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Research Article

Effect of Two Years of COVID-19 Pandemic on Maximum Oxygen Uptake among Amateur Runners: A Prospective Study

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Abstract

In this prospective study we compared the maximum oxygen uptake ($\dot{V}O_2max$), physical activity levels, and time spent on a sedentary lifestyle measured before the COVID-19 pandemic period (January 2020) with that measured two years after (January 2022). Thirty-four male runners (46.8 ± 11.7 years) answered a questionnaire that consisted of personal data, health conditions, and current level of physical activity. They participated in cardiopulmonary maximal exercise tests for $\dot{V}O_2max$ assessment between January 2020 and January 2022. We observed a significant decrease (16.7 ± 7.3%) in $\dot{V}O_2max$ in January 2022 compared to January 2020 ($p<0.001$, $d=2.152$). Despite no change in physical activity levels between the two evaluations ($p=0.07$, $d=0.325$) being recorded, there was a reduction in the time dedicated to performing vigorous-intensity activities ($p=0.03$, $d=0.035$), a significant increase in walking time ($p=0.04$, $d= -0.42$), and a significant increase in the weekly sitting time ($p<0.001$, $d=0.77$). The observed change in the physical activity pattern during the COVID-19 pandemic (increased sitting time and decreased vigorous activities) negatively impacted the functional capacity of the amateur runners, as shown by the $\dot{V}O_2max$ assessment. Therefore there is a need to reduce sedentary behavior, such as sitting time throughout the day, in addition to the importance to increase the physical activity pattern.

Keywords: COVID-19; $\dot{V}$O2max; physical exercise

Introduction

At the end of 2019, an outbreak of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), a virus of the coronavirus family, emerged in the city of Wuhan in the Chinese province of Huchina [1]. This disease quickly spread worldwide and has evolved into a pandemic.

On March 2020, several measures to control and contain the spread of the virus were taken by government institutions and health authorities in Brazil[2], including isolation measures for people infected or suspected of being infected with the Coronavirus Disease 2019 (COVID-19). Schools, universities, and parks were closed in the second half of March, and commercial and nonessential services were suspended [2]. The measures aimed to ensure physical distancing between people to contain the spread of SARS-CoV-2. Additionally, physical activity was encouraged, as it has been proven to be beneficial in improving several clinical conditions, such as diabetes, hypertension, and cardiovascular diseases, which are most frequently comorbidities associated with severe COVID-19.

Despite the incentives to perform physical activities [3], which should be carried out in open environments with the use of a mask, there has been a significant reduction in the population's activity levels in several parts of the world, including Brazil [4–6]. This reduced level of physical activity has been reported as a serious public health risk [4,5], as it may negatively impact the individual functional capacity. An important predictor of functional capacity is maximum oxygen uptake ($\dot{V}O_2$max), which reflects the maximum capacity for the integrated functioning of the cardiovascular, muscular, and respiratory systems [7].

Measurement of $\dot{V}O_2$max has become increasingly important. It has been shown that high $\dot{V}O_2$max is associated with good health conditions and low $\dot{V}O_2$max with worse health conditions. Myers et al. (2012) showed that a low $\dot{V}O_2$max is a stronger predictor of death than established clinical variables or risk factors, such as hypertension, smoking, and diabetes, as well as other exercise test variables, including ST-segment depression or development of arrhythmias during exercise in healthy individuals [8]. There is also plenty of evidence that low $\dot{V}O_2$max levels are associated with increased mortality rates of men and women, regardless of other risk factors [9]. Thus, individuals with high $\dot{V}O_2$max values have a longer life expectancy [10]. In addition to the longer life expectancy, there is also evidence that high levels of physical activity are associated with a lower number of years that a person lives with some limitation; i.e., for the same age at death, individuals with higher levels of physical activity spend fewer years living with some type of disability than the general population [11].

Considering that there was a significant decrease in the level of physical activity during the pandemic, especially among people who were initially considered very active [4], we were interested in the reduction in activity and its impact on $\dot{V}O_2$max levels in individuals who were very active in January 2020.

This study aimed to compare $\dot{V}O_2$max measured before the pandemic (January 2020) with that measured in January 2022 among individuals classified as very active before the pandemic. We also compared the $\dot{V}O_2$max change between those who increased or did not increase weekly sitting hours. We hypothesized that the pandemic period would impair $\dot{V}O_2$max and physical activity level, and we also hypothesized that those who increase sedentary behaviors would present a greater reduction in $\dot{V}O_2$max values.

Materials and Methods

Participants

All experimental procedures were approved by the Human Research Ethics Committee of the Federal University of São Paulo-UNIFESP (approval number 4.354.386) and conformed to the principles outlined in the Declaration of Helsinki. The participants were invited to participate in the study through contact with clubs, social media, and coaches. Initially, 69 male amateur runners were contacted, and 34 completed all required tests. Inclusion criteria were: body mass index lower than 39.9 kg/m^2, runners for at least three years, training at least three times a week, and age between 20-79 years. Participants with a medical contraindication to performing maximal effort, a history of smoking, and chronic diseases were excluded from the study. The participant's characteristics are presented in Table 1.

Variables	2020 (n=34)	2022 (n=34)	p value	Effect Size (d)	CI for Effect size	Power (1-ß)
Age (years)	46.8 ± 11.7	48.8 ± 11.8	<0.001	-4.416	2.3 to 6.6	1.00
Body mass (kg)	74.3 ± 10.6	75.2 ± 12.4	0.174	-0.578	-0.1 to 1.3	0.99
Height (cm)	173.5 ± 6.8	173.7 ± 6.7	0.189	-0.569	-0.1 to 1.3	0.99
BMI (kg/m²)	24.6 ± 2.48	24.9 ± 3.18	0.244	-0.203	-0.1 to 0.5	0.82
Data presented as mean ± standard deviation. BMI, body mass index. CI, confidence interval						

Table 1: Descriptive characteristics of the participants.

Study design

Each participant visited the laboratory twice: the first visit was in January 2020 (before the pandemic), and the second was in January 2022, both visits occur during the morning period. At each of the two visits, the participants answered a questionnaire about personal data, health conditions, and current level of physical activity measured using the International Physical Activity Questionnaire (IPAQ). Anthropometric data were collected and a cardiopulmonary maximal exercise test was performed. The participants were instructed not to perform strenuous training in the last 24 h before the laboratory visit, to abstain from hyper-stimulating foods on the day, for example, caffeine or tea, and to wear light clothes and comfortable sneakers.

Assessment Questionnaire

The questionnaire consisted of three stages. The first deals with general data, such as name, age, date of birth, sex, and level of education. The second stage addressed aspects related to COVID-19, such as contagion by the coronavirus (yes or no), development of COVID-19 disease (yes or no), need for hospitalization (yes or no), intubation (yes or no), vaccination (yes or no), presence of any other chronic disease (yes or no, and if yes, which disease?). The next step was related to the current level of physical activity measured using the IPAQ [12]. This instrument has acceptable measurement properties for estimating physical activity levels with previously reported internationally validated results [13], which were translated and validated for the Brazilian Portuguese language in 2001 [14]. Based on the answers provided by the participants, the level of physical activity was classified into five categories (very active, active, irregularly active A, irregularly active B, and not active) according to Matsudo et al. [14].

Cardiopulmonary maximal exercise test

The participants underwent a maximal cardiopulmonary exercise test on a motorized treadmill (Imbrasport, ATL, Brazil) to determine the $\dot{V}O_2$max. Perceived exertion was rated using the Borg scale [15]. The Ellestad protocol was applied in each of the two visits because of its ability to assess participants with different levels of physical fitness [16].

During the test period, the participants were encouraged to exercise for as long as possible until voluntary exhaustion, assessed by dyspnea or lower limb fatigue and subjective feeling of fatigue. Oxygen uptake was measured breath-by-breath using a metabolic analyzer (Quark, Rome, Italy), and the measured data were averaged over 20 s for analysis. Calibration was performed according to the manufacturer's instructions prior to each test. At the end of the test, $\dot{V}O_2$max was determined as a clear $\dot{V}O_2$ plateau (an increase lower than 1.5 mL/kg/min between two consecutive stages). In case of no clear $\dot{V}O_2$ plateau, the following three criteria were required for the attainment of $\dot{V}O_2$max: a respiratory exchange ratio value ≥1.15, attainment of a maximal heart rate value (HRmax) above 95% of the age-predicted maximum (207-0.7 x age) [17], and exhaustion according to the Borg scale [15]. All the participants reached $\dot{V}O_2$max.

Statistical analysis

Data are presented as mean and standard deviation. Physical activity level was also presented as a percentage value. All variables presented normal distribution and homogeneous variability, according to the Shapiro-Wilk and Levene tests, respectively. To compare the measured variables between the two test periods, a paired t-test was used. The G*Power version 3.1.9.2 (Program written, concept and design by Franz, Universität Kiel, Germany; freely available windows application software) was used to determine the power level. For power level calculation, a t-test family was selected, and mean values, standard deviations and effect sizes were included in the calculation. The measures of the effect size for differences between periods were determined by calculating the mean difference between the two periods and then dividing the result by the pooled standard deviation. By calculating effect sizes, the magnitude of any change was judged according to the following criteria: $d<0.2$ considered no effect, $0.2 \leq d<0.5$ considered a "small" effect size; $0.5 \leq d<0.8$ represented a "medium" effect size; and $d \geq 0.8$ a "large" effect size [18]. The significance level was set at $p<0.05$. Statistical analyses were performed using SPSS version 26.0 (SPSS Inc., Chicago, IL, USA).

Results

Although the level of physical activity of the runners did not show a significant reduction when compared to the period before the COVID-19 pandemic (2020) (Table 3), the percentage of very active runners, according to the IPAQ, dropped from 67.6 to 50.0% during the two years of follow-up (Table 2).

Variables	2020 (n=34)	2022 (n=34)	p value	Effect Size	CI for Effect Size	Power (1-ß)
Physical activity level	4 (3-4)	3.5 (3-4)	0.07	0.325	0.0 to 0.6	0.64
$\dot{V}O_2max$ (mL/kg/min)	57.9 ± 10.2	48.2 ± 9.4	<0.001	2.152	1.1 to 3.2	1.00
Sitting Time (min/wk)	1788 ± 786	2432 ± 1086	<0.001	-0.767	0.4 to 1.1	0.85
Vigorous Activity Time (min/wk)	275 ± 223	205 ± 217	0.03	0.346	0.1 to 0.6	0.53
Moderate Activity Time (min/wk)	351 ± 318	252 ± 195	0.20	0.336	-0.1 to 0.8	0.86
Walking Time (min/wk)	279 ± 377	409 ± 493	0.04	-0.417	0.1 to 0.7	0.73
Data are presented as mean ± standard deviation. VO2max, maximum oxygen uptake						

Table 2: Absolute (and relative) frequency for the physical activity level between January 2020 and January 2022.

There was a reduction in the time dedicated to performing vigorous-intensity physical activities ($p=0.03$ and $d=0.035$) and a significant increase in walking time ($p=0.04$ and $d= -0.42$) compared to the assessment made in 2020. Additionally, there was a significant increase in the time that the participants remained seated during the week ($p<0.001$ and $d= -0.77$) (Table 3).

IPAQ	2020 (n=34)	2022 (n=34)
Sedentary	0	1 (2.9%)
Irregularly active B	0	0
Irregularly active A	0	1 (2.9%)
Active	11 (34.4%)	15 (44,1%)
Very Active	23 (67.6%)	17 (50.0%)
IPAQ, International Physical Activity Questionnaire		

Table 3: Comparison of the physical activity level, physical activity characteristics, and $\dot{V}O_2max$ values between January 2020 and January 2022.

Concomitant with the change in the physical activity pattern, there was a significant decrease (16.7 ± 7.3%) in $\dot{V}O_2max$ in the 2022 assessment when compared to the 2020 assessment ($p<0.001$ and $d=2.152$) (Table 3). In addition to a significant reduction in $\dot{V}O_2max$ in the entire group during the assessment period, it was also observed that the reduction was significantly greater ($p=0.04$ and $d=0.50$) among runners who had increased sitting time during the week (18.8% ± 9.8) compared to those who did not increase sitting time (13.8% ± 10.0).

Discussion

The main results of the present study were as follows: (i) the overall physical fitness level did not differ between 2020 and 2022; (ii) there was a significant reduction in the time dedicated to performing vigorous physical activities; (iii) there was a significant increase in the time spent in walking activities; (iv) there was a significant increase in the time spent in sitting activities; (v) $\dot{V}O_2max$ reduced significantly between 2020 and 2022 in the entire group; and (vi) the $\dot{V}O_2max$ reduction was greater among those who had increased spending time on sitting activities.

In contrast to the initial hypothesis, the physical activity level for the entire runner group evaluated by the IPAQ did not change between 2020 and 2022. This result contradicts previous findings that demonstrated a significant reduction in physical activity levels during the COVID-19 pandemic period in the general population [4]. Despite maintaining the general physical activity level, it was evident that the COVID-19 pandemic period negatively impacted physical fitness, even among well-trained runners. This decline in physical activity can be observed through a significant reduction in weekly hours spent in vigorous activities and increased time spent walking and sitting. It is important to note that physical activity intensity is considered important for achieving substantial health benefits [19]. More recently, the World Health Organization (WHO) has updated the guidelines for physical activity. The new recommendation is to perform at least 150-300 min moderate to vigorous intensity physical activity, or 75-150 min of vigorous-intensity aerobic activity exercise per week [20]. In addition to having a significant reduction in the number of hours spent on these activities intensity in 2022 compared to 2020, there was an increase of more than 100% in people who do not reach the WHO physical activity recommendation. In 2020, there were only five runners, and by 2022, there were 12 runners who spent less than 300 min per week on moderate-to vigorous-intensity activities. In 2020, there were only two runners, and in 2022, there were 10 runners who spent less than 75 min of vigorous-intensity aerobic exercise. Therefore, despite the maintenance of the overall physical activity level according to the IPAQ, the negative impact on physical activity level during the COVID-19 period was evident, even among runners.

The activities evaluated in the IPAQ that classify the level of physical activity included vigorous activities, which decreased during the period, and walking activities, which increased during the pandemic. Therefore, although there was a significant reduction in vigorous intensity activities with increasing walking time, there was no change in the overall level of physical activity according to the IPAQ.

This change in the physical activity profile was associated with a significant reduction in the $\dot{V}O_2max$ values between 2020 and 2022. In the two years of the COVID-19 pandemic, there was a drop of 16.7% in the VO_2max of the participants, a significantly higher value than that expected as the result of natural aging, which is around 1% per year [21]. This reduction is worrying because $\dot{V}O_2max$ is considered the main predictor of aerobic performance and cardiovascular fitness (CF), which is an independent predictor of cardiovascular health [22]. Low CF has been considered a major risk factor more important than obesity, smoking, and hypertension for all mortality causes [22]. However, it is important to point out that despite the significant reduction in VO_2max, the values measured in 2022 remain above the expected values for the age of the participants of a non-athlete population [23].

Vigorous activities have been suggested to maintain or increase $\dot{V}O_2max$ [24]. The reasons that justify the need for vigorous activities to increase $\dot{V}O_2max$ values remain unclear; however, it is believed that vigorous exercise is necessary to recruit large motor units and attain near-to-maximal cardiac output, which jointly signals for oxidative muscle fiber adaptation and myocardium enlargement, which are limiting factors for $\dot{V}O_2max$ [25]T@$$ \\dot{V} $$O2maxas inferred from blood lactate accumulation. It is believed that an optimal stimulus to produce maximal cardiovascular and peripheral adaptations, and therefore, to increase the $\dot{V}O_2max$ values, is one where individuals stress the oxygen transport and utilization systems, which is possible only during vigorous activities [19]. Therefore, the observed significant reduction in vigorous activity among the participants in the present study may have contributed to the observed reduction in $\dot{V}O_2max$.

Another important finding from the study was the significant increase in sedentary behavior, which was evaluated through weekly sitting hours. In 2020, the mean value of the weekly seating hours was 1,788 min, and in 2022, this time increased to 2,432 min per week, representing 36% more hours dedicated to seating time in 2022. The increase in sitting time of approximately 640 min per week represents an increase of 2890 min per month, which for two years between the two assessments means an increase in sitting time of 69,000 min, that is, 48 more days of sitting time during the two years. Sedentary behavior has been associated with an increase in molecular mechanisms abnormalities and an increase in oxidative stress and inflammation [26], thereby increasing the risk of cardiovascular diseases and mortality [27]. In recent public health research, the physical activity level has been treated as an important term separate from sedentary behavior [28]. Both have been considered independent risk factors for several diseases, such as metabolic syndrome or depression [29,30]. Finally, the increase in the sitting hours per week also may be associated with the decrease in $\dot{V}O_2max$ values observed in the present study. Reduced vigorous activities and sedentary behavior have also been previously reported to be negatively associated with $\dot{V}O_2max$ [29].

Conclusions

In addition to the damage caused by the COVID-19 disease in the population that contracted the virus, the pandemic also reduced $\dot{V}O_2max$ values, increased sedentary habits, and reduced vigorous-intensity activities of the population. Therefore, to mitigate the negative impacts of these two years, there is a need to increase physical activity. It is also important to reduce sedentary behavior, such as sitting time throughout the day and moving around whenever possible.

Disclosure

Author Contributions: Conceptualization, L.V. and M.S.A.; methodology, A.S., V.R.A.S, and R.A.C; software, A.S.; validation, C.A.B.L, R.L.V, M.S.A.; formal analysis, L.V.; investigation, M.S.A; resources, L.V, A.S., V.R.A.S.; data curation, B. K.; writing—original draft preparation, L.V.; writing—review and editing, K.W, B. K. and M.S.A; supervision, B.K. and M.S.A.

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Institutional Review Board Statement: All experimental procedures were approved by the Human Research Ethics Committee of the Federal University of São Paulo and conformed to the principles outlined in the Declaration of Helsinki (approval number approval number 4.354.386). This study was guided by ethical standards and national and international laws. All athletes signed the consent form after receiving instructions regarding the possible risks and benefits and were granted privacy, confidentiality, and anonymity rights. The participants were free to stop participating any stage of the experiment without giving reasons for their decision.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the patient(s) to publish this paper.

Data Availability Statement: Data supporting the study results can be provided followed by request sent to the corresponding author's e-mail.

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Conflicts of Interest: None.

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