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Long-term impact of the COVID-19 pandemic on physical activity and estimated cardiorespiratory fitness in south American adults: a multi-country cross-sectional online survey

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Abstract

Background Restriction measures during the COVID-19 pandemic may have reduced opportunities to engage in physical activity. This study explored the changes in self-reported physical activity level (PAL), risk factors, and estimated cardiorespiratory fitness (eCRF) among south American adults by comparing data reflecting the pre-pandemic period to data collected during the survey.

Methods We conducted a cross-sectional online survey between July 2021 through March 2022 using validated questionnaires (e.g., GPAQ and WHO-STEPS) on a convenience sample of 1,934 adults (68.7% women) from Argentina ($n=484$), Brazil ($n=405$), Chile ($n=279$), Colombia ($n=343$) and Uruguay ($n=423$). We compared self-reported PAL, risk factors, and eCRF before the pandemic period and at the time of the survey (mean 842 days from the first reported case in each country). Data were presented as medians (interquartile range [IQR]) or means (95% confidence interval [CI]) for continuous variables and percentages for categorical ones. Paired data analyses were conducted using paired t-tests, Wilcoxon Signed Rank test, and McNamar's tests, as applicable.

Results We observed a decrease in PAL at work (median, 0 METs/min/week and interquartile range, [0—240] vs. 0 METs/min/week [0—30]; $p=0.032$) and active transportation domains (0 METs/min/week [0—693] vs. 0 METs/min/week [0—594]; $p=0.008$). In addition, the median sedentary time on weekdays increased by 60 min/day (360 [240—540] vs 420 [240—600]; $p<0.001$). We also observed an increase in the proportion of participants with hypertension (12.9 vs. 16.5%), diabetes (6.8 vs. 9.8%), dyslipidemia (18.9 to 24%), depression symptoms (14.4 to 15.4%) and obesity (15.4 to 18.2%) compared with pre-pandemic levels (all p-values < 0.05). The eCRF was significantly lower at the survey

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time compared with pre-pandemic levels (mean difference, -1.17 mL/min/kg (or 3.34%): 95% CI, -1.03 to -1.30) even after adjusting for age (-0.50 mL/min/kg (or 1.45%): 95% CI -0.37 to -0.64).

Conclusions Across five countries in South America, social restriction policies to control the COVID-19 pandemic may have reduced physical activity and estimated cardiorespiratory fitness with no recovery until the survey time.

Keywords SARS-Cov-2, Coronavirus, $\dot{V}O_{2max}$, Cardiovascular risk, Exercise

Text box 1. Contributions to the Literature

- This study addresses a regional evidence gap by illustrating how COVID-19 restrictions in five South American countries resulted in enduring declines in cardiorespiratory fitness, work- and transport-related physical activity, and increased sedentary time.
- It also connects these changes to worsening cardiometabolic risks, such as hypertension, diabetes, and obesity.
- Some domains of physical activity and fitness levels may not recover after the restrictions.
- The results emphasize the necessity for public health strategies to tackle sedentary lifestyles and fitness loss in the future crises.

Background

In March 2020, the World Health Organization (WHO) declared the coronavirus infection (SARS-CoV-2; COVID-19) a pandemic [1]. In response, numerous countries implemented restrictions and measures to mitigate the virus's spread, including the closure of commercial establishments, parks, gyms, and sports facilities and restrictions on public transport [2]. While these measures played a vital role in arresting virus transmission, they also led to unintended consequences, leading to a notable decline in physical activity (PAL) [3].

Promoting healthy lifestyles is crucial to prevent chronic non-communicable diseases, particularly cardiovascular diseases. Every instance of physical activity is vital in achieving the minimum recommended levels of 150 to 300 min per week of moderate to vigorous physical activity, as endorsed for health benefits [4]. Higher physical activity levels are consistently linked to reduced risks of cardiovascular disease, obesity, diabetes, and mortality [5]. Regular physical activity also contributes to enhanced immune function and a decreased likelihood of experiencing influenza, herpesvirus, and upper respiratory tract infections. A higher CRF was strongly associated with lower risks of death, hospitalization, and intubation due to COVID-19, even after adjusting for multiple health factors. These protective effects were consistent across age groups and among patients with common comorbidities such as hypertension, diabetes, cardiovascular disease, and chronic kidney disease [6]. These findings underscore the significance of maintaining movement, particularly during confinement associated with the former COVID-19 pandemic [7–9].

A systematic reduction in exercise negatively impacts cardiorespiratory fitness (CRF) [10, 11], which is associated with cardiovascular disease outcomes more strongly than self-reported physical activity levels. The low CRF is linked to various health issues, including all-cause mortality, diabetes, hypertension, coronary artery disease, and certain cancers [12]. Increasing one metabolic equivalent (MET) in CRF is related to a reduced death risk by 10 to 30% [13]. Recognizing its significance, the American Heart Association recommends integrating CRF as a vital sign in cardiovascular health assessments [12]. However, the widespread use of Cardiopulmonary Exercise Testing is often impractical due to its high costs and complexity. Therefore, employing a prediction equation to estimate maximum oxygen uptake ($\dot{V}O_{2max}$) becomes crucial, particularly in resource-limited settings [10, 14].

While numerous online surveys have delved into the repercussions of strategies aimed at curbing the transmission of COVID-19 on individuals' health and behavior [15], none have specifically detailed the effects on CRF or the extent to which individuals can resume their normal lifestyle behaviors in the long term. Moreover, scant data exist on the consequences of restrictive measures and lockdowns related to COVID-19 among the adult population in low- and middle-income countries. Given these nations' distinctive sociodemographic and environmental characteristics, the impact on behavior and clinical outcomes may differ significantly compared to populations in developed countries [16]. We hypothesize that despite the restoration of the pre-pandemic PA access, PA levels and especially CRF were fully rebound, reflecting a temporal dissociation between behavioral normalization and physiological readaptation.

Through an online survey, we aimed to explore the changes in physical activity level (PAL) and self-reported risk factors. We estimated CRF (eCRF) among South American adults, comparing data reflecting the pre-pandemic period to data collected at the time of the survey.

Methods

Study design and participants

We conducted a cross-sectional, quantitative, online study using validated questionnaires to assess outcomes of interest in a convenience sample. The research was designed by a multidisciplinary group of scientists and academics from the Physical Activity and Fitness Network (PA&FIT network) from the Bernard Lown Scholars in Cardiovascular Health Program at Harvard T.H. Chan School of Public Health, Boston, United States. Local Human Research Ethics Committees approved the study protocol in five countries. All participants provided an informed consent form, ensuring they fully understood the study's purpose, procedures, risks, and benefits before participation.

Recruitment covered 28 months. In total, 2,986 individuals visited the research link (Fig. 1). The sample included adults aged 18 and over who resided in Argentina, Brazil, Chile, Colombia, and Uruguay from July 2021 through March 2022. Recruitment used various channels, including social networks, newspapers, and the researchers' email contacts.

Sample size

The Raosoft Sample Size Calculator (http://www.raosoft.com/samplesize.html) was employed to determine the minimum necessary sample size. Because the prevalence of low CRF (< 8 METs, i.e., 28 ml/min/kg) in the population to be evaluated was unknown due to the natural phenomenon of the pandemic, a prevalence of 50% of low cardiorespiratory fitness was assumed, as it provides the largest sample size. Considering a 95% confidence interval, the minimum sample size for this research was determined to be 385 respondents per country, ensuring a 5% margin of error.

We selected a convenience sample by disseminating the link to the survey via emails, official university websites, and social networks. We distributed the survey via links to researchers' contacts, the university, and researchers' social networks. None of the emails were obtained outside of these sources. Each of the five countries had a unique link with the same survey either in Portuguese or Spanish. Participants were required to indicate their country of residence in one of the responses. If participants stated they were under 18, the survey automatically closed after a thank-you message.

Data collection

We collected and stored the data on the REDCap platform [17]. The online survey form was available in Portuguese and Spanish and included the following sections:

1. Eligibility and consent: The inclusion criteria were individuals aged 18 or older residing in Argentina, Brazil, Chile, Colombia, and Uruguay. The exclusion criteria involved incomplete or inconsistent responses concerning the history of COVID-19, physical activity, and cardiovascular risk factors (necessary for eCRF calculation). This section included an introduction to the research, describing the objectives, the names of the researchers responsible for the project, the local leading researcher, research risks, data processing, data protection, storage and sharing, and obtaining consent.

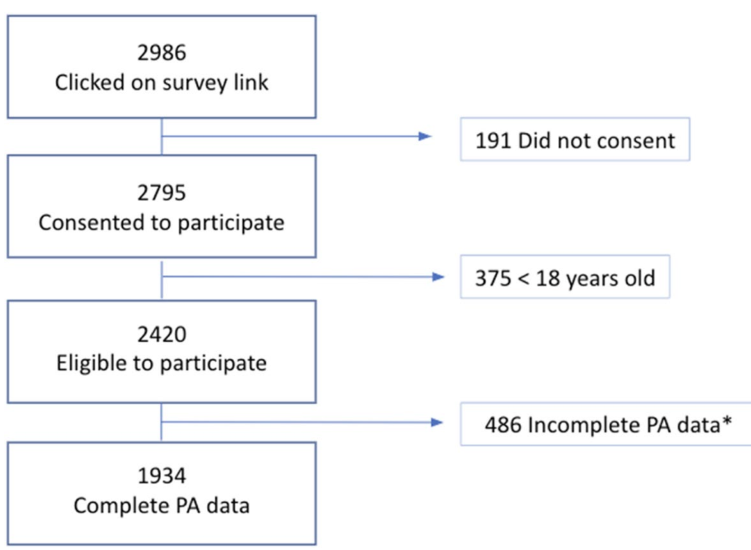

Fig. 1 Flowchart of the present study. *We considered inconsistent information in case of missing values, mistyped data, as well as spurious (out of range) numbers

2. Sociodemographic: Country of residence, age, sex, education, marital status and work status. For marital and work status, participants had the options "before the pandemic" and "survey time" format answers obtained from the WHO-STEPS questionnaires, validated in Spanish and Portuguese [18]. The WHO STEPwise Approach to Surveillance (STEPS) offers a systematic approach for collecting, analyzing, and disseminating data on key non-communicable disease risk factors worldwide. Its goal is to support countries in tracking national trends, identifying successful practices, and developing targeted policies and programs.
3. Clinical history: Self-reported data on COVID-19 diagnosis, hospitalization, treatments, and vaccination were collected using questions designed for this study. Depression symptoms were assessed by asking, "Have you ever been told by a doctor or other health worker that you have symptoms of depression?" with "Before the pandemic" and "Survey time" options for answers.
4. Cardiovascular risk factors: Self-reported data on hypertension, diabetes mellitus, hypercholesterolemia (excluding diagnoses made during pregnancy), current smoking status, body weight, and height were collected using validated versions of the WHO-STEPS questionnaires [18]. All questions included "Before the pandemic" response options and "Survey time" to evaluate changes over the specified period.
5. Level of physical activity: Assessed by the Global Physical Activity Questionnaire (GPAQ), developed and validated by the World Health Organization [19]. The GPAQ is a 16-question instrument that assesses physical activity across various settings. It collects information on activities at work, commutes, recreational pursuits, and sedentary behavior. We selected the GPAQ because it is widely recognized as a surveillance tool for monitoring physical activity levels in diverse populations. These questions had the options "Before the pandemic" and "Survey time" for answers. This approach included specific temporal clarifications to help participants accurately differentiate between their pre-pandemic and current activity levels, such us: *"We are going to ask you about the time you spent engaging in different types of physical activity during a typical week at work (paid or unpaid) before the start of the COVID-19 pandemic and the time you spend currently."* We also assessed the level of physical activity through a single question: *"Do you perform 150 min or more of moderate physical activity or 75 min or more of vigorous physical activity per week? (i.e., physical activities that increase your ventilation)"* [18].

Data confidentiality

No personal data capable of identifying individual participants were collected during this study, ensuring complete anonymity. All electronically captured data were securely stored on a password-protected hard drive, with stringent measures to safeguard data integrity. Access to confidential information was strictly limited to authorized research team members who adhered to ethical data handling protocols.

Study outcomes

The primary outcomes were (a) Absolute difference in the eCRF (i.e., estimated $\dot{V}O_{2max}$) and the proportion of individuals with low eCRF (< 8 METs, i.e., 28 mL/min/kg) [12] from before the COVID-19 pandemic until the survey time; (b) Absolute difference in the total PA per week and PA in each domain, expressed as MET/minutes per week and the proportion of individuals engaging in insufficient physical activity level, defined as less than 600 METs/min/week; (c) Absolute difference in the proportion of participants reporting a history of hypertension, diabetes mellitus, hypercholesterolemia, current smoking status, obesity, and depression symptoms. We assessed self-reported height and weight, which were used to calculate body mass index (BMI), with obesity defined as a BMI of ≥ 30 kg/m^2; d) We also examined the Absolute difference in sedentary time, expressed as total daily minutes on a typical weekday and weekend.

Covariates

Age, sex, BMI, education, work status, hypertension, diabetes, hypercholesterolemia, current smoking status, clinical conditions related to COVID-19 infection (hospitalization, treatment with supplemental oxygen or mechanical ventilation), and health status vaccination against COVID-19.

Estimation of the cardiorespiratory fitness ($\dot{V}O_{2max}$)

To estimate CRF, we used a previously-developed longitudinal prediction equation including treadmill tests from 2,117 adults in the United States and Brazil from "The Fitness Registry and the Importance of Exercise National Database Registry's data" [20]. The chosen equation predicts $\dot{V}O_{2max}$ based on age, sex, BMI, country, arterial hypertension, hypercholesterolemia, diabetes, current smoking, and insufficient PA, defined as less than 150 min of moderate activity or 75 min of vigorous activity per week or less than 600 MET/min/week [4]. The equation chosen was as follows:

$$\dot{V}\mathbf{O_{2max}}(\mathbf{mLO_2}\cdot \mathrm{kg}^{-1}\cdot \mathrm{min}^{-1}) = 61.731 - (0.212\times \mathbf{Age}_{\mathrm{years}}) - (0.001\times \mathbf{Age}\times \mathbf{Age}) + (5.657\times \mathbf{Sex}_{\mathrm{males=1;\ females=0}}) - (0.656\times \mathbf{BMI_{km/m2}}) + (2.802\times \mathbf{Country}_{\mathrm{developed=1;\ developing=0}}) - (0.883\times \mathbf{Hypertension}_{\mathrm{no=0;\ yes=1}}) - (0.398\times \mathbf{Hypercholesterolemia}_{\mathrm{no=0;\ yes=1}}) - (1.985\times \mathbf{Smoking}_{\mathrm{no=0;\ yes=1}}) - (4.450\times \mathbf{InsufficientPAL}_{\mathrm{no=0;\ yes=1}}) - (0.653\times \mathbf{Diabetes}_{\mathrm{no=0;\ yes=1}})$$

We chose a treadmill-based CPET equation because of its advantages over cycle ergometers, including higher ($\dot{V}O_{2max}$), improved oxygen utilization, and greater full-body muscle engagement. Treadmills are also more familiar and motivating for participants, which enhances adherence, while accommodating a wider range of exercise intensities and allowing for more comprehensive fitness assessments [21].

Physical activity levels

We adopted the available guidelines to analyze the GPAQ data and assigned a value of 4 METs for moderate and 8 METs for vigorous activities. One MET is the energy cost of sitting still, equivalent to 1 kcal/kg/hour of caloric consumption [19].

Statistical analysis

We estimated pre-pandemic eCRF, taking as a reference date the first case of COVID-19 in 2020 in each country (REF), and compared those with the estimated eCRF at the time of the survey. Given the significant influence of age on the decline in $\dot{V}O_{2max}$, we estimated a second set of eCRFs while maintaining the participant's age at the time of the survey in both estimations. To assess differences in continuous variables comparing data "before the pandemic" versus "survey time", parametric paired t-test and non-parametric Wilcoxon signed rank test were used based on normality. Categorical variables were compared using the McNemar test. All statistical tests were carried out using the SPSS package, version 24. We set the probability of alpha error at 5% (i.e., p value < 0.05).

Results

Of 2,986 individuals who visited the link in 28 months of research, 191 did not consent to participate. Among 2,795 consented individuals, 375 were under 18 and excluded. We found 486 incomplete or inconsistent PA data among 2,420 eligible participants. Thus, our final analytical dataset included data from 1,934 adults (484 from Argentina, 405 from Brazil, 279 from Chile, 343 from Colombia, and 423 from Uruguay) (Fig. 1).

The excluded participants and the final sample were similar in terms of mean age (36 ± 14 vs. 37 ± 13 years); however, those excluded had a higher proportion of women (83.1 vs. 66.3%; $p = 0.003$) and a lower proportion of those with postgraduate diploma (31.7% vs. 41.6%; $p = 0.047$).

At the time of the survey, the mean time from lockdown to survey was 2.3 years. The mean age of participants ($N = 1{,}934$) was 39.5 ± 14.0 years, with most females (68.8%) and a large proportion (70.4%) with tertiary or university education completed. More than half of the participants (55.8%) reported contracting COVID-19, and 93.8% had completed their COVID-19 vaccination. However, the hospitalization rates due to COVID-19 were low, with only 1.4% of participants reporting being hospitalized. (Table 1).

Regarding marital status, 43% of the participants had never married, while 33% were married at the time of the survey. Employment data indicated that 32% were non-government employees, 24.3% were government employees, and 14.8% were students. The proportion of self-employed and retired participants was higher at the time of the survey compared with pre-pandemic levels (14.4% to 16.2%; p = 0.005; and 4% to 5.5%; p < 0.001, respectively) (Supplementary Table 1).

As for self-reported cardiovascular risk factors prevalence, high cholesterol was the most prevalent (18.9%), followed by obesity (15.1%) and hypertension (12.9%) (Table 1). When comparing the pre-pandemic period to the time of the survey, we observed a significant increase in cardiovascular risk factors (Fig. 2). We found 70 new cases of self-reported hypertension (3.6%), 58 of diabetes mellitus (3.0%), 53 of obesity (2.8%), 98 of high cholesterol (5.1%), and 141 new cases of depressive symptoms (7.2%). These increments were also observed across all countries, with unchanged smoking rates (Supplementary Fig. 1).

A high percentage of participants were physically active, engaging in sufficient levels of PA (≥ 600 METs.min/week) during the survey, primarily through leisure activities. The proportion of being physically active remained stable from the pre-pandemic period (75.8%) to the time of the survey (72.9%), with no significant differences observed across the selected countries (Fig. 3A).

Overall, we found no significant changes in the total or leisure time physical activity. However, we observed a decrease in PAL at work (median, 0 METs/min/week:

Table 1 General characteristics of the studied sample at the time of the survey response

n	Total 1934	Argentina 484	Brazil 405	Chile 279	Colombia 343	Uruguay 423
First reported COVID-19 case (2020)		03/03/2020	26/02/2020	02/03/2020	06/03/2020	13/03/2020
Time from lockdown to survey, mean days (SD)	842.5 (119.6)	842.5 (119.6)	842.5 (119.6)	842.5 (119.6)	944.6 (26.8)	944.6 (26.8)
Age (years)	39 ± 14	41 ± 14	37 ± 12	36 ± 12	37 ± 13	43 ± 15
Sex, n (%)						
Females	1327 (68.8)	366 (75.5)	269 (66.6)	189 (68.0)	212 (61.8)	288 (68.9)
Males	602 (31.2)	119 (25.5)	136 (33.4)	91 (32.0)	131 (38.2)	130 (31.2)
Completed higher education, n (%)	1362 (70.4)	301 (62.1)	282 (69.6)	223 (80.2)	282 (82.2)	271 (64.8)
Weight (kg)	71.1 ± 16.9	70.9 ± 17.7	74.1 ± 18.5	69.3 ± 14.7	67.4 ± 14.1	72.7 ± 17.1
Height (cm)	166.6 ± 9.3	165.5 ± 78.2	167.7 ± 9.3	165.4 ± 9.6	165.2 ± 9.7	166.5 ± 9.1
Body mass index (kg/m^2)	25.5 ± 5.1	25.1 ± 5.3	26.1 ± 5.4	25.2 ± 4.3	24.6 ± 4.4	26.1 ± 5.5
Self-reported COVID-19, n (%)	1080 (55.8)	277 (57.1)	216 (53.3)	164 (59.0)	196 (57.1)	226 (54.1)
Hospitalization	28 (1.4)	11 (2.3)	8 (2.0)	2 (0.2)	5 (1.5)	2 (0.5)
Nasal oxygen	23 (1.2)	7 (1.4)	6 (1.2)	4 (1.4)	6 (1.7)	-
Mechanical ventilation	6 (0.3)	2 (0.4)	3 (0.7)	-	1 (0.3)	-
Complete COVID-19 vaccination, n (%)	1815 (93.8)	471 (97.1)	341 (84.2)	271 (97.5)	325 (94.8)	402 (96.2)
Cardiovascular risk, n (%)						
Hypertension[1]	249 (12.9)	55 (11.3)	42 (10.4)	25 (9.0)	47 (13.7)	77 (18.4)
Diabetes[2]	131 (6.8)	17 (3.5)	30 (7.4)	24 (8.6)	27 (7.9)	32 (7.7)
High cholesterol[3]	365 (18.9)	87 (17.9)	75 (18.5)	45 (16.6)	67 (19.5)	89 (21.3)
Obesity[4]	233 (15.1)	72 (14.8)	78 (19.3)	32 (11.5)	37 (10.8)	73 (17.5)
Current Smoking[5]	275 (14.2)	86 (17.7)	68 (16.8)	47 (16.9)	24 (7.0)	48 (11.5)
Insufficient PAL[6]	859 (44.4)	249 (51.3)	166 (41.0)	117 (42.1)	145 (42.3)	179 (42.8)
Depression symptoms[7]	236 (12.2)	48 (10.0)	65 (16.0)	65 (23.2)	40 (11.6)	18 (4.2)

PAFIT online survey was conducted between June 2021 and January 2023

1. Hypertension or high blood pressure told by a doctor or other health worker (excluding diagnoses made during pregnancy)

2. Diabetes or high blood sugar told by a doctor or other health worker (excluding diagnoses made during pregnancy)

3. High cholesterol told by a doctor or other health worker

4. Obesity was defined as BMI ≥ 30

5. Current Smoking was defined as those who are currently smoking tobacco products, such as cigarettes, cigars, or pipes

6. Insufficient PAL was defined as less than 600 METs/min/week

7. Depressive symptoms told by a doctor or other health worker

interquartile range [IQR], 0—240 vs. 0 METs/min/week: 0—30; $p = 0.032$) and active transportation domains (0 METs/min/week: 0—693 vs. 0 METs/min/week: 0—594; $p < 0.008$). In addition, the median sedentary time on weekdays increased by 60 min per day (360 min/day: [240—540] to 420 min/day: [240—600]; $p < 0.001$). (Table 2).

The proportion of participants with low eCRF increased significantly by 3.8 percentage points in the total sample comparing pre-pandemic to survey time (from 15.5% to 19.3%, $p < 0.001$, primarily due to increases in Argentina, Brazil, and Colombia (Fig. 3B).

In the pooled sample from all countries, the estimated $\dot{V}O_{2max}$ at the time of the survey was significantly lower than pre-pandemic values, both unadjusted (mean difference, −1.17 mL/min/kg: 95% CI, −1.03 to −1.30) and adjusted for age (−0.50 mL/min/kg: −0.37 to −0.64). We observed the same pattern of significant reductions in all countries (Table 2 and Fig. 4). Also, we found no significant influence of the self-reported diagnosis of COVID-19 and the decline in eCRF in mL/min/kg in the total sample both for unadjusted (non-COVID-19: −1.318 vs. COVID-19, −1.239, $p > 0.05$) and adjusted for age (non-COVID-19: −0.545 vs. COVID-19, −0.464, $p > 0.05$).

Discussion

This cross-sectional survey of adults residing in five South American countries observed no overall or leisure time physical activity change. Still, we noted reduced work and transport-related activities, increased sedentary time, and lower estimated $\dot{V}O_{2max}$ when comparing post-pandemic with pre-pandemic levels. Beyond the decline in eCRF, we observed a slight rise in the proportion of individuals with low eCRF regardless of history of COVID-19 infection. Although recent studies have

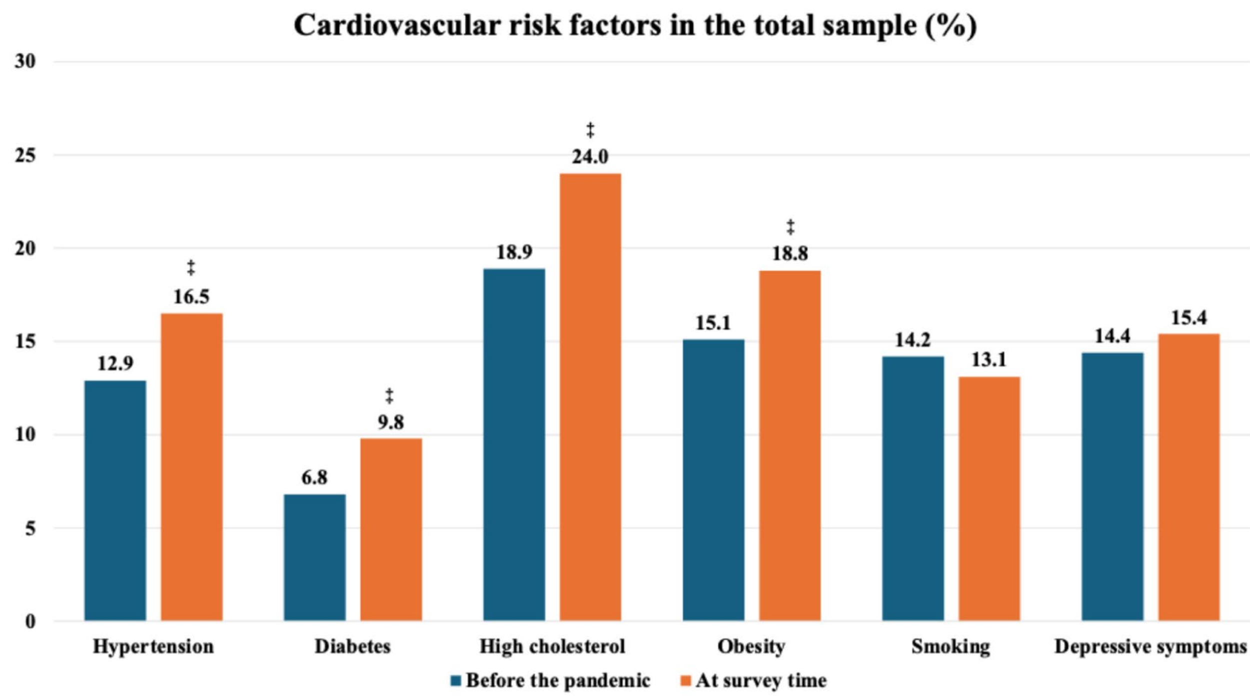

Fig. 2 Self-reported prevalence of cardiovascular risk factors and depression symptoms before the pandemic and at the time of the survey. PAFIT online survey was conducted between June 2021 and January 2023. ‡$p < 0.05$

shown that patients infected with COVID-19 significantly decreased aerobic capacity [22–24], our findings reinforce that not only did the infection affect the population's health, but also the restrictive measures of the pandemic may have had an effect.

Several studies have evaluated changes in CRF related to the COVID-19 pandemic. However, most were restricted to the lockdown period, primarily assessing children and adolescents, and involved participants mainly from high-income countries [25–29]. Additionally, studies that investigated these changes in CRF directly through gas analyzers are scarce and, when available, involved a limited number of homogeneous individuals [30, 31].

Our findings align with those previously described, with eCRF values remained below pre-pandemic levels even one year after the pandemic was under control [32]. Martinko et al. [32] examined the long-term impact of COVID-19 restrictions on children's physical fitness. Data from 41,330 Slovenian children aged 5–17 showed a significant drop-in overall fitness across all weight categories between 2019 and 2020. Although fitness levels recovered slightly by 2022, they remained well below pre-pandemic levels, with one of the most significant declines in CRF. In adults, a retrospective study [33] investigated changes in physical fitness among first-year university students over the course of a year during the COVID-19 pandemic (2019—2020). Comparing 2,239 participants from the 2020 cohort to a historical control group, the study found significant declines in fitness due to the lockdowns. The mean time for the 1000-m run in the study group, a proxy of CRF, was lower, approximately 2% in males and 4.7% in females.

The eCRF decline we observed in the present study was more significant than expected due to aging. We observed an average decrease of 1.17 mL/min/kg (3.34%) for 28 months, representing an annualized rate of decline of 1.45% per year. This finding is more pronounced than patterns observed in previous studies [34]. In Brazilians undergoing cardiopulmonary exercise testing on a treadmill, declines of around 9% per decade of ($\dot{V}O_{2max}$) were noted in both men and women [35]. Notably, Letnes et al. [34] conducted a review of various ($\dot{V}O_{2max}$) prediction studies, commonly reporting an absolute change of approximately −0.3 to −0.5 mL/min/kg per year, with a generally acceptable linear decline of around 10% per decade (annualized rate of decline of 1%). Alternatively, using baseline age in our estimated CRF, we estimated an average decline of 0.5 mL/min/kg (1.45%) for 28 months, i.e., an age-adjusted annualized decline rate of 0.63%.

Only a few studies have directly assessed the long-term changes in CRF during the COVID-19 pandemic. These studies, which used small and homogeneous samples,

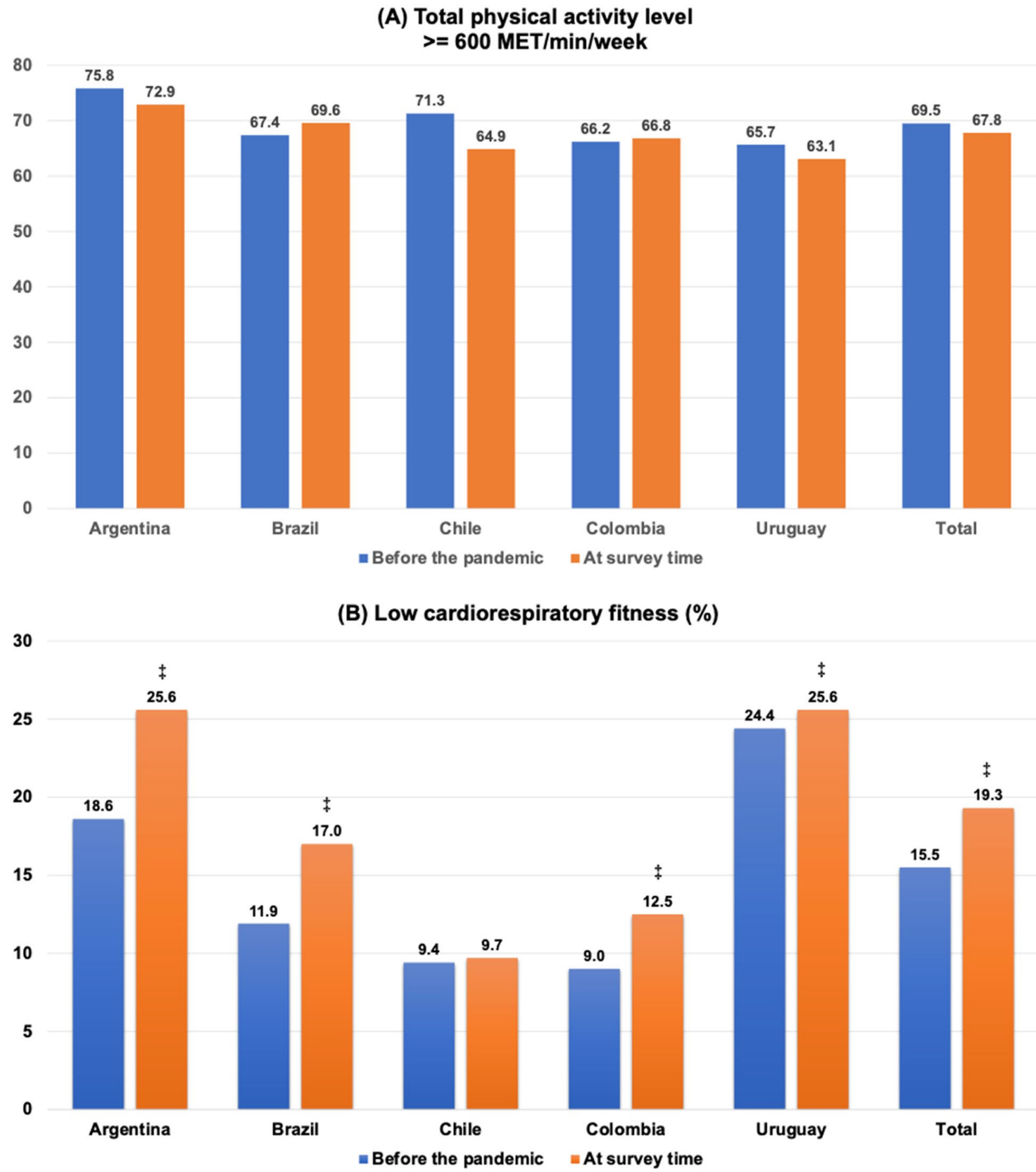

Fig. 3 Self-reported prevalence of cardiovascular risk factors and depression symptoms before the pandemic and at the time of the survey. PAFIT online survey was conducted between June 2021 and January 2023. ‡ $p < 0.05$. **A** Proportion of physically active participants (≥ 600 METs/min/week). **B** The proportion of participants with ow age-adjusted estimated cardiorespiratory fitness (≤ 8 metabolic equivalents (28 mLO_2•kg^{-1}•$min.^{-1}$))

suggested that the impact of the COVID-19 pandemic on CRF may be substantially worse than what was estimated in the present study. Over the 3-year study period, industrial workers experienced a significant decrease in $\dot{V}O_{2max}$ from 39.6 to 34.0 mLO_2•kg^{-1}•min^{-1}, equating to an annual loss of 4.6% [30]. Another study examined the impact of the COVID-19 pandemic on CRF in 14 young healthy adults [31]. The authors assessed fitness before the

Table 2 Estimated cardiorespiratory fitness, physical activity levels, and sedentary time "Before" the pandemic and at the time of the survey response

	Before pandemic	At survey
Estimated cardiorespiratory fitness (mL/min/kg)		
Unadjusted for age	35.0 ± 7.0	33.9 ± 6.8‡
Adjusted for age	34.4 ± 7.0	33.9 ± 6.8‡
Physical activity (MET/min/week)		
Total	1,768 (360—4,410)	1,685 (248—4,190)
Work	0 (0—240)	0 (0—30)‡
Transportation	0 (0—693)	0 (0—594)‡
Leisure	720 (0—2,400)	720 (0—2,400)
Sedentary time (min)		
Weekend	300 (180—480)	300 (196—480)
Weekday	360 (240—540)	420 (240—600)‡

Data presented as mean ± standard deviation or median (interquartile range). ‡: $p < 0.05$; before the pandemic vs. at the survey time

pandemic and after one year of public health measures. Changes in CRF were even more prominent than those mentioned above (roughly 7 $mLO_2 \cdot kg^{-1} \cdot min^{-1}$) [31].

As observed in this study, the amount of leisure-time physical activity did not differ between the pre-pandemic period and the survey time. However, work and transportation-related activity declined, and sedentary time increased. Indeed, the number of steps, a proxy of PA, of 1,255,811 individuals from 200 countries fell sharply in January 2020, with South America being the region with the most significant decline (29%) and, although it returned to levels very close to pre-pandemic levels in January 2022, it remained globally at 97% of pre-pandemic values [36]. These results suggest that not all PA domains may have returned to pre-pandemic values.

Our study could not assess changes in PAL between the pre-pandemic period and during the pandemic at the height of restrictive measures. However, according to recent studies, leisure-time PAL returned to its pre-pandemic levels after a likely decrease during lockdowns. For example, [37] in a sample of 2773 asymptomatic adults that provided physical activity data by an online survey administered from July to October 2023, a reduction in total PAL between pre-pandemic and during the pandemic and a return to post-pandemic PA levels was observed. Furthermore, insufficiently active participants increased from 25 to 56% during the pandemic and returned to 25% post-pandemic [37].

Although leisure-time PAL has been described as the primary determinant of CRF [38], eCRF in the present study remained significantly lower at the survey time despite the "recovery" of leisure-time PAL. While occupational physical activity may not have the same beneficial health effects as leisure PAL [39], transportation activity can significantly reduce disability-adjusted life-years [40]. As for sedentary behavior, it is directly related to a higher risk of all-cause mortality and cardiovascular events, especially in individuals with low PA [41, 42] and low CRF [43].

Indeed, a recent meta-analysis (primarily small, low-quality) of randomized controlled trials of reducing sedentary time has shown a moderate impact on improving CRF [44]. Therefore, we might speculate that the decline in eCRF in our study could be related to the observed reductions in work and transport-related PA and the increase in sedentary time.

Latin American countries implemented various social restrictions in response to the COVID-19 pandemic, such as travel bans, school closures, and workplace shutdowns, though the stringency differed [45]. Argentina imposed one of the strictest and earliest lockdowns, while Colombia initially had strict measures but later adopted localized restrictions. Chile maintained stringent localized quarantines, easing as vaccinations rose. Uruguay pursued voluntary social distancing with a less restrictive approach but saw early success. Brazil's response was inconsistent, with regional variations and moderate restrictions, primarily due to political differences [45]. Despite these variations, the study's overall findings were consistent across countries, suggesting a negative impact of social restrictions on PAL and CRF, regardless of the timing and severity of those restrictions. Indeed, one of the primary early worries focused on whether measures like social distancing, school and business closures, and stay-at-home orders would reduce PA and increase sedentary behavior (SB). Current evidence confirms these initial concerns—the COVID-19 pandemic has exacerbated the PA/SB crisis [46].

Moreover, our sample was composed primarily of women. It has been suggested that women, who commonly have lower levels of physical activity (e.g., pre-pandemic), showed a smaller reduction in activity compared to men during the lockdown, demonstrating greater resilience to the impact of the pandemic [47]. In this context, the non-significant differences described here may be related to our sample's higher proportion of women [48].

On the one hand, our sample may have been subject to a recall bias due to the large proportion of participants with a high level of education. On the other hand, standard PA questionnaires often require respondents to recall and sum their activity levels across different domains over a recent time period. Individuals with lower education may struggle more with interpreting and accurately answering these questions. Therefore, the high level of education in our sample likely minimized such bias [48–50].

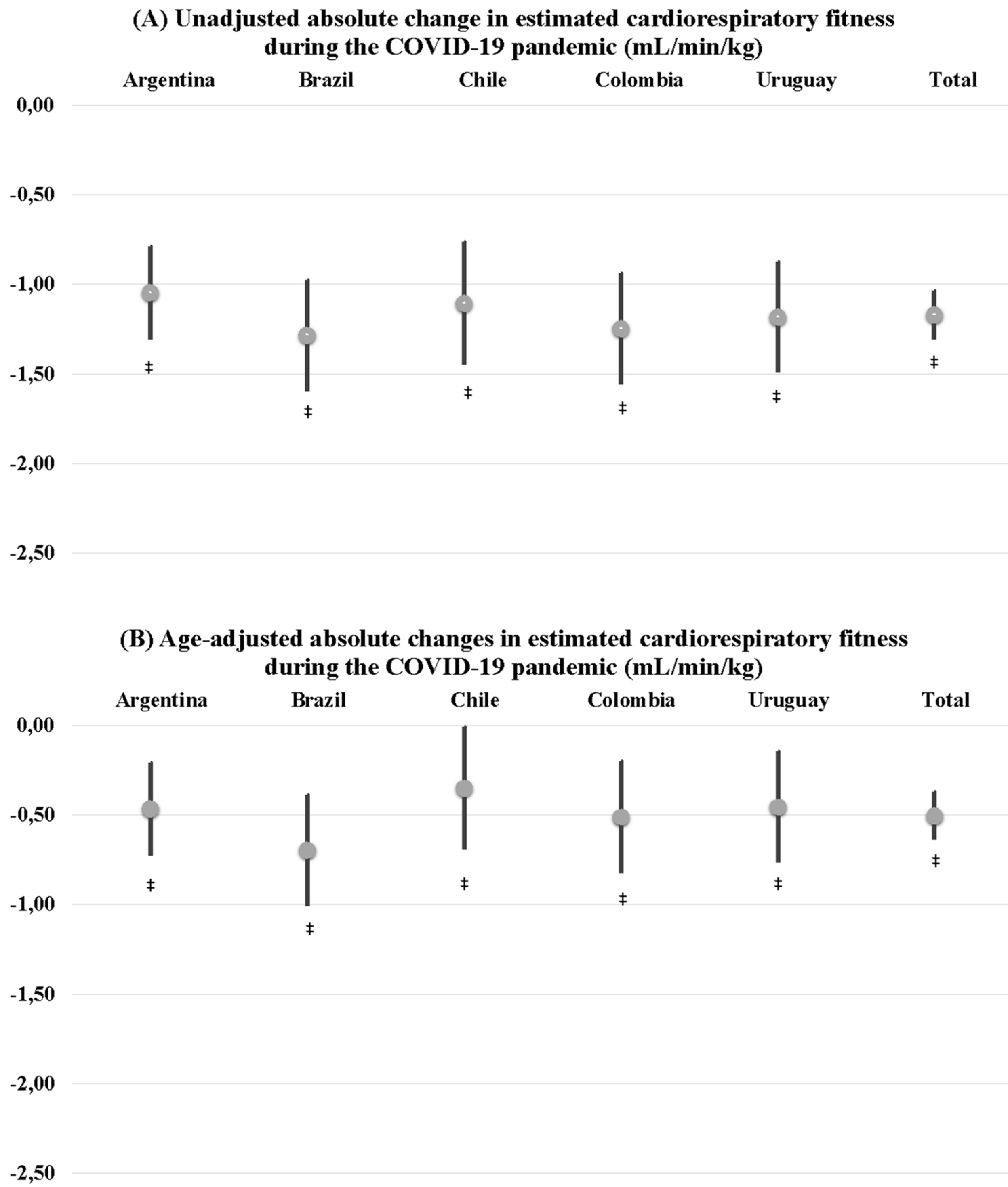

Fig. 4 Mean absolute change in estimated cardiorespiratory fitness from "Before" the pandemic up to the time of the survey response. Estimated cardiorespiratory fitness and 95% confidence intervals expressed in $mLO_2 \cdot kg^{-1} \cdot min^{-1}$. **A** Unadjusted. **B** Adjusted for age

A key strength of this study is its focus on South American participants, providing valuable insights into a population that is underrepresented in global health literature. Furthermore, we utilized a validated questionnaire to assess physical activity, ensuring consistency and reliability in data collection. Finally, we used a validated prediction of $\dot{V}O_{2max}$ recently developed for Brazilians who present similar sociodemographic characteristics to the remaining four countries included in the present study [20].

There is a lack of validated $\dot{V}O_{2max}$ prediction equations specific to Argentina, Colombia, Chile, or Uruguay, as existing studies either use field tests in adolescents or involve populations that are not comparable to the general adult population, or they overestimate $\dot{V}O_{2max}$ values compared to the equation used here [51–56]. While this may seem like a limitation, prior research using the six-minute walk test showed similar performance among Colombians, Uruguayans, and Brazilians, suggesting comparable cardiorespiratory fitness [57]. By applying a standardized equation without a country-specific coefficient related to the United States, and observing similar self-reported patterns of cardiovascular risk and physical activity across countries, the study reasonably speculates that CRF trends were likely similar among the populations examined.

On the other hand, the present study has more significant limitations. Unfortunately, based on our cross-sectional design, it remains unclear whether the decline in eCRF led to an increase in the risk of hypertension/diabetes/dyslipidemia or vice versa. Furthermore, because conditions such as hypertension, dyslipidemia, and diabetes have a silent and slow progression, participants who reported having been diagnosed at the time of the survey may have already been affected by undiagnosed hypertension/diabetes/dyslipidemia. It's also possible that the pandemic made some participants more health-conscious, leading to improved diagnoses of chronic conditions. Another limitation is sample selection bias, as online surveys often cannot reach individuals without Internet access, older adults, or those facing various health disparities due to socio-economic factors. The results showed consistency across countries despite variations in pandemic-related restriction levels. However, due to the highly educated nature of the sample, caution is warranted in interpreting these findings. The distribution of MET-min/week in the PA work and transportation domains exhibited medians near zero and wide interquartile ranges, potentially obscuring the true variability in PA within these domains during the study period. This pattern likely arose because some participants reported no PA in these domains. Although sedentary behaviour tends to be underestimated by the GPAQ when compared to accelerometers [58], the questionnaire was applied uniformly before and after the pandemic. Therefore, the net change in sedentary time is less likely to be affected by this bias.

Accordingly, the results do not represent the general population of the participating countries. Recall bias could also affect the results. Highly educated individuals tend to have stronger comprehension of abstract time frames and conceptual distinctions (e.g., recognizing pre- and post-pandemic behavior differences). They also often possess greater health literacy and survey experience, enhancing response accuracy. Nevertheless, even among this group, recall bias can persist, particularly with longer retrospective periods. To mitigate this, an internationally validated physical activity questionnaire (GPAQ), enhanced with an event-based recall method, was integrated into the study. This approach included specific temporal clarifications to help participants accurately differentiate between their pre-pandemic and current activity levels (See method section) [59].

Conclusions

In conclusion, COVID-19 restrictions contributed to long-term declines in work and transport-related PAL and eCRF, alongside increased cardiovascular risk factors in a sample of South American adults. These findings highlight the need for public health authorities to weigh the unintended effects of social restrictions, especially on physical activity, when responding to future epidemics. Since cardiorespiratory fitness is vital for health and longevity, the pandemic's impact could have lasting consequences. National and global health bodies should prioritize safe, accessible exercise options during future public health crises, such as outdoor exercise programs and telehealth fitness initiatives.

Abbreviations

PA/PAL	Physical Activity Level
$\dot{V}O_{2max}$	Maximum Oxygen Uptake
CRF	Cardiorespiratory Fitness
eCRF	Estimated Cardiorespiratory Fitness
MET	Metabolic Equivalents
PA&FIT	Lown Scholars in Physical Activity and Fitness Network
GPAQ	Global Physical Activity Questionnaire
BMI	Body Mass Index

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s13690-025-01664-7.

Supplementary Material 1.

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Authors' contributions

RP and VZD are the principal investigators of the present study. VZD was responsible for the full access to the study's data and took responsibility for its integrity and accuracy. VZD also conducted most of the data analysis. VZD and RP wrote the first version of the manuscript. GD is the chair of the Lown

Scholars Program and was responsible for the orientation and revision of the present paper until this submission version. MSMPS was the Co-Principal Investigator in Brazil, and VZD designed online surveys in RedCap and revised the final version of this manuscript for submission. VTL was the coordinator of the survey distribution in Brazil. MSMPS and VTL also wrote the manuscript draft and approved the final version. AO was the Co-Principal Investigator in Uruguay. RPS, IPG, and SLA were local principal investigators in Colombia, Chile, and Uruguay. They were responsible for the survey management in their countries and the reading and approval of this submitted paper version. ISW and LAS are Lown Scholars who contributed significantly to the data interpretation and endorsement of the final version. They are principal investigators responsible for conducting surveys in Indonesia and Lebanon. All the authors approved the final version of the manuscript.

Authors' information

As the Title Page shows, most authors in the present study are from the Bernard Lown Scholars in Cardiovascular Health Program at Harvard T.H. Chan School of Public Health.

The Lown Scholars Program develops an international network of health professionals dedicated to preventing cardiovascular diseases and promoting heart health in developing countries, as recognized by the United Nations. Since 2008, the program has supported over 80 scholars from Asia, Latin America, Africa, and the Middle East, fostering long-term collaborations with the faculty of Harvard T.H. Chan School of Public Health.

Named in honor of Dr. Bernard Lown, a pioneering cardiologist and public health activist, the program currently supports 104 health professionals from 25 countries. Their work focuses on universal primary healthcare, cardiovascular health in urban populations, and the impact of psychosocial stress on cardiovascular disease. The program aims to create enduring partnerships between Lown Scholars and Harvard faculty.

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Data availability

Because this is a multi-country study, we want to state other research questions. Thus, the datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

The present Multi-country Study was approved by all the local Ethics Committees: *Comitê de Ética em Pesquisa com Seres Humano da Universidade Federal de São Paulo (UNIFESP)*, Brazil (#5.453.598), *Comitéde Bioética e Ética de la Investigación de Cátedra de Salud Pública, Facultad de Ciencias Médicas, Universidad Nacional de La Plata,* Argentina (Ref. 116); *Comité de Ética em Investigación con Seres Humanos de la Universidad de Chile, Facultad de Medicina*, Chile (#020–2022/053), *Comité de Ética de la Investigaón de la Facultad de Medicina, de la Universidad de los Andes*, Colombia (#20220703), and *El Comité de Ética en Investigación con Seres Humanos de la Universidad Católica del Uruguay*, Uruguay (#20/05/2022), following the Declaration of Helsinki.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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