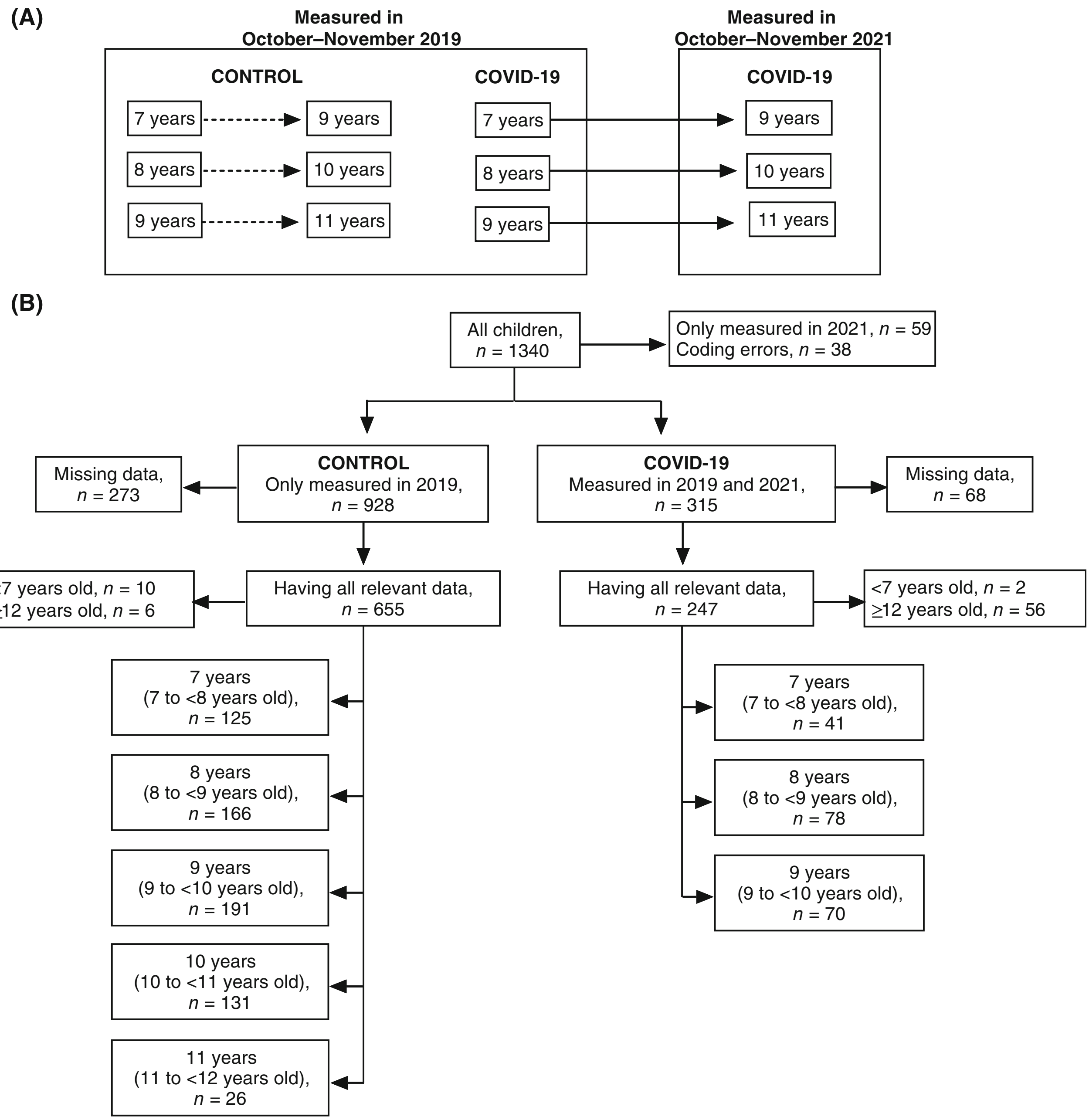


**FIGURE 1** Design and selection of participants. (A) Matching of age-groups for the statistical analyses; dashed arrows indicate different children measured cross-sectionally, whereas solid arrows indicate the same children measured twice. (B) Flow chart for the selection of participants.

2021 (i.e., they had repeated measures). In this study, these children represent the 'COVID-19' group, who were exposed to the 2-year school closure during the COVID-19 pandemic. Important, in this group, the potential effect of school closure on the outcomes is confused by the effect of the two extra years of age (from 2019 to 2021). To control for the effect of age, we used a time-matched 'control' group[24] composed of age-matched children belonging to the same population (schools) unexposed to the pandemic. This group included children of different ages that were measured cross-sectionally in 2019 (see Figure 1A). The difference in the outcomes between control children with 2 years of difference was considered the expected response to age. Then the changes observed in the COVID-19 group were contrasted with the expected response observed in the 'control' group. A change in the COVID-19 group different than expected suggests that the school closure during the pandemic influenced the outcome.

For each outcome, the changes in 7-year-old children from 2019 to 2021 (COVID-19 group) were contrasted with the difference between 7- and 9-year-old children (control group) only measured in 2019; the changes in 8-year-old children from 2019 to 2021 (COVID-19 group) were contrasted with the difference between 8 and 10-year-old children (control group); and the changes in 9-year-old children from 2019 to 2021 (COVID-19 group) were contrasted with the difference between 9- and 11-year-old children (control group). Figure 1 schematizes the design. The current study thus represents an observational, analytical, with a mixed cohort ('COVID-19' group) and cross-sectional ('control' group) design.[25]

Children from seven public schools belonging to six municipalities of Santiago (Chile) were included. Based on a vulnerability index from 0 to 100 points, where higher values indicate greater vulnerability,[26] the schools were highly vulnerable: mean [SD] (min–max) of 91.5 [5.4] (88–98) points. Professionals trained in Nutrition or Physical Activity applied, in person, the surveys about dietary habits, physical activity and psychological variables, and conducted the measurements of adiposity and fitness during school days. More details about the design, setting and participants have been previously described.[27]

## 2.2 | Ethical approval

All measurements were made after obtaining authorization from the school authorities, written parental consent and the child's assent, both of which were obtained in person. The protocol was approved by the Ethics Committee of the Universidad de Santiago de Chile (record number 187/2019).

## 2.3 | Instruments and data collection

### 2.3.1 | Dietary habits

Dietary habits were measured based on semi-structured questions of the Chilean Food Guidelines for children from 2 years of age.[28] The guidelines include recommendations for the daily intake of water (at least 1 L), vegetables (at least three portions), fruits (at least two portions), dairy (at least three portions) and bread (up to one portion), as well as for the weekly intake of legumes (at least two portions) and fish and seafood (at least two portions). The intake of each food was categorized as meeting or not the recommendation. Additionally, the consumption of processed food such as sugary drinks, fast food, candies, salty snacks and cakes was registered.

### 2.3.2 | Physical activity

Physical activity was estimated using the Physical Activity Questionnaire for Older Children (PAQ-C) by Kowalski et al.[29] From nine questions about physical activity in the last 7 days, a score between 1 and 5 was calculated. The higher the level of activity, the higher the score.[29] A score ≥2.73 has been considered a cut-off to consider children as physically active.[30] Children reaching those scores would meet the 60 min of moderate-to-vigorous physical activity recommended for health in children.[31]

### 2.3.3 | Adiposity

Adiposity markers included weight status, waist circumference and body fat. To determine weight status, body mass index (BMI) was calculated from the weight and height measured with an electronic scale Seca 813 and with a stadiometer Seca 213 (Seca®, Hamburg, Germany). The BMI *z*-scores for 5- to 19-year-old children were calculated using the AnthroPlus software to categorize weight status as underweight (<−1.00), normal weight (−1.00 to 1.00), overweight (>1.00 to 2.00) or obesity (>2.00).[32] Waist circumference was measured with a non-elastic tape on the uppermost lateral border of the right ilium at the end of a normal expiration. Elevated waist circumference and abdominal obesity were determined using published reference values.[33] Skinfolds were measured using a Lange® adipometer (Bloomington, Minnesota, USA), and body fat was calculated by the Slaughter equation.[34]

### 2.3.4 | Physical fitness

Physical fitness assessments included handgrip strength and standing long jump tests. These tests have high reliability in children and offer valuable insights into muscular fitness, a key aspect of physical health in young populations.[35] Handgrip strength was measured with a Jamar® PC-5030 hand hydraulic dynamometer (Jamar Dynamometer, Lafayette, IN, USA). Schoolchildren performed two attempts with each hand. The average of the maximum value (in kilograms) of each hand was considered for analysis. The standing long jump test was used to measure the explosive power of the legs. Children jumped as far as they could with their feet together. The distance between toes at take-off and heels at landing was recorded to the nearest 0.1 cm. Children performed three attempts and the longest one (in centimetres) was used for analysis.

### 2.3.5 | Psychological outcomes

Psychological outcomes included self-esteem and self-concept. Self-esteem was estimated by the Rosenberg questionnaire containing 10 statements for which children indicated their agreement from 1 (highly disagree) to 4 (highly agree). Negative statements were reverse-scored for final calculations. The final score ranged from 10 to 40 points, where the higher the score the higher the self-esteem. Self-concept was estimated using the Five-Factor Self-concept questionnaire (AF-5), which assesses five dimensions of self-concept: academic, social, emotional, family and physical. The questionnaire consists of 30 items (six per dimension) scored using a 5-option Likert-type frequency scale, where 1 = 'never', and 5 = 'always'. The score of all dimensions was averaged to provide an overall score, where the higher the score, the higher the self-concept.[36]

**TABLE 1** Comparison between children measured in 2019 (Control) versus children measured in 2019 and 2021 (COVID-19) at different age ranges.

| | Control | | COVID-19 | | Two-way ANOVA | | |
|---|---|---|---|---|---|---|---|
| | 7 years ($n = 125$) | 9 years ($n = 191$) | 7 years ($n = 41$) | 9 years ($n = 41$) | Age | Group | Age × Group |
| Girls, % | 44.0 | 47.0 | 59.0 | 59.0 | | | |
| Age, years | 7.7 (7.5–7.8) | 9.6 (9.2–9.8) | 7.8 (7.6–7.9) | 9.7 (9.5–9.8) | **<0.001** | **<0.001** | 0.452 |
| Weight, kg | 26.4 (23.5–32.2) | 34.8 (29.3–41.6) | 27.4 (24.4–32.1) | 38.0 (34.2–47.1) | **<0.001** | 0.056 | 0.059 |
| Height, cm | 124.4 (119.9–129.1) | 135.2 (131.4–140.6) | 126.0 (121.0–130.0) | 140.0 (134.0–143.0) | **<0.001** | 0.057 | 0.271 |
| BMI, kg/m$^2$ | 17.5 (15.4–20.1) | 18.8 (16.6–21.5) | 17.8 (16.1–19.4) | 21.0 (18.2–23.6) | **<0.001** | 0.150 | 0.063 |
| BMI, *z*-score | 1.03 (−0.14–2.14) | 1.14 (0.26–1.99) | 1.04 (0.23–1.80) | 1.77 (0.95–2.48) | 0.050 | 0.223 | 0.090 |
| Waist circumference, cm | 60.0 (55.2–66.6) | 65.3 (59.8–73.6) | 62.0 (56.0–67.0) | 70.0 (65.0–77.0) | **<0.001** | 0.173 | 0.173 |
| Body fat, % | 19.7 (14.0–24.4) | 22.9 (17.0–27.0) | 19.2 (15.2–24.1) | 28.5 (22.3–32.6)** | **<0.001** | **0.011** | **0.024** |
| Physical activity, score | 2.8 (2.4–3.3) | 2.8 (2.4–3.2) | 3.0 (2.4–3.4) | 2.6 (2.2–3.0) | **0.006** | 0.468 | **0.018** |
| Handgrip strength, kg | 9.0 (6.0–12.0) | 12.0 (10.0–15.0) | 8.0 (8.0–11.0) | 12.0 (9.0–12.5) | **<0.001** | 0.859 | 0.059 |
| Standing long jump, cm | 98.0 (83.7–110.7) | 104.0 (91.5–116.0) | 104.0 (92.0–112.0) | 110.0 (97.0–125.0) | **0.005** | **0.035** | 0.730 |
| Self-esteem, score | 29.0 (25.5–32.0) | 29.0 (26.0–31.0) | 28.0 (25.0–31.0) | 28.0 (26.0–31.0) | 0.939 | 0.641 | 0.727 |
| Self-concept, score | 3.5 (3.1–3.8) | 3.3 (2.9–3.6) | 3.6 (3.3–3.9) | 3.3 (3.1–3.8) | **0.036** | 0.056 | 0.878 |
| | **Control** | | **COVID-19** | | **Two-way ANOVA** | | |
| | **8 years ($n = 166$)** | **10 years ($n = 131$)** | **8 years ($n = 78$)** | **10 years ($n = 78$)** | **Age** | **Group** | **Age × Group** |
| Girls, % | 48.0 | 48.0 | 49.0 | 49.0 | | | |
| Age, years | 8.6 (8.3–8.8) | 10.3 (10.2–10.5) | 8.4 (8.2–8.6) | 10.3 (10.1–10.6) | **<0.001** | **0.009** | 0.082 |
| Weight, kg | 31.4 (26.9–38.1) | 38.8 (34.0–46.8) | 30.0 (25.8–35.2) | 42.5 (34.9–49.9) | **<0.001** | 0.798 | **0.009** |
| Height, cm | 130.6 (126.5-)134.4 | 141.5 (136.9–145.4) | 130.0 (125.5–132.7) | 142.7 (136.6–148.2) | **<0.001** | 0.910 | 0.086 |
| BMI, kg/m$^2$ | 18.3 (16.6–21.5) | 19.5 (17.6–22.4) | 17.3 (16.1–20.2) | 20.7 (17.9–23.3) | **<0.001** | 0.695 | **0.015** |
| BMI, *z*-score | 1.18 (0.37–2.25) | 1.17 (0.40–1.97) | 0.78 (0.13–1.73) | 1.68 (0.53–2.31) | 0.258 | 0.653 | **0.024** |
| Waist circumference, cm | 63.0 (57.9–72.4) | 68.6 (62.3–76.0) | 61.4 (57.2–67.7) | 73.1 (63.0–82.0) | **<0.001** | 0.729 | **0.014** |
| Body fat, % | 21.7 (16.2–27.0) | 22.9 (17.9–27.9) | 18.8 (15.5–24.8) | **28.3 (20.6–33.3)**** | **<0.001** | 0.251 | **<0.001** |
| Physical activity, score | 2.8 (2.4–3.2) | 2.7 (2.3–3.1) | 2.9 (2.5–3.2) | 2.4 (1.9–2.9) | 0.223 | **0.016** | 0.337 |
| Handgrip strength, kg | 10.0 (8.8–13.0) | 14 (12.0–16.0) | 10.0 (8.0–12.0) | 14.0 (10.0–17.0) | **<0.001** | 0.358 | 0.729 |
| Standing long jump, cm | 100.9 (90.0–112.7) | 108.0 (94.4–121.0) | 105.0 (92.6–115.2) | 110.0 (92.8–122.0) | **0.014** | 0.269 | 0.263 |
| Self-esteem, score | 29.0 (26.0–31.0) | 29.0 (26.0–32.0) | 29.0 (26.0–31.3) | 29.0 (26.0–32.0) | 0.403 | 0.550 | 0.726 |
| Self-concept, score | 3.3 (3.1–3.7) | 3.3 (3.0–3.6) | 3.4 (3.1–3.8) | 3.5 (3.1–3.7) | 0.592 | **<0.001** | 0.086 |

(Continues)

**TABLE 1** (Continued)

| | Control | | COVID-19 | | Two-way ANOVA | | |
|---|---|---|---|---|---|---|---|
| | 9 years ($n = 191$) | 11 years ($n = 26$) | 9 years ($n = 70$) | 11 years ($n = 70$) | Age | Group | Age × Group |
| Girls, % | 47.0 | 27.0 | 39.0 | 39.0 | | | |
| Age, years | 9.6 (9.2–9.8) | 11.4 (11.3–11.5) | 9.4 (9.2–9.6) | 11.3 (11.2–11.6) | **<0.001** | 0.072 | 0.827 |
| Weight, kg | 34.8 (29.3–41.6) | 43.4 (34.9–55.9) | 34.3 (31.0–40.2) | 48.9 (42.7–56.5) | **<0.001** | 0.096 | 0.082 |
| Height, cm | 135.2 (131.4–140.6) | 146.3 (142.0–151.7) | 135.2 (131.9–139.2) | 147.0 (143.3–152.0) | **<0.001** | 0.785 | 0.094 |
| BMI, kg/m$^2$ | 18.8 (16.6–21.5) | 20.5 (17.4–24.7) | 18.6 (17.2–21.9) | 22.4 (19.3–26.5) | **<0.001** | **0.048** | 0.178 |
| BMI, z-score | 1.10 (0.30–2.00) | 1.27 (0.06–2.17) | 1.06 (0.44–2.27) | 1.68 (0.84–2.74) | 0.146 | **0.030** | 0.333 |
| Waist circumference, cm | 65.3 (59.8–73.6) | 71.6 (60.7–83.1) | 64.6 (60.7–74.9) | 77.2 (68.5–87.4) | **<0.001** | 0.118 | 0.130 |
| Body fat, % | 22.9 (17.0–27.0) | 26.7 (18.7–31.7) | 22.5 (17.5–27.2) | 30.5 (22.6–36.9) | **<0.001** | 0.070 | 0.126 |
| Physical activity, score | 2.8 (2.4–3.2) | 2.6 (2.3–3.4) | 2.9 (2.5–3.4) | **2.4 (2.0–2.8)*** | 0.079 | **0.033** | **0.043** |
| Handgrip strength, kg | 12.0 (10.0–15.0) | 16.0 (12.3–18.3) | 12.0 (11.0–16.0) | 14.0 (12.0–18.0) | **<0.001** | 0.902 | 0.688 |
| Standing long jump, cm | 104.0 (91.5–116.0) | 115.6 (96.0–138.3) | 110.0 (96.0–122.5) | 113.0 (102.0–127.1) | 0.093 | 0.095 | 0.803 |
| Self-esteem, score | 29.0 (26.0–31.0) | 29.0 (25.8–32.3) | 28.0 (25.0–32.0) | 28.0 (26.0–32.3) | 0.660 | 0.793 | 0.607 |
| Self-concept, score | 3.3 (3.0–3.6) | 3.2 (2.5–3.4) | 3.3 (3.0–3.6) | **3.4 (3.0–3.6)**** | 0.136 | **0.013** | **0.014** |

*Note*: Data are median (interquartile range) or percentage. Data for continuous variables were $log_{10}$-transformed before analyses, except for Z-BMI.
**$p < 0.01$ versus same age in the control group, Bonferroni post hoc test.

## 2.4 | Analyses

Shapiro–Wilk was used to test the normal distribution of continuous variables. All the variables measured in 2019 had a non-normal distribution, whereas some of those measured in 2021 had a normal distribution. For consistency, we present all continuous variables as median with interquartile range. Categorical variables are presented as percentages. Chi-square was used to test associations between groups and categorical variables at each age. Two-way ANOVA was used to determine the main effects of age (7–9 years, 8–10 years or 9–11 years), group (control vs. COVID-19) and the age × group interaction on $log_{10}$-transformed continuous variables. A significant age × group interaction indicates that the response (increase, decrease or no change) in the COVID-19 group is different than expected based on the control group. In the case of significant age × group interaction, Bonferroni post hoc was used to compare children of the same age between groups. Prism 9 for MacOS version 9.4.1 was used for analysis. A $p < 0.05$ was considered statistically significant.

# 3 | RESULTS

Figure 1A summarizes how the groups were matched for analyses and Figure 1B shows a flow chart for the selection of participants. Of 1340 children, 655 had complete data in the control group, and 247 in the COVID-19 group. As the number of children aged <7 years or ≥12 was small, those children were excluded from analyses. Thus, the COVID-19 group was stratified (based on their age in 2019) into 7 years (7–<8 years old), 8 years (8–<9 years old) and 9 years (9–<10 years old). The control group was stratified similarly but included 10 years (10–<11 years old) and 11 years (11–<12 years old). This allowed us to analyse the effects of 2 years of school closure during the COVID-19 pandemic on children 7–9 years old.

## 3.1 | 7–9 years old

The COVID-19 group was 0.1 years older than the control group (main effect of group) (Table 1), without differences in the proportion of girls at 7 ($p = 0.105$) or 9 years old ($p = 0.165$). As expected, there was a main effect of age on anthropometric variables that change during growth, including body weight, height, BMI and waist circumference (Table 1).

Figure 2 compares the effects of age on meeting dietary recommendations, physical activity, adiposity markers, fitness and psychological variables between the control and COVID-19 groups. There were no differences between groups in the proportion of children meeting the dietary recommendations at 7 or 9 years old (Figure 2A). Physical activity score showed an age × group interaction, with decreases in the COVID-19 group that were 0.4 points larger than expected (Figure 2B). Consequently, although the prevalence of

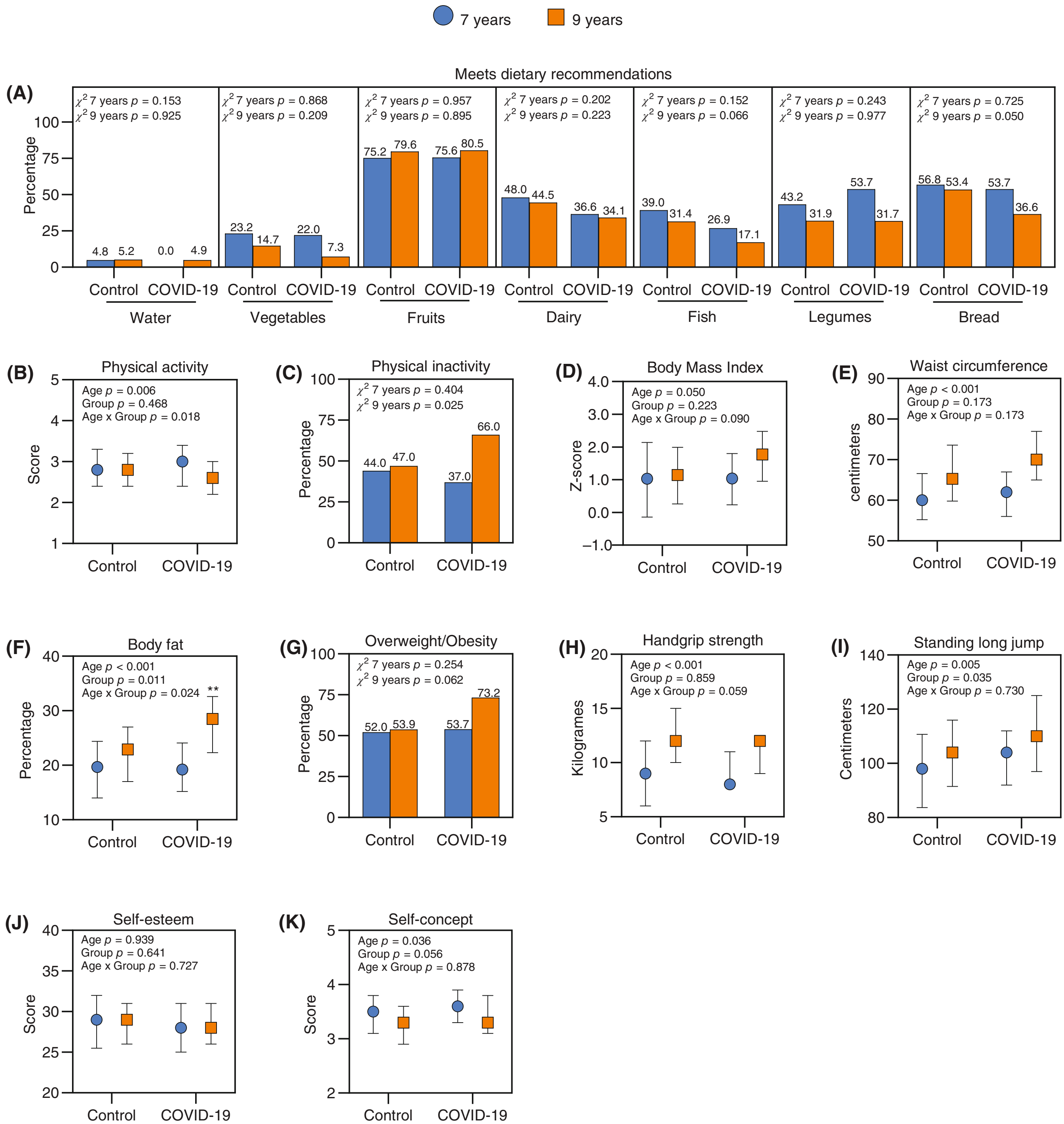


**FIGURE 2** Comparison between children 7 and 9 years old measured in 2019 (control group) versus children measured in 2019 and 2021 (COVID-19 group). ***p* < 0.01 versus control of the same age, Bonferroni post hoc test.

physical inactivity was not different between groups at 7 years old, it was 19 percent points higher in the COVID-19 group at 9 years old (Figure 2C). No age × group interactions were observed for the z-score BMI (Figure 2D) or waist circumference (Figure 2E). In contrast, body fat percentage showed an age × group interaction, with increases in the COVID-19 group that were 6.1% points larger than expected resulting in higher body fat percentage at 9 years old (Figure 2F). The prevalence of overweight/obesity was, however, not different between groups at 7 or 9 years old (Figure 2G). Handgrip strength and standing long jump increased with age (approximately 3.5 kg and 6 cm, respectively; main effect of age) but no age × group interactions were detected (Figure 2H,I). There were no age × group interactions in self-esteem or self-concept, yet self-concept decreased by approximately 0.3 points with age (main effect of age; Figure 2J,K). Table 1 presents the median and interquartile range of all these variables.

### 3.2 | 8–10 years old

The COVID-19 group was 0.1 years older than the control group (main effect of age) (Table 1), without differences in the proportion of girls at eight ($p = 0.869$) or 10 years old ($p = 0.930$). As expected, there was a main effect of age on anthropometric variables that change during growth, including body weight, height, BMI and waist circumference (Table 1).

Figure 3 compares the effects of age on meeting the dietary recommendations, physical activity, adiposity markers, fitness and psychological variables between the control and COVID-19 groups. There were no differences between groups in the proportion of children meeting the dietary recommendations at 8 or 10 years old (Figure 3A). The COVID-19 group showed approximately 0.1-point lower physical activity score than the control group (main effect of group) but no age × group interaction was detected (Figure 3B). Yet although the prevalence of physical inactivity was no different at 8 years old, it was 20 percent points higher in the COVID-19 versus the control group at 10 years old (Figure 3C). *z*-score BMI and waist circumference showed age × group interactions. Thus, in the COVID-19 group, increases in *z*-score BMI were 0.90 units larger than expected, and increases in waist circumference were 6.1 cm larger than expected (Figure 3D,E). An age × group interaction was also observed in body fat percentage with increases in the COVID-19 group that were 8.3 percent points larger than expected resulting in higher body fat percentage at 10 years old (Figure 3F). The prevalence of overweight/obesity was, however, not different between groups at 8 or 10 years old (Figure 3G). Handgrip strength and standing long jump increased with age (4 kg and approximately 6 cm respectively; main effect of age) but no age × group interactions were detected (Figure 3H,I). There were no age × group interactions in self-esteem or self-concept, yet self-concept was 0.2 points higher in the COVID-19 versus the control group (main effect of group; Figure 3J,K). Table 1 presents the median and interquartile range of all these variables.

### 3.3 | 9–11 years old

The control and COVID-19 groups had similar ages, and proportions of girls at 9 ($p = 0.247$) and 11 years old ($p = 0.288$). As expected, there was a main effect of age on anthropometric variables that change during growth, including body weight, height, BMI and waist circumference (Table 1).

Figure 4 compares the effects of age on meeting the dietary recommendations, physical activity, adiposity markers, fitness and psychological variables between the control and COVID-19 groups. There were no differences between groups in the proportion of children meeting the dietary recommendations at 9 or 11 years old (Figure 4A). Physical activity score showed an age × group interaction, with decreases in the COVID-19 group that was 0.3 points larger than expected resulting in lower physical activity at 11 years old (Figure 4B). The prevalence of physical inactivity was, however, no different between groups at 9 or 11 years old (Figure 4C). No age × group interactions were observed for *Z*-score BMI, waist circumference, or body fat percentage (Figure 4D–F). *Z*-score BMI was 0.19 points higher in the COVID-19 versus the control group (main effect of group, Figure 4D), while waist circumference and body fat percentage increased with age in both groups (approximately 9.5 cm and 5.9 percent points respectively; main effect of age; Figure 4E,F). The prevalence of overweight/obesity was not different between groups at 9 or 11 years old (Figure 4G). Handgrip strength increased with age in both groups (~3 kg, main effect of age) but no age × group interaction was detected (Figure 4H). No effect of age, group, or age × group interaction was detected for the standing long jump (Figure 4I) or self-esteem (Figure 4J). In contrast, self-concept showed an age × group interaction, with increases in the COVID-19 group that were 0.2 units larger than expected resulting in higher values in the COVID-19 group at 11 years old (Figure 4K). Table 1 presents the median and interquartile range of all these variables.

## 4 | DISCUSSION

This study analysed the changes in lifestyle behaviours, physical fitness, adiposity and psychological variables induced by school closure during the COVID-19 pandemic in a group of schoolchildren in Chile. To distinguish the effects of the school closure from those of normal growth and development, we included an age-matched control group of children from the same population who were measured only in 2019. Thus, outcomes with a similar response to age (increase, decrease or no change) between the COVID-19 and control groups were considered unaffected by school closure. For example, handgrip strength consistently increased with age independently of the group (main effect of time), whereas self-esteem showed no changes at any age in any group. In contrast, outcomes with a different response to age (increase, decrease or no change) between groups (age × group interaction) were considered affected by school closure. When the change was larger in the COVID-19 group compared with the control group, school closure was considered to have induced a larger-than-expected change. This was the case, for example, for body fat percentage in the youngest children.

The lifestyle behaviours considered in the present study were dietary habits and physical activity. When comparing the changes in meeting the dietary recommendations and consumption of processed food (data not shown), no differences were observed between the control and COVID-19 groups in any age range. These findings suggest that school closure did not affect these variables, which may be due to the reinforcement of the school feeding programme in Chilean schools.[37] Even when the children were not attending school, this aid was maintained during the most critical periods of the pandemic. The common delivery of prepared meals at school was replaced by

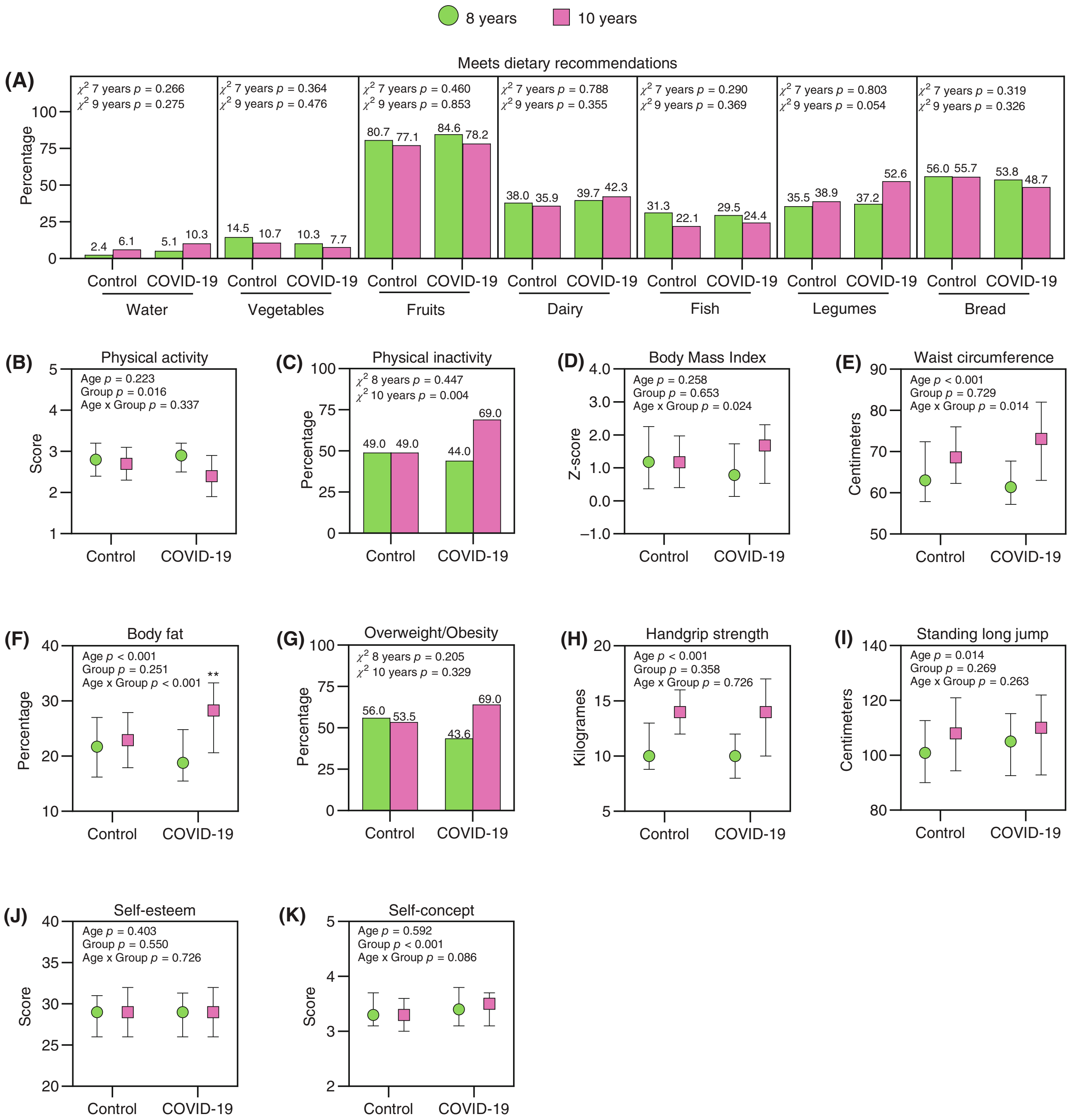


**FIGURE 3** Comparison between children of 8 and 10 years old measured in 2019 (control) versus children measured in 2019 and 2021 (COVID-19). $^{**}p < 0.01$ versus control of the same age, Bonferroni post hoc test.

the delivery of a package of non-perishable food to cover the requirements of the children and their families.[7] Note, however, that the meeting of dietary guidelines was not adequate before the pandemic, so the dietary aid prevented a worsening of eating habits. Studies on children's dietary changes during other periods without attending school, such as school vacations, are limited and report mixed results.[38] Thus, it is unclear whether a worsening of the diet is associated with negative health outcomes, particularly increases in adiposity-related markers. Additionally, because self-reporting is subject to subjective bias, children may not accurately report their dietary habits.

Before the pandemic, the prevalence of physical inactivity (i.e., <60 min/day of moderate-to-vigorous physical activity) was reported in approximately 73% in Chilean schoolchildren.[39] This result was based on a single question about how many days the child accumulates 60 min of moderate-to-vigorous physical activity. In our

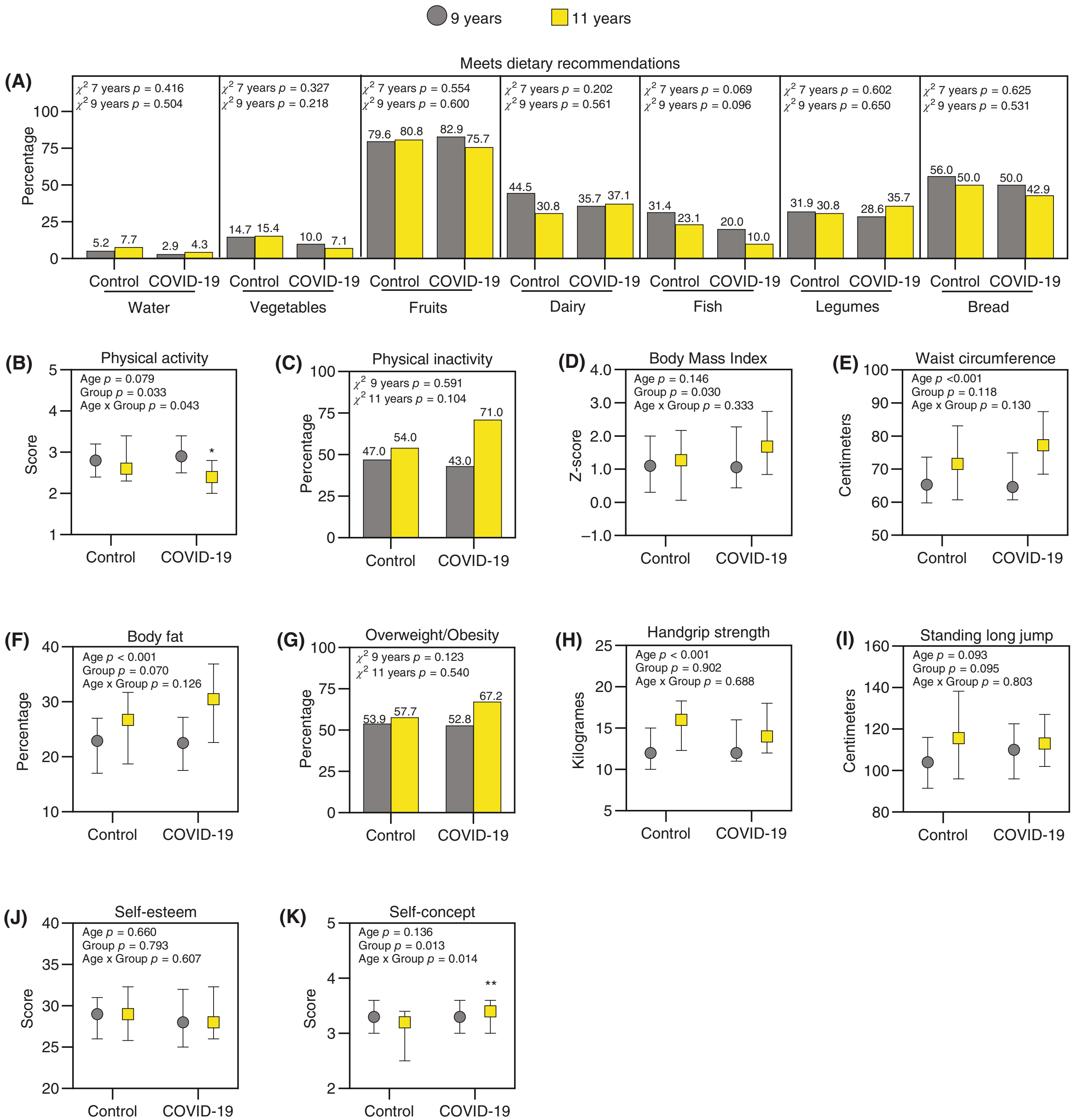


**FIGURE 4** Comparison between children of 9 and 11 years old measured in 2019 (control) versus children measured in 2019 and 2021 (COVID-19). $^*p < 0.05$; $^{**}p < 0.01$ versus control of the same age, Bonferroni post hoc test.

current study, we used the physical activity questionnaire for older children (PAQ-C). This instrument provides a score derived from nine items asking about physical activity at different moments of the day in the last 7 days. We observed that in the 7-to-9 years age range, control and COVID-19 groups had similar prevalence of physical inactivity at 7 years old. Nevertheless, the prevalence of physical inactivity was higher in the COVID-19 versus the control group at 9 years old. The same was observed in the 8-to-10 years age range. These results indicate that the school closure due to the COVID-19 pandemic increased the prevalence of physical inactivity in children. Studies on the effects of not attending school, such as during summer vacations, report similar results.[38] Reduced options to access structured and unstructured activities inside and outside school may explain our findings. The PAQ-C collects information about physical activity during the school period including questions about the physical education class, recess and after-school time in the last 7 days. Although at the time of the measurements in 2021 the schools were open, some restrictions were still in place. These restrictions included reduced time for physical education classes, limited interaction with other children during recess, and limited extracurricular sports activities.[40] Consequently, physical activity outside of school in the form of free play and unstructured activities should have been the main source of movement, as was proposed in another study.[10] Yet these movement opportunities may still be limited if children cannot play with their peers or have access to spaces to play.[13] In contrast to the dietary support provided during the pandemic, existing measures such as online classes were insufficient to maintain children's physical activity. Changes in physical activity did not seem to affect physical fitness components measured in this study (handgrip strength and standing long jump), as we observed the expected increases with age in the COVID-19 group without age × group interactions. Basterfield et al.[16] also reported increases in muscular fitness with age in children during the pandemic, although they did not have a control group to distinguish whether those increases were expected because of the increase in age or were affected by the pandemic.[16]

Adiposity markers, including *Z*-score BMI, waist circumference and body fat, showed larger-than-expected increases in the COVID-19 group with age. This was consistently observed in the transition from 8 to 10 years, which included the largest sample size and thus statistical power among the age groups studied. The other age groups manifested similar trends. Even so, these effects were not strong enough to influence the prevalence of overweight/obesity, which showed no difference between groups at any age. Diverse studies reported increases in overweight/obesity prevalence associated with accelerated rates of BMI change during the pandemic. Pierce et al. (2023) in a longitudinal cohort of more than 200 000 children aged 2–19 years in the United States, examined differences in rates of change in BMI, weight and obesity prevalence among three periods: pre-pandemic (January 2018–February 2020), early pandemic (March–December 2020) and later pandemic (January–November 2021). This study reported a rate of increase in BMI of 0.056 kg/m$^2$ per month in the pre-pandemic period, 0.104 kg/m$^2$ per month in the early stages of the pandemic and 0.035 kg/m$^2$ per month in the later pandemic. These results indicated an accelerated rate of BMI changes early in the pandemic, which was attenuated in 2021.[22] Although some studies report that, despite the rate of increase being attenuated, the values remained higher than pre-pandemic levels.[16,41] It may be that at the date of our measurement (October 2021) the rapid increase in BMI and overweight/obesity prevalence, reported by other studies during the first months of the pandemic, has probably slowed down in the later pandemic.[17] In our current study, the measurements were conducted in October–November 2019 and October–November 2021, without measurements in between. Therefore, our design does not allow us to identify any fluctuations. The prevalence of overweight/obesity in Chilean schoolchildren aged 6–13 years was reported at approximately 54% in 2020.[42] In contrast, our results showed 63%–73% in our COVID-19 groups in the post-pandemic period in 2021. Unfavourable responses to stress including overeating and decreasing physical activity and their effects on weight gain could be more affected by the uncertainty during the first months of the pandemic. A study of adults from the United States indicated that the weight gained during the pandemic from March 2020 to March 2021 was, on average, less than 1.3 kg. The authors discussed that other studies reporting larger increases in body weight were based on convenience samples and relied on self-reported information, potentially leading to over-reporting.[43] In addition to these difficulties in studying weight gain during the pandemic in adults, the effects of normal growth and development must be considered when studying children. In this sense, the weight increase observed after 2 years in the COVID-19 groups might not be that different from the expected increase due to growth and development.

In addition to weight status, body fat is another adiposity marker used in our current study. The body fat observed in the COVID-19 groups in the post-pandemic period in all three age ranges (28%–30%) was higher than what we have previously observed in Chilean schoolchildren of similar age (21%–24%).[44] Changes in body fat and its distribution during the pandemic have been scarcely reported. Unlike body weight and height, body fat is difficult to self-report and thus relies on objective measurements. In the 7–9 age range, the higher-than-expected increase in body fat observed in the COVID-19 group, coincides with a higher-than-expected decrease in physical activity, as reported previously.[45,46] Moursi et al.[47] compared changes in BMI and body fat between one group of children with two measurements before the pandemic and a second group with one measurement before and another measurement during the pandemic. No differences in the changes in BMI or body fat were detected between groups. The authors suggested that this was due to the favourable socio-economic background of their sample, which may have protected the children from weight and fat gain during the pandemic.[47] This would not be the case in our current study, because children were from highly vulnerable schools. Another study reported no differences in body fat measurements in children before and during the pandemic.[48] In such a study, children seemed to be motivated to follow healthy lifestyle habits, particularly physical activity, based on their access to home activities through online applications.

No differences were observed in the changes in self-esteem between COVID-19 and control groups. These findings suggest that school closure did not affect self-esteem in our children. Most studies that reported perturbations of mental health were conducted during the initial months of the pandemic.[19] In a long-term study of adolescents in Japan, Goto et al.[23] showed that mental well-being was more negatively affected during the initial stages of the pandemic (May 2020) but then improved and stabilized by the end of 2021. Therefore, the greatest negative effects may have occurred when the confinement measures were stricter. In our current study, the measurements were conducted in October–November 2019 and October–November 2021, without measurements in between. Therefore, our design does not allow us to identify fluctuations in these psychological variables. Children potentially spent more time at home with their families during the pandemic, which could be a protective factor for mental health. In agreement, we observed that self-concept in the 9-to-11 years age range increased more than expected in the

COVID-19 group. This was explained specifically by the increase in the emotional dimension (i.e., the feeling of well-being and personal satisfaction) of the questionnaire in the COVID-19 group (data not shown).

Our study has two major strengths. First, although the study was not designed to compare changes before and after the pandemic, the initial measurements allowed us to have the required data. Few studies were able to have data just before starting the pandemic and just after school reopening. Second, we considered children who were only measured in 2019 as the control group. These children belonged to the same population and were measured under the same conditions as the COVID-19. This age-matched control group allowed us to determine whether the response in lifestyle behaviours, adiposity markers and health outcomes was different from what would be expected due to growth and development. Among the limitations, it is worth noting that the control group is composed of children who, for different reasons, were unavailable for remeasurement upon school reopening. Whether such a difference influences our outcomes is unknown. Moreover, due to the restrictions implemented in Chile during the pandemic, contacting schools and children was only possible when the schools reopened in 2021. This prevented us from documenting changes during the most critical moments of the pandemic. The changes are therefore the result of the accumulated effect of 2 years. Another limitation is that we did not conduct measurements after 2021. Whether the trends in lifestyles and health outcomes were maintained, worsened or returned to pre-pandemic levels in our sample is therefore unknown. Studies conducted in other countries indicated that physical activity levels remained lower in 2021 but returned to pre-pandemic levels in 2022, 1 year after most countries lifted the restrictions.[49,50] Regarding adiposity markers, studies showed that the increase in BMI observed early in the pandemic persisted for 1 to 2 years, even after restrictions were eased.[16,41] These findings highlight the long-lasting impacts of the pandemic, underscoring the need for public health efforts to address these challenges. A final limitation is that we did not include additional physical fitness outcomes that are also relevant for health, particularly cardiorespiratory fitness.

In conclusion, school closure during the pandemic (and potentially due to whatever reason) worsens the normal physical activity pattern of children and negatively impacts adiposity markers. Notably, by using a time-matched control group, we showed that the negative effects were less pronounced compared with previous reports. Nevertheless, our results suggest that schools have a unique position for promoting healthy lifestyle behaviours that may impact the health and well-being of children.

## AUTHOR CONTRIBUTIONS

*Conceptualization*: M.S.-R., R.F.-V. and D.Q.-S. *Analysis and software*: R.F.-V. and M.S.-R. *Funding acquisition*: T.P. and A.C.P. *Writing—original draft*: M.S.-R. *Writing—review and editing*: R.F.-V., D.Q.-S., T.P. and A.C.P. *Visualization*: M.S.-R. All authors have read and agreed to the published version of the manuscript.

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## CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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