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Deleterious effects of COVID-2019 *Lockdown* on health responses in adolescents with obesity: longitudinal study

Efeitos deletérios do Lockdown frente à COVID-19 sobre respostas à saúde de adolescentes com obesidade: um estudo longitudinal

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ABSTRACT
This longitudinal and observational study investigated the consequences of the coronavirus disease 2019 lockdown on health-related physical fitness and biochemical responses in 16 overweight or obese male adolescents (aged 12.6±1.8 years). The anthropometry, body composition, physical fitness tests, and measures of blood biomarkers (fasting blood glucose, total cholesterol [TC], low-density lipoprotein cholesterol [LDL-c], triglycerides [TG], aspartate aminotransferase [AST], and alanine aminotransferase [ALT]) were evaluated before and after 8 months of lockdown. The results showed increased body weight, fat-free mass, and waist and hip circumference (p<0.05) after 8 months. Maximum isometric handgrip strength and flexibility increased, while muscle endurance decreased (p<0.05). Fasting blood glucose, TC, LDL-c, TG, TG/glucose, AST, ALT, TG/HDL-c, CT/HDL-c, and LDL/HDL increased (p<0.05), while the HDL-c levels decreased significantly (p<0.05). Therefore, eight months of social isolation promoted harmful effects on adolescents' morphological parameters and physical fitness. However, the small sample size prevents the generalization of these findings.

Keywords: Chronic disease indicators. Health promotion. Obesity. Youth, exercise.

RESUMO
Trata-se de um estudo longitudinal e observacional que investigou as consequências do *lockdown* em decorrência do coronavírus em 2020, na aptidão física relacionada à saúde e respostas bioquímicas de 16 adolescentes do sexo masculino com sobrepeso ou obesidade (idade 12,6 ± 1,8 anos). A antropometria, composição corporal, testes de aptidão física e medidas de biomarcadores sanguíneos (glicemia em jejum, colesterol total [CT], colesterol de lipoproteína de baixa densidade [LDL-c], triglicerídeos [TG], aspartato aminotransferase [AST] e alanina aminotransferase [ALT]) foram avaliados antes e após 8 meses de *lockdown*. Os resultados mostraram um aumento do peso corporal, massa livre de gordura e circunferência da cintura e do quadril (*p*<0,05) após 8 meses. A força isométrica máxima de preensão manual e a flexibilidade aumentaram, enquanto a resistência muscular diminuiu (*p*<0,05). A glicemia em jejum, CT, LDL-c, TG, TG/glicose, AST, ALT, TG/HDL-c, CT/HDL-c e LDL/HDL aumentaram (p<0,05), ao passo que os níveis de HDL-c diminuíram significativamente (p<0,05). Portanto, 8 meses de isolamento social promoveram efeitos deletérios sobre parâmetros morfológicos e aptidão física em adolescentes. No entanto, o pequeno tamanho da amostra impede a generalização desses achados.

Palavras-chave: Indicadores de doença crônica. Promoção à saúde. Obesidade. Juventude, exercício.

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INTRODUCTION

Coronavirus infection led to coronavirus disease 2019 (COVID-19) which triggered highly contagious respiratory infections mainly transmitted through respiratory droplets and close contact[1]. This virus is easily spread, with transmission possible by asymptomatic infected individuals[1]. Therefore, the potential of overloading their public and private health systems and minimizing the unavailability of hospital beds for all patients were concerns in many countries, including Brazil, where COVID-19 was first detected on February 26, 2020 [2]. Thus, to curb the spread of the virus, social distancing was implemented[1], and several states decreed social isolation. COVID-19 caused the death of more than 727 children and adolescents in the United States of America until January 19, 2022[3]. Studies have shown that obesity and other comorbidities contribute to the risk of severe symptoms[4].

Most of the population's daily tasks were compromised during the lockdown, and eating habits were drastically modified. Likewise, sedentary behavior increased significantly, with increased time sitting, lying down, watching television, playing video games, and using cell phones[5]. Considering that the lockdown reduced the level of physical activity (PA) and promoted changes in the population's daily living, its impact on physical, physiological, nutritional, and metabolic factors could have harmful effects on the health status of individuals, particularly those who are obese.

Among the population groups affected by restrictive measures, the daily habits of children and adolescents were significantly affected[6]. As COVID-19 is a new disease, the effects of lockdown on adolescents' anthropometric, biochemical, and physical responses require evaluation. During the most limited period of lockdown, some adolescents at risk (i.e., those with a sedentary lifestyle, poor diet, overweight or obesity, or with other chronic diseases) became "invisible" due to reduced diagnosis, prevention routines, and treatment due to a scarcity of resources or fear of infections combined with the decrees at municipal and state levels that restricted people from practicing structured and unstructured PA[7]. There remains a lack of evidence on the effects of the lockdown and its consequences on health and PA, specifically in adolescents.

Furthermore, understanding the biological changes caused by the lockdown in adolescents with obesity is essential for directing public policies. Therefore, the present study aimed to verify the consequences of 8 months of COVID-19 confinement on health-related physical fitness and biochemical responses of overweight or obese adolescents. Based on the evidence discussed above, the study hypothesis was that the most restrictive period of confinement worsened morphological parameters, physical fitness, and metabolic biomarkers, as obese adolescents experienced significant changes in their routines that affected their daily lives.

METHODOLOGY

EXPERIMENTAL DESIGN

This longitudinal and observational study that followed the guidelines of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement[8]. This study is part of an extension project at UniCesumar University performed between 2017–2021,[9–11] by the Interdisciplinary Laboratory of Intervention in Health Promotion. Therefore, one study step was carried out before the lockdown in Brazil. Another step was performed after 8 months to observe the effects of the COVID-19 lockdown on health-related physical fitness and metabolic biomarkers in overweight or obese adolescents. The first stage of the study was conducted one week before implementing of the municipal, state, and federal decrees, which established the COVID-19 lockdown in March 2020. The assessments and reassessments were carried out in 3 days, following the same methodology: the same time for data collection, the exact processes for conducting the measurements, and the same researchers who performed the sizes of our research group[9–11]. On the first day, the participants underwent a medical screening with a complete anamnesis, release for blood collection, and completed the International PA Questionnaire (IPAQ) validated for adolescents[12]. On the second day, blood samples were collected after 12 h of fasting, body composition assessment was performed, and the anthropometric data of the adolescents were recorded. On the last day, the following physical fitness tests were performed: ***(i)*** maximum isometric handgrip strength, ***(ii)*** maximum isometric lumbar traction strength, ***(iii)*** dynamic abdominal resistance in 60 s, ***(iv)*** isometric plank, ***(v)*** flexibility in the Wells bench, and ***(vi)*** cardiorespiratory fitness via the Léger and Lambert test[13], with 48 h of rest between them. After 8 months (in November), the tests were repeated, following the same protocol.

PARTICIPANTS

Thirty Brazilian male adolescents living in Maringá-PR were recruited using the following inclusion criteria: ***(i)*** age 10–19 years; ***(ii)*** overweight or obese according to the criteria established by Cole and Lobstein[14] and ***(iii)*** assessments performed before the COVID-19 lockdown and after 8 months. The exclusion criteria were: ***(i)*** adolescents who were underweight or normal weight or with a restrictive diet, ***(ii)*** use of drugs to control appetite, and ***(iii)*** no participation in the final assessments. Moreover, 13 adolescents dropped out of the reassessment. Therefore, the final analysis included 16 adolescents. No physical, nutritional, or psychological interventions were implemented during the COVID-19 lockdown. The adolescents were recommended to follow their routines within the limitations imposed by the COVID-19 lockdown. This study was approved by the Ethics and Local Research Committee (approval number: 3.837.408/2020). The adolescents were asked to complete the consent form, and their parents or guardians were asked to sign a free and informed consent form. This research project followed resolution 466/2012 of the Ministry of Health of Brazil.

MEDICAL APPOINTMENTS

A medical team consulted with the participants, following the standard anamnesis model, to identify the clinical history and possible use of controlled or uncontrolled medications and pulmonary and cardiac auscultation in the adolescents.

MEASURING PHYSICAL ACTIVITY (PA)

The IPAQ is a questionnaire adapted for adolescents seeking to measure their level of PA[12]. The IPAQ consists of questions that assess the weekly time spent in PAs of moderate and vigorous intensity at different times of the day and the time spent in passive activities performed in the sitting position. From the answers, it was possible to quantify adolescents' PA level before the COVID-19 lockdown and after eight months.

BIOCHEMICAL MEASUREMENTS

Blood samples were collected in the morning after fasting for 12 hours, according to the recommendations of the Brazilian Society of Clinical Pathology/Laboratory Medicine[15]. The samples were drawn in vacuum collection tubes (Vacuplast®) containing stacking gel for lipid and liver profile analysis or sodium fluoride for fasting blood glucose analysis and centrifuged at 3,000 rpm for 15 min at room temperature to obtain serum. The studies were performed in triplicate, with the average of the three values used for analysis. An MHLab URIT 8021® automatic biochemical and turbidimetric analyzer was used to measure the following biochemical parameters: aspartate aminotransferase (AST), alanine aminotransferase (ALT), gamma-glutamyl transferase (gamma GT), alkaline phosphatase (ALP), fasting glucose, triglycerides (TG), total cholesterol (TC), high-density lipoprotein cholesterol (HDL-c), and low-density lipoprotein cholesterol (LDL-c). Gold Analyze Diagnostic kits (Belo Horizonte, Minas Gerais, Brazil) to perform the blood tests. The analyses complied with the standards specified by the kits manufacturers. The LDL-c values were estimated using the Friedewald formula (LDL-c = TC – HDL-c + TG/5). For TG values >400 mg/dL, the Martins formula or non-HDL cholesterol was used (LDL-c = TC – HDL-c – TG/x, with x ranging from 3.1 to 11.9 [16]. Additionally, the following indices were calculated: the ratio of triglycerides to fasting glucose (TyG index), TG/HDL-c, TC/HDL-c, and LDL/HDL.

MORPHOLOGICAL PARAMETER ASSESSMENTS

Body composition assessment: An electrical bioimpedance analysis (BIA) (InBody, model 570®, BioSpace, Seoul, South Korea) with multiple tactile points was used to assess body composition.

The participants were informed about the technical procedures to perform the measurement, which included: ***(i)*** 12-hour fasting; ***(ii)*** no PA in the 24 hours preceding the test; ***(iii)*** urinating and evacuating before testing; ***(iv)*** removal of metals such as earrings, bracelets, and rings to perform the test. The following measurements were obtained using BIA: body weight, body mass index (BMI), total body water (L), lean mass (%), fat-free mass (kg), musculoskeletal mass (kg), fat mass (kg), visceral fat level, and basal metabolic rate (kcal).

ANTHROPOMETRY

A mobile stadiometer with an accuracy of 0.1 cm (Welmy®, W200, Santa Bárbara do Oeste, São Paulo, Brazil) was used to measure height. Waist, hip, relaxed right arm, and neck circumference were measured using measuring tape with an accuracy of 0.1 cm, as described by Heyward[17].

PHYSICAL TESTS

Before performing the physical fitness tests, the participants were familiarized with the following tests: ***(i)*** maximum isometric handgrip strength, ***(ii)*** maximum isometric lumbar traction strength, ***(iii)*** strength-endurance abdominal test for 60 seconds, ***(iv)*** isometric plank, ***(v)*** flexibility in the Wells bench, and ***(vi)*** cardiorespiratory fitness via the Léger and Lambert test[13].

ISOMETRIC HANDGRIP STRENGTH

A dynamometer (Jamar®, Asimow Engineer, Los Angeles, CA, United States) was used to measure the handgrip strength. The participants performed a maximum voluntary contraction on the handgrip dynamometer for 3–5 s, with the arm extended and standing that, performed with both hands (right and left hands). Three measurements were performed for each hand with an interval of 60 s between them. The highest value was used for the analyses[9].

MAXIMUM ISOMETRIC LUMBAR TRACTION STRENGTH

A dynamometer (Kratos®; Industrial Equipment, model DS, São Paulo, Brazil) was used to measure the maximum isometric lumbar traction strength. The participants were instructed to place their feet on the dynamometer, keeping their knees extended and the trunk flexed to approximately 120 with the neck and head aligned with the trunk. The adolescents held the bar of the device in front of their patellar bone. Three measurements were performed with a rest of 60 s between sets, with a maximum voluntary contraction between 3 and 5 s. The highest value of the measurements was used for the analyses[9].

THE STRENGTH-ENDURANCE ABDOMINAL 60-SECOND TEST

The strength and endurance of the abdominal muscles were assessed as described by Plowman and Meredith[18].

FLEXIBILITY TEST (SIT AND REACH)

The chair sit-and-reach test was used to assess lower-body flexibility. The test was conducted as described by Plowman and Meredith[18].

CARDIORESPIRATORY FITNESS

Cardiorespiratory fitness (VO_2max) was measured using the Léger and Lambert test[13], consisting of an interval run in 21-speed stages, starting at 8.5 km/h and increments of 0.5 km/h per stage. VO_2max was calculated using the equation $VO_2max = 31.025 + (3.288*X) - (3.248*A) + (0.1536*A*X)$, where X is the speed in each stage, and A is the age in years.

STATISTICAL ANALYSIS

Data were tabulated in Excel (version 2013, Microsoft, USA). The tables were prepared with the pre-and post-assessment variables, expressed as means and (±) standard deviation, Cohen's d, and relative and absolute deltas. The pre-and post-assessment moments were compared using Student's t-test for paired samples, assuming a significance level of 5%. Cohen's classification[19] was used to calculate the effect sizes as follows: <0.20 (*trivial effect*) 0.20 <0.5 (*small effect*), >0.50 to <0.8 (*moderate effect*) and > 0.8 (*large effect*). Statistical analyses were conducted using IBM SPSS Statistics for Windows, version 22.0 (IBM Corp., USA).

RESULTS

The IPAQ responses reported by adolescents did not differ significantly before and after eight months (p>0.05). Table 1 shows the morphological variables of the adolescents evaluated before and after eight months (n = 16).

Table 1. Morphological variables of the adolescents participating in the present study

Variables	**Before**	**After eight months**	**Cohen's *d***	**Δ relative values**	**Δ absolute values**
Age (years old)	12.6 ± 1.8	**13.3 ± 1.9***	0.38 *(small)*	0.7	5.4%
Body weight (kg)	83.9 ± 21.2	**90.3 ± 23.3***	0.29 *(small)*	6.4	2.5%
Height (cm)	162.3 ± 10.3	**166.3 ± 9.8***	0.40 *(small)*	4.0	2.5%
BMI (kg/m²)	31.7 ± 6.2	32.5 ± 6.8	0.13 *(trivial)*	0.8	2.6%
Total body water (L)	34.7 ± 6.7	38.8 ± 8.6	0.57*(moderate)*	4.0	11.7%
Lean mass (%)	44.6 ± 8.6	45.65 ± 10.4	0.11 *(trivial)*	1.1	2.5%
Fat-free mass (kg)	47.4 ± 9.1	**49.7 ± 9.3***	0.25 *(small)*	2.3	4.8%
Musculoskeletal mass (kg)	25.9 ± 5.4	27.3 ± 5.5	0.26 *(small)*	1.4	5.6%
Fat mass (kg)	36.6 ± 14.9	40.7 ± 16.96	0.25 *(small)*	4.1	11.2%
Body fat percentage (%)	42.0 ± 11.0	43.3 ± 11.6	0.12 *(trivial)*	1.3	3.1%
Visceral fat level (L)	16.2 ± 5.4	16.8 ± 5.64	0.11 *(trivial)*	0.6	3.9%
Waist circumference (cm)	92.7 ± 13.5	**95.3 ± 15.2***	0.18 *(trivial)*	2.6	2.8%
Hip circumference (cm)	110.8 ± 13.7	**114.0 ± 13.9***	0.23 *(small)*	3.2	2.9%
Arm circumference (cm)	33.7 ± 5.8	36.0 ± 3.6	0.48 *(small)*	2.3	6.8%
Neck circumference (cm)	34.9 ± 2.6	35.7 ± 5.1	0.20 *(small)*	0.8	2.2%
Resting metabolic rate (kcal)	1773.9 ± 676.4	1854.6 ± 505.0	0.14 *(small)*	80.7	4.5%

Note: Data are expressed as mean and standard deviation; BMI = Body mass index **Δ** = *absolute delta and relative delta values;* * = p<0.05.

After eight months, the participant's age, body weight, height, fat-free mass, waist circumference, and hip circumference had increased significantly ($p<0.05$). However, BMI, total body water, lean mass, musculoskeletal mass, fat mass, visceral fat level, arm circumference, neck circumference, and resting metabolic rate did not differ significantly ($p>0.05$). Although the differences were not statistically significant, the percentage variations for MBI, fat mass, body fat percentage, and arm circumference were 2.6%, 11.2%, 3.9%, and 6.8%, respectively, all of which were related to obesity risk and associated comorbidities. Table 2 shows the results of the physical tests of the adolescents evaluated before and after 8 months.

Table 2. Physical fitness responses of the adolescents participating in the present study

Variables	Before	After eight months	Cohen's *d*	Δ absolute	Δ relative
Maximum isometric handgrip strength (right hand) (kgf)	25.3 ± 4.7	**28.5 ± 6.4***	0.57 *(moderate)*	3.1	12.4%
Maximum isometric handgrip strength (left hand) (kgf)	24.2 ± 4.5	**27.5 ± 6.2***	0.61 *(moderate)*	3.2	13.4%
Maximum isometric lumbar traction strength (kgf)	68.9 ± 20.5	71.4 ± 18.6	0.13 *(trivial)*	2.6	3.7%
Plank torso (s)	52.1 ± 36.9	**32.3 ± 27.6***	-0.61 *(moderate)*	-19.8	-37.9%
Abdominals (60s)	41.6 ± 10.4	**31.2 ± 9.4***	-1.05 *(large)*	-10.4	-25.0%
Back-saver sit and reach right side (cm)	23.7 ± 7.8	**29.1 ± 9.0***	0.64 *(moderate)*	5.4	22.8%
Back-saver sit and reach left side (cm)	23.0 ± 7.6	**26.9 ± 9.0***	0.47 *(small)*	3.9	16.8%
VO_2max ($mL.kg^{-1}.min^{-1}$)	18.6 ± 6.9	18.6 ± 3.1	0.01 *(trivial)*	-0.1	-0.4%

Note: data are expressed as mean and standard deviation; VO_2max = cardiorespiratory fitness; Δ = absolute delta and relative delta values; * = $p<0.05$

Significant increases were observed for the maximum isometric strength of right and left handgrip, back-saver sit and reach to the right side, and back-saver sit and reach to the left side ($p<0.05$). In contrast, significant reductions were observed for the abdominals in the 60 s and plank torso after the lockdown ($p<0.05$). However, no significant differences were observed in the maximum isometric strength of the lumbar traction and VO_2max ($p>0.05$). Table 3 shows the results of the biochemical tests of the adolescents evaluated before and after 8 months.

Table 3. Biochemical responses of the adolescents participating in the present study

Variables	Before	After eight months	Cohen's *d*	Δ absolute	Δ relative
Fasting glucose (mg/dL)	87.5 ± 5.3	**93.0 ± 10.1***	0.70 (*moderate)*	5.4	6.2%
Total cholesterol (mg/dL)	149.6 ± 26.3	**179.4 ± 17.7***	1.3 *(large)*	29.8	19.9%
LDL-c (mg/dL)	136.2 ± 27.9	**175.1 ± 21.4***	0.20 *(small)*	38.9	28.5%
HDL-c (mg/dL)	28.2 ± 7.4	**24.0 ± 5.1***	0.70 (*moderate)*	-4.1	-14.7%
Triglycerides (mg/dL)	74.0 ± 21.9	**98.6 ± 39.3***	0.80 *(large)*	24.6	33.3%
TyG index (mg/dL)	8.0 ± 0.3	**8.3 ± 0.5***	0.70 (*moderate)*	0.32	3.9%
Alkaline phosphatase (U/L)	207.3 ± 60.8	184.8 ± 72.1	0.30 *(small)*	-22.5	-10.9%
Gama GT (U/L)	32.6 ± 33.0	38.9 ± 12.8	0.30 *(small)*	6.3	19.2%
ALT (U/L)	21.6 ± 5.48	**25.1 ± 4.7***	0.70 (*moderate)*	3.4	15.9%
AST (U/L)	22.4 ± 5.1	**26.1 ± 5.7***	0.70 (*moderate*)	3.7	16.5%
TG/HDL-c	2.8 ± 1.1	**4.2 ± 1.9***	0.90 *(large)*	1.4	52.1%
Total cholesterol/HDL-c	5.6 ± 1.8	**7.7 ± 1.6***	1.2 *(large)*	2.1	36.9%
LDL/HDL	5.2 ± 1.9	**7.6 ± 1.8***	1.3 *(large)*	2.4	45.6%

Note: data are expressed as mean and standard deviation; **Δ** = *absolute delta na relative delta values;* * = $p<0.05$; LDL-c = low density lipoprotein; HDL-c = high density lipoprotein; TyG index = fasting triglyceride/glucose ratio; Gama GT = gamma glutamyl transferase; ALT = alanine aminotransferase; AST = aspartate aminotransferase; TG/HDL-c = triglycerides and high-density lipoproteins ration; Total cholesterol/HDL-c = total cholesterol and high-density ratio; LDL/HDL = low-density and high-density lipoproteins ratio.

Significant increases were observed in fasting glucose, TC, LDL-c, triglycerides, TyG index, ALT, AST, TG/HDL-c, TC/HDL-c, and LDL/HDL ($p<0.05$). The HDL-C levels decreased after the COVID-19 lockdown ($p<0.05$). However, FA and gamma GT did not differ significantly after the lockdown ($p>0.05$). The effect sizes for fasting glucose, CT, HDL-c, TG, TyG index, ALT, AST, TG/HDL-c, CT/HDL-c, and LDL/HDL ranged from "moderate" to "large". Factors associated with relative and absolute deltas indicate significant changes in biochemical variables after eight months of COVID-19 lockdown.

DISCUSSION

The results of the present study showed that, after eight months of COVID-19 lockdown, ***(i)*** fat-free mass increased significantly; ***(ii)*** waist and hip circumference increased significantly; ***(iii)*** maximum isometric handgrip strength of the right and left hands increased; ***(iv)*** isometric strength resistance via the torso plank decreased; ***(v)*** back chain flexibility increased significantly; ***(vi)*** fasting glucose level increased significantly; ***(vii)*** TG level increased significantly; ***(viii)*** TyG index increased significantly; ***(ix)*** TC and fractions differed significantly (increased LDL-c and decreased HDL-c); ***(x)*** ALT and AST levels increased, and ***(xi)*** TG/HDL-c, TC/HDL, and LDL/HDL indicators increased. Although the differences in fat mass were insignificant, the Cohen's *d* showed a small effect for fat mass. Similarly, neck and arm circumferences showed a positive impact (increase) after eight months of COVID-19 lockdown.

The increases in fat-free mass, body weight, and height likely occurred because the study was carried out over eight months in a target audience aged between 12 and 17 years, during a potential growth spurt phase[20]. The observed increases in the waist and hip circumference and the fat-free mass were also most likely related to the spurt period as the adolescents always showed a fat gain. Although the BMI did not differ significantly, the average BMI value was already very high in the pre-participation measurement, with values ranging from 31.7 kg/m² to 32.5 kg/m² in the post-participation period. Although this difference was insignificant, the BMI increased an average of 2.6% over eight months. Moreover, the fat mass and body fat percentage also showed considerable gains, with relative increases of 11.2% and 3.1%, respectively. Therefore, the morphological assessments inferred that physical health worsened during this period. Furthermore, despite the lack of significant increase during the study period, even before the COVID-19 pandemic, the neck circumference was already high, with mean values of 35.7 cm during the period of social isolation, indicating an increased risk for the development of cardiovascular diseases (≥34.8 cm)[21].

After eight months, the maximum isometric handgrip strength increased. Figueiredo et al.[22] reported that adolescents at a more advanced stage of development generally show better strength, power, and speed than younger teens. Thus, these findings were not unexpected due to the time difference between the two measurements. In contrast, muscle resistance decreased, and flexibility increased. As the adolescents did not perform any structured PA, a reduction in muscle resistance was expected. In contrast, flexibility increased significantly during the re-evaluation period. Since the present study was observational, individual differences may be related to increased viscoelastic muscle relaxation[23].

Regular PA positively affects glycemic control since insulin-dependent pathways are activated; thus, GLUT-4 increases glucose transport into the muscle[24]. Therefore, the insulin threshold needed to start the pathway decreases, and less insulin is required to activate GLUT-4 [24]. The increase in fasting blood glucose level occurred is due to changes in PA (social isolation: less structured and unstructured PA in daily living) as well as possible changes in the eating habits of adolescents, with increased consumption of high glycemic index carbohydrates, which are also associated with increased risks of cardiovascular diseases and type 2 diabetes mellitus[25], although a qualitative and quantitative analysis of food intake was not performed. Even if blood glucose levels were below the cut-off point for type 2 diabetes mellitus, the group increased by 6.2% during this period, which is a reason for attention, considering that adolescents were at risk. Hence, adolescents should begin practicing PA regularly and increase their consumption of healthy foods, regarding the association of high glycemic levels with cardiovascular diseases[26].

The observed significant increase in TG levels is related to an increased risk of metabolic syndrome and consequently, increased cardiometabolic risk[27]. Furthermore, the significant increases in TC and its fractions (reduced HDL-c and increased LDL-c levels) were characteristics of dyslipidemia. Additionally, the TyG index and an instrument used to check insulin resistance (IR), prehypertension, and hypertension increased significantly[27]. Simental-Mendía et al.[27] related this index to adolescents with pre-systemic arterial hypertension; thus, the participants in the present study were at risk for the future development of two chronic diseases. Moreover, Vieira-Ribeiro et al.[28] reported an increased risk of developing IR in children with values of 7.88 mg/dL for the TyG index. Thus, the values observed in the adolescents in this study after eight months of COVID-19 lockdown (~8.30 mg/dL) were a suggestive factor for IR.

After eight months of social isolation, the levels of liver enzymes, ALT, and AST significantly increased. The reference values for these enzymes were <40 U/L. However, although the values are below the cut-off point proposed for adolescents for diagnosing non-alcoholic hepatic steatosis, dietary changes are suggested to reduce the consumption of processed and ultra-processed foods, as the risk of chance for non-alcoholic fatty liver disease tends to increase. Notably, increased AST and ALT levels are also associated with IR[29]. The TG/HDL-c, LDL-c/HDL-c, and TC/HDL-c markers were used to assess the risk of other metabolic diseases[30]. Increases in these markers, as mentioned above, indicate higher cardiometabolic risk and early development of atherosclerosis[26,30]. The change in the TC/HDL-c ratio values also suggests a risk for the development of cardiovascular diseases[26], while the cut-off value is 3.8; the reassessments in the adolescents showed a value of 7.7 ± 1.6, an increase of 36.9%. The significant harmful effects on the physical and metabolic health of the adolescents who participated in the present study underscore the essential need for public policies to encourage safe PA, nutritional re-education, and behavioral changes to restore the population's health.

One potential limitation of the present study was the absence of a control group. However, during the COVID-19 pandemic, it was impossible to organize a control group; furthermore, it was not possible to control for the growth phase of the adolescents participating in the present study. The strengths of this study are related to the development of public and private policies to promote activities aiming to maintain the positive health status of adolescents. In addition, developing health technologies to improve PA and healthy nutrition is indispensable for all age groups, considering traffic in big cities, reducing treatment costs, and improving the number of people who need specialized services.

FINAL CONSIDERATIONS

Eight months after the COVID-19 lockdown, its harmful effects on the morphological parameters, physical fitness, and cardiometabolic risk of obese adolescents were verified. Public policies for health promotion focused on PA promotion, food re-education, and behavioral changes are essential and critical to overcome these adverse effects. However, these findings cannot be generalized owing to the small sample size of the present study (*n* = 16 adolescents who performed pre- and post-assessments).

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