

Assessment of hemodynamic changes in high school students following COVID-19 infection: a cross-sectional study

Abstract

Objective: To assess hemodynamic changes in high school students during the McArdle step test following COVID-19 infection.

Methods: This cross-sectional study involved high school students aged 14 to 17 years, divided into two groups: those previously infected with COVID-19 (CV-19) and a control group (CG). Systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR), and oxygen saturation (SaO₂) were monitored. Participants also performed a stair-climbing test, consisting of climbing and descending stairs for 3 minutes.

Results: Twenty-four volunteers participated—12 in the CV-19 group (mean age 17.0 ± 0.0 years) and 12 in the CG group (mean age 16.5 ± 0.7 years). Regarding the measured variables, resting HR (CV-19 vs. CG) was 67.5 ± 3.5 vs. 72.5 ± 0.7 bpm ($p = 0.548$); post-test HR was 93 ± 19.7 vs. 115 ± 16.9 bpm ($p = 0.229$). Baseline SBP was 102 ± 9.8 vs. 122 ± 16.9 mmHg ($p = 0.570$); post-test SBP was 123 ± 14.1 vs. 138 ± 21.2 mmHg ($p = 0.092$). Baseline DBP was 58 ± 0.0 vs. 71 ± 16.5 mmHg ($p = 0.417$); post-test DBP was 69 ± 2.8 vs. 76 ± 13.8 mmHg ($p = 0.429$). Baseline SaO₂ was 94.5 ± 3.5% in both groups ($p = 0.859$); post-test SaO₂ was 96 ± 1.4 vs. 96.5 ± 0.7% ($p = 0.889$).

Conclusion: Although the results of this pilot study suggest that COVID-19 infection did not significantly affect blood pressure, heart rate, or oxygen saturation responses in high school students, it is important to note that the small sample size (12 participants per group) limits the statistical power of the analysis. Therefore, the findings should be interpreted with caution, and studies with larger sample sizes are needed to confirm these results.

Keywords: Adolescents, blood pressure, heart rate, COVID-19, physical fitness

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Introduction

Coronavirus disease 2019 (COVID-19) originated in Wuhan, China, and belongs to a family of viruses that cause respiratory infections with a broad clinical spectrum, typically characterized by respiratory symptoms, fever, cough, and fatigue. Both symptomatic and asymptomatic presentations are possible, with a wide range of severity.¹ COVID-19 may result in systemic complications, including increased heart rate (HR), hypoxemia, and reduced oxygen saturation, which compromise cardiopulmonary function.² In addition to respiratory impairment, cardiac involvement has been observed. During the acute phase of the infection, elevations in blood pressure (BP) may occur due to increased levels of high-sensitivity cardiac troponin I. Viral invasion of cardiac tissues can lead to heart rate alterations and impaired oxygen delivery to peripheral tissues.³

Impairment of respiratory muscles contributes to decreased functional capacity, limiting the performance of daily activities. Activities commonly affected include stair climbing, pushing objects, and reaching overhead.¹ Physical activity levels declined during the COVID-19 pandemic due to social distancing measures.⁴ Children and adolescents who were out of school became less physically active, experienced increased screen time, sleep disturbances, and dietary changes, leading to weight gain and reduced cardiorespiratory fitness. Consequently, the health effects of the pandemic were particularly pronounced in adolescents.⁵

Engaging in physical activity during adolescence is associated with multiple health benefits, including improved mobility, blood pressure

regulation, weight control, and prevention of chronic diseases.⁶ The prevalence of overweight and obesity among children and adolescents has increased substantially in recent decades.⁷ Adolescence is a critical period marked by physical and emotional changes and the development of autonomy, playing a key role in the formation of long-term health behaviors.⁸ Increased BP during adolescence is rarely isolated and is often linked to risk factors such as high salt intake, low physical activity, and, most significantly, overweight and obesity.⁹ Childhood obesity is strongly associated with adult obesity and is a major risk factor for type 2 diabetes, hypertension, and vascular abnormalities that predispose individuals to atherosclerosis later in life.¹⁰

The incidence of arterial hypertension has risen across all age groups and geographic regions, including among children and adolescents. It often persists into adulthood, increasing the long-term risk of cardiovascular disease.¹¹ Early detection of cardiovascular alterations and autonomic dysfunction can be achieved using simple measures such as resting heart rate (RHR). Sedentary adolescents with abdominal obesity typically exhibit reduced heart rate variability and increased sympathetic activity, resulting in elevated RHR and a higher lifetime risk of cardiac complications.¹²

Maximal oxygen consumption (VO₂max) represents an individual's peak aerobic capacity during exercise and is a key indicator of cardiovascular and respiratory fitness. It is primarily determined by genetics, muscle mass, age, sex, and body weight.¹³ By definition, VO₂max is the maximum amount of oxygen that can be consumed, transported, and utilized by the body's tissues during high-intensity exercise.¹⁴ Several methods exist to assess cardiorespiratory

fitness and physiological responses. The McArdle step test is a simple, cost-effective, and practical tool, consisting of stepping up and down a platform for three minutes.¹⁵ Given these considerations, the present study aimed to evaluate hemodynamic responses in high school students from São João dos Patos, Maranhão, Brazil, during the McArdle step test following COVID-19 infection.

Material and methods

Experimental design

This was a cross-sectional, quantitative study conducted among high school students of both sexes, aged between 14 and 17 years. Participants were divided into two groups: the COVID-19 group (CV-19), consisting of individuals who had previously been infected with COVID-19, and the control group (CG), comprising individuals without a history of infection.

Volunteers were selected based on the following criteria:

- I. **Inclusion criteria:** enrollment in the participating school, both sexes, and absence of comorbidities that could interfere with study procedures.
- II. **Exclusion criteria:** use of medications affecting the central or cardiovascular systems, pregnancy, or the presence of physical or mental impairments.

A total of 24 students agreed to participate. The sample was selected using a non-probabilistic, convenience sampling method.

Ethical considerations

Participants were selected randomly, and all volunteers received detailed information about the study’s procedures, along with an Informed Assent Form and an Informed Consent Form. Legal guardians of the students also signed a school authorization declaration. The study was approved by the Institutional Research Ethics Committee under approval number 6, 269, 336.

Blood pressure and heart rate measurement

Systolic and diastolic blood pressure (SBP and DBP) and heart rate (HR) were measured using a professional-grade arm blood pressure monitor (model HBP-1100, OMRON, USA), utilizing the oscillometric method, validated by the British Hypertension Society and the European Society of Hypertension.¹⁶ Measurements were taken at baseline and immediately after completion of the step test. Recovery assessments were conducted with the participant seated, feet flat on the floor, and arm supported at heart level, following the guidelines of the VIII Brazilian Guidelines on Arterial Hypertension.¹⁷

Oxygen saturation

Oxygen saturation (SaO₂) was evaluated using a portable pulse oximeter (model AS-302-L, Medclín). Measurements were taken at two time points: at rest (baseline) and immediately after the 3-minute step test (post-test), to identify possible differences between the CV-19 and control groups.

McArdle step test

Cardiorespiratory fitness was assessed using the McArdle step test. A wooden step (height: 40.6 cm; length and width: 40 cm) was used. Participants were instructed to step up and down continuously for 3 minutes. A metronome application installed on a smartphone was used to standardize the cadence through an audio track until the test was completed.¹⁵

Body composition

Body mass index (BMI) was calculated using the standard formula: weight (kg) divided by height squared (m²).¹⁸ Weight was measured with a digital scale (Omron, accuracy 0.1 kg), and height with a portable stadiometer (Avanutri, accuracy 0.1 cm). Data were classified into categories representing healthy or health-risk zones. Waist circumference was measured with an anthropometric tape (Avanutri, precision 1 mm), positioned midway between the lower edge of the last rib and the top of the iliac crest, in accordance with the PROESP-Br manual for fitness testing in children and adolescents.¹⁸ Body fat percentage was estimated using a two-site skinfold measurement protocol (subscapular and triceps), appropriate for children and adolescents aged 7 to 18 years. Three measurements were taken at each site using a scientific skinfold caliper (Avanutri).

Statistical analysis

Data normality was assessed using the Shapiro-Wilk test. Descriptive statistics are presented as mean ± standard deviation. Between-group and within-group comparisons were performed using the independent samples t-test, while non-parametric variables were analyzed using the Mann-Whitney U test. Pearson’s correlation was used to determine associations between variables. A significance level of 5% (p < 0.05) was adopted. Data were analyzed using **Jamovi** software version 2.3.21.

Results

Twelve adolescents with a history of COVID-19 who met the inclusion and exclusion criteria, along with 12 healthy controls (recruited from the research database), were included in the study. All participants underwent a series of hemodynamic and anthropometric assessments, including weight, height, body mass index (BMI), waist circumference (WC), waist-to-height ratio (WHtR), and body fat percentage (%FM). Descriptive data and classifications are presented in Table 1.

Table 1 Descriptive statistics for age, anthropometric measures, and classification variables (mean ± SD)

Variables	CV-19 (n=12)	CG (n=12)
Age (years)	17±0.0	16.5±0.7
Weight (kg)	51.8±6.7	71.6±17.1
Height (m)	1.66±0.1	1.66±0
MBI (kg/m²)	19.8±2.4	21.3±0.7
WC (cm)	55±11.3	74±16.9
WHtR (cm)	0.32±4.5	0.44±9.4
FM (%)	19.3±2.5	19.8±3.5
Fat mass classification		
Normal	10	11
Above average	2	0
High	0	1
BMI classification		
Health zone	12	11
Health risk zone	-	1

Notes: BMI: body mass index; WC: waist circumference; WHtR: waist-to-height ratio; %FM: fat mass percentage; kg: kilograms; m: meters; cm: centimeters.

There were no statistically significant differences between groups for any of the anthropometric variables analyzed. Most participants were classified within the healthy range for both %FM and BMI, with no individuals in the low or poor classification categories. Only one control participant fell into the health risk zone for BMI.

Cardiovascular and hemodynamic parameters

Figure 1 presents the basal and post-test heart rate (HR) values. Although the CV-19 group demonstrated lower mean HR at rest and post-test compared to the CG group (25.5 ± 23.3 vs. 42.5 ± 16.2), no statistically significant difference was observed between the groups. However, there was a significant increase in HR from rest to post-test within both groups ($p < 0.05$).

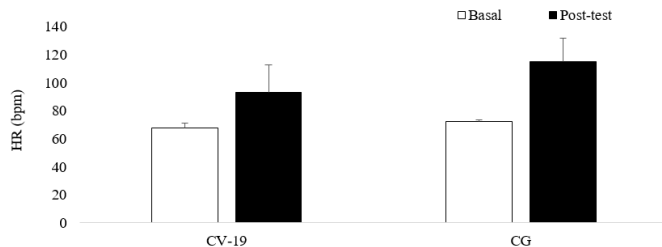


Figure 1 Heart rate (HR) in beats per minute (bpm) at rest and post-test.

Figure 2 illustrates systolic blood pressure (SBP) responses. At baseline, SBP was 102 ± 9.8 mmHg in the CV-19 group and 122 ± 16.9 mmHg in the CG group ($p = 0.570$). Post-test values were 123 ± 14.1 mmHg and 138 ± 21.2 mmHg, respectively ($p = 0.092$). Although intergroup differences were not statistically significant, both groups exhibited significant increases in SBP from baseline to post-test (CV-19: $p < 0.001$; CG: $p < 0.001$). The mean SBP increase was 21 ± 24 mmHg for the CV-19 group and 16 ± 4.2 mmHg for the CG. Pearson's correlation between basal SBP and BMI showed a weak, positive association ($r = 0.118$, $p = 0.582$), limiting the generalizability of this relationship in adolescent populations.

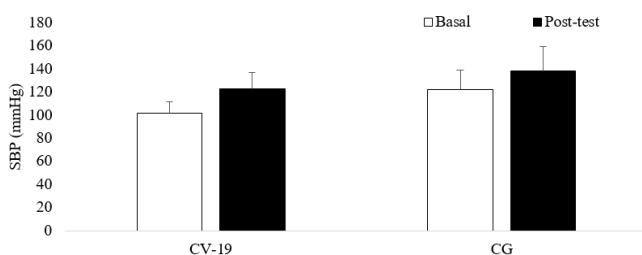


Figure 2 Systolic blood pressure (SBP) at rest and post-test.

Figure 3 shows diastolic blood pressure (DBP) values. Baseline DBP was 58 ± 0 mmHg in the CV-19 group and 71 ± 16.5 mmHg in the CG group ($p = 0.417$), while post-test DBP values were 69 ± 2.8 mmHg and 76 ± 18.3 mmHg, respectively ($p = 0.429$). Differences between baseline and post-test were 11 ± 2.8 mmHg (CV-19) and 5 ± 1.4 mmHg (CG). Though no between-group differences were statistically significant, within-group increases from baseline to post-test were significant for both groups (CV-19: $p < 0.001$; CG: $p < 0.001$).

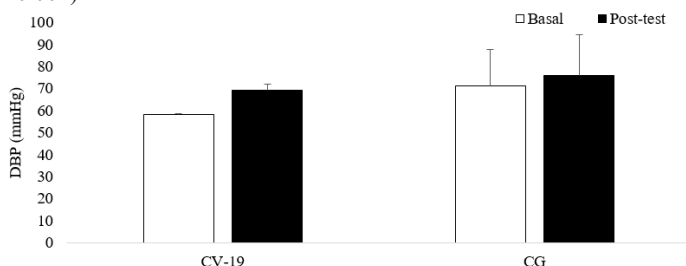


Figure 3 Diastolic blood pressure (DBP) at rest and post-test.

Figure 4 presents oxygen saturation (SaO_2) data. Baseline SaO_2 values were $94.5 \pm 3.5\%$ for CV-19 and $94.5 \pm 2.1\%$ for CG ($p = 0.859$); post-test values were $96 \pm 1.4\%$ and $96.5 \pm 0.7\%$, respectively ($p = 0.889$). The change in SaO_2 from baseline to post-test was $1.5 \pm 2.1\%$ (CV-19) and $2 \pm 1.4\%$ (CG). A significant increase in SaO_2 was observed only in the CG group ($p = 0.014$), while the increase in the CV-19 group did not reach statistical significance ($p = 0.061$).

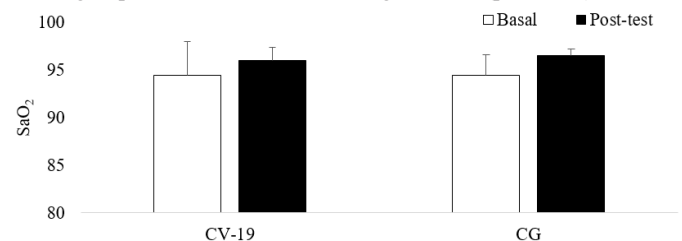


Figure 4 Blood oxygen saturation (SaO_2) at rest and post-test.

Discussion

COVID-19 did not significantly affect systolic blood pressure (SBP), diastolic blood pressure (DBP), heart rate (HR), or oxygen saturation (SaO_2) responses in the adolescent participants. Although the CV-19 group demonstrated lower values both at rest and post-exercise compared to the control group (CG), the between-group differences were not statistically significant. These results align with previous studies involving adolescents aged 14 to 18, which examined body image, body composition, anthropometric indicators, and sedentary behavior. Higher BMI, fat mass percentage, and WHtR were associated with lower body image satisfaction, potentially impacting quality of life through diminished self-esteem and well-being, as well as contributing to psychophysiological changes.¹⁹

Despite the absence of significant differences between groups, HR increases following physical exertion were evident. Exposure to COVID-19 may influence HR responses, as respiratory and cardiovascular impairments can trigger compensatory mechanisms, such as sympathetic activation, resulting in elevated HR. Although both groups showed a significant increase in HR from rest to post-test, the increase was smaller in the CV-19 group, suggesting a possible lingering effect of previous infection.²⁰

Several studies have investigated the mechanisms of COVID-19, with findings indicating inflammatory responses, physiological stress, and cardiorespiratory complications in more severe cases. These factors may contribute to HR changes through sympathetic stimulation and hypoxemia (20). For instance, in individuals with post-COVID-19 syndrome, a one-minute sit-to-stand test elicited significant HR increases, supporting the results observed in our study.²¹ Similarly, studies employing the six-minute walk test in post-COVID-19 patients have reported significant post-exercise increases in HR, mirroring the trend observed among CV-19 volunteers in our analysis.³ These patterns underscore the need for further investigations to elucidate the underlying factors contributing to altered HR responses in adolescents post-infection.

Autonomic function may also be a relevant factor. One study suggested that the sensitivity and specificity of resting HR cut-off points in adolescents may be affected by autonomic responses. COVID-19-related sympathetic stimulation and inflammation may predispose individuals to future autonomic dysfunction. Thus, HR may serve as a predictive indicator for conditions such as overweight and delayed sexual maturation.²¹ Cardiovascular complications have been widely reported among COVID-19 patients, particularly those

requiring intensive care. Manifestations such as acute cardiac injury, arrhythmias, and shock may lead to adverse outcomes, including acute heart failure.²² Although the adolescents in our study were asymptomatic and did not require hospitalization, potential long-term effects, including low-grade inflammation and subclinical cardiovascular alterations, cannot be ruled out.^{23,24}

Regarding SBP, other investigations using a one-minute sit-to-stand test in post-COVID-19 and control groups found increases in SBP in both groups, with affected individuals showing lower absolute values—findings consistent with our results.²⁵ Similarly, the 6-minute walk test has demonstrated improvements in SBP among post-COVID-19 patients, indicating enhanced functional capacity despite infection history.³

Our findings are also in line with data from hospitalized COVID-19 patients over 50 years of age, where SBP increased significantly after physical exertion, despite differences in age and comorbidity profiles. Age is a known confounder in blood pressure responses and may partially account for differences observed across studies.²⁶ Previous research has demonstrated a significant positive correlation between SBP and BMI in school-aged children ($r = 0.542$, $p < 0.0001$), reinforcing the potential risk of chronic conditions emerging from early anthropometric deviations.²⁷ In our study, although a weak and non-significant correlation between SBP and BMI was found ($r = 0.118$, $p = 0.582$), the trend remains relevant in the context of adolescent health surveillance.

DBP results before and after a one-minute sit-to-stand test in individuals with post-COVID-19 also revealed non-significant increases, paralleling our observations. CV-19 participants presented lower DBP values at both time points compared to controls.²¹ This aligns with evidence that DBP, like SBP, may be influenced by BMI through mechanisms such as increased cardiac output, vascular resistance, sympathetic overactivity, and adipokine secretion.²⁸ Although our correlation between DBP and BMI was weak ($r = 0.068$, $p = 0.751$), this does not negate the possibility of a physiologically meaningful association, particularly given that maturation, physical activity levels, and genetic predisposition in adolescents may modulate this relationship.²⁸ The potential long-term cardiovascular consequences of increased adiposity during adolescence remain a critical area of investigation.²⁷

Oxygen saturation (SaO₂) is another key indicator in post-COVID-19 assessments. Some studies report increased post-test SaO₂ in both affected and unaffected individuals after a one-minute sit-to-stand test. These changes may reflect respiratory compensations following exertion, which were observed in our data as well.²¹ In contrast, lower SaO₂ values have been observed in hospitalized post-COVID-19 patients undergoing a six-minute step test, with values below those found in our adolescent cohort. The discrepancy is likely due to differences in age, baseline health status, and severity of infection.²⁶

Despite its small sample size limits the statistical power of the analysis, this study contributes valuable insights into the physiological responses of adolescents post-COVID-19. The findings suggest that, while significant differences between infected and control groups were not observed, subtle trends—particularly in HR and SBP—warrant further investigation. Therefore, the findings should be interpreted with caution, larger and more comprehensive studies are essential to better understand the medium- and long-term impacts of COVID-19 on adolescent cardiovascular and respiratory health.

Conclusion

Based on the findings of this study, it can be concluded that COVID-19 did not significantly affect blood pressure, heart rate (HR), or blood oxygen saturation (SaO₂) responses in the adolescent participants. Although the CV-19 group exhibited lower values at rest and post-exercise compared to the control group, these differences were not statistically significant. However, significant differences were observed between resting and post-test values within each group, which can be attributed to the physiological demands of the exercise protocol. Pearson's correlation analysis revealed a positive, though weak, association between blood pressure and body mass index (BMI), suggesting that adolescents with higher BMI may experience elevated blood pressure values, consistent with previous literature.

In terms of anthropometric parameters, the study identified acceptable classifications for both body fat percentage and BMI among the participants. Nonetheless, elevated values of these indicators may negatively affect performance during physical fitness assessments and potentially influence cardiovascular responses. These findings underscore the importance of greater attention from policymakers and healthcare professionals to monitor and assess physiological changes in individuals affected by COVID-19, even in asymptomatic cases. Moreover, promoting physical activity as a preventive and rehabilitative strategy should be prioritized. Future research on post-COVID-19 hemodynamic responses across different age groups is essential to expand current knowledge and inform the development of targeted interventions aimed at enhancing long-term health outcomes and quality of life.

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Conflicts of interest

There are no conflicts of interest.

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