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Covid-19 pandemic, fitness and health outcomes in older adults with hypertension: a longitudinal study

Pandemia de covid-19, aptidão física e desfechos de saúde em pessoas idosas com hipertensão: um estudo longitudinal

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ABSTRACT

Objective: This study examined changes in cardiovascular health-related outcomes, movement behaviors, and body composition in older adults with hypertension 15 months after the onset of the covid-19 pandemic. Methods: Fifteen older adults were included in this longitudinal study with a 15-month follow-up. Assessments included cardiac structure and function, vascular health markers (arterial stiffness, endothelial function, and carotid intima-media thickness), 24-hour blood pressure and heart rate variability, cardiorespiratory fitness, accelerometer-based physical activity (PA) and sedentary behavior (SB), and body composition. Generalized linear mixed models were used for data analysis. Results: After 15 months, participants showed a significant increase in SB (β = 41 min/day; p = 0.007), a reduction in light-intensity PA (β = −39 min/day; p = 0.008), a decrease in step count (β = −1,343 steps/day; p = 0.002), and a reduction in peak oxygen uptake (β = −1.7 mL/kg/min; p = 0.034). A small but significant decrease was also observed in left ventricular posterior wall thickness (β = −0.5 mm; p = 0.046). No significant changes were found in other outcomes (p > 0.05). Conclusion: Deleterious changes in movement behaviors and cardiorespiratory fitness were observed 15 months after the onset of the covid-19 pandemic in older adults with hypertension, despite the absence of significant changes in a broader range of cardiovascular health-related outcomes.

Keywords: Covid-19, Echocardiography, Cardiopulmonary exercise test, Sedentary behavior, Physical activity.

RESUMO

Objetivo: Este estudo examinou as mudanças em desfechos relacionados à saúde cardiovascular, comportamentos de movimento e composição corporal em pessoas idosas com hipertensão após 15 meses do início da pandemia de covid-19. Métodos: Quinze pessoas idosas foram incluídas neste estudo longitudinal com acompanhamento de 15 meses. As avaliações incluíram estrutura e função cardíaca, marcadores de saúde vascular (rigidez arterial, função endotelial e espessura médio-íntimal da carótida), pressão arterial de 24 horas e variabilidade da frequência cardíaca, aptidão cardiorrespiratória, atividade física (AF) e comportamento sedentário (CS) avaliados por acelerometria e composição corporal. Modelos lineares generalizados de efeitos mistos foram utilizados para a análise dos dados. Resultados: Após 15 meses, os participantes apresentaram aumento significativo do CS (β = 41 min/dia; p = 0,007), redução da AF de intensidade leve (β = −39 min/dia; p = 0,008), diminuição da contagem de passos (β = −1.343 passos/dia; p = 0,002) e redução do consumo máximo de oxigênio (β = −1,7 mL/kg/min; p = 0,034). Observou-se também uma pequena, porém significativa, redução na espessura da parede posterior do ventrículo esquerdo (β = −0,5 mm; p = 0,046). Não foram encontradas alterações significativas nos demais desfechos (p > 0,05). Conclusão: Alterações deletérias nos comportamentos de movimento e na aptidão cardiorrespiratória foram observadas 15 meses após o início da pandemia de Covid-19 em pessoas idosas com hipertensão, apesar da ausência de mudanças significativas em uma gama mais ampla de desfechos relacionados à saúde cardiovascular.

Palavras-chave: *Covid-19; Ecocardiograma; Teste de exercício cardiopulmonar; Comportamento sedentário; Atividade física.*

Introduction

Cardiovascular disease remains the leading cause of death worldwide, accounting for 17.7 million deaths in 2017[1]. Among older adults, the burden of cardiovascular disease is particularly high, with hypertension being the most prevalent modifiable risk factor, affecting over two-thirds of individuals aged 60 and above[2]. The covid-19 pandemic has introduced additional challenges that may have heightened cardiovascular risk, especially among older adults, who were disproportionately affected by its indirect consequences. Social distancing, lockdowns, and disruptions in healthcare services reduced opportunities for regular physical activity (PA) and increased sedentary behavior (SB) in this population[3].

Behavioral changes, including reduced PA and increased SB, have been observed in older adults with hypertension during periods of social isolation[4,5]. Such changes have been accompanied by impairments in body composition and cardiorespiratory fitness (CRF), both of which are independently associated with increased cardiovascular disease risk[6,7]. While previous studies have explored behavioral changes linked to cardiovascular disease risk during the early phases of the pandemic[8,9], few have examined its long-term impact on cardiovascular health outcomes, movement behaviors (PA and SB), and body composition. Therefore, this study aimed to assess a broader range of cardiovascular health-related outcomes, movement behaviors, and body composition in older adults with hypertension 15 months after the onset of the covid-19 pandemic.

Methods

Study design

This longitudinal exploratory study was conducted at the Onofre Lopes University Hospital and the Department of Physical Education at the Federal University of Rio Grande do Norte between January 2020 and July 2021. The study followed the principles outlined in the Declaration of Helsinki and was approved by the Research Ethics Committee of the Onofre Lopes University Hospital (protocol no. 3.180.310/2019). All participants received detailed information about the study procedures and provided written informed consent.

Participants

Participants in the current study were originally recruited for the HEXA Study, a clinical trial investigating different exercise training approaches in older adults with hypertension[10]. Between January 24 and March 10, 2020, a total of 41 individuals were screened and met the eligibility criteria: aged 60-80 years; medical diagnosis of hypertension without uncontrolled blood pressure; physically inactive; no history of cardiovascular events or other cardiovascular diseases; no contraindications to exercise; and no progressive neurological disorders. These participants completed baseline assessments, which included a comprehensive evaluation of cardiovascular health-related outcomes, accelerometer-measured movement behaviors, and body composition via bioelectrical impedance analysis. Following the first confirmed case of covid-19 in Natal, RN, Brazil, the HEXA Study was suspended on March 12, 2020. Subsequently, in June 2020, 35 of the original 41 participants agreed to take part in a follow-up assessment involving one week of accelerometer wear and a telephone-based questionnaire. Sterilized accelerometers were delivered to participants' homes between June 1 and June 3, 2020[4,5]. Fifteen months after the baseline, all 35 participants were recontacted and invited to participate in the present longitudinal exploratory study. However, only 15 participants completed all assessments at both time points and were included in the final analysis. The main reasons for attrition included refusal to attend in-person assessments due to covid-19–related concerns, health-related issues unrelated to the study, and one death attributed to coronavirus disease.

Study procedures

Data collection followed a standardized four-day protocol. On day 1, resting brachial blood pressure, cardiopulmonary exercise testing, and accelerometer placement were performed. On day 2 (one week later), participants returned for accelerometer removal, bioelectrical impedance analysis, carotid intima-media thickness via ultrasound, and echocardiography. Day 3 involved the assessment of arterial stiffness and central blood pressure, along with the installation of 24-hour ambulatory blood pressure monitoring and a 24-hour Holter monitoring. On day 4, both ambulatory blood pressure monitoring and Holter devices were removed. After 15 months, the second wave of data collection followed the same procedures, which occurred between June 4 and July 17, 2021. By that time, all participants had received at least the first dose of a covid-19 vaccine. Recruitment for the second wave of the data collection was conducted via telephone.

Cardiovascular health-related outcomes

- **Cardiac structure and function**

Echocardiographic assessments were performed by an experienced sonographer using a high-resolution ultrasound system (Vivid I, GE Healthcare, USA) equipped with a 2.5 MHz sector transducer, following the guidelines of the American Society of Echocardiography[11]. Two-dimensional images were acquired in the parasternal long-axis view to evaluate structural and functional cardiac parameters, including interventricular septal thickness (IVS), posterior wall thickness (PW), and left ventricular end-diastolic (LVEDD) and end-systolic diameters (LVESD). Relative wall thickness (RWT) was calculated as: (2 × PW thickness) / LVEDD. Left ventricular volumes (end-diastolic and end-systolic) and ejection fraction (LVEF) were estimated using the Teichholz method. Diastolic function was assessed by measuring early (E wave) and late (A wave) diastolic filling velocities of the mitral valve using pulsed-wave Doppler in the apical four-chamber view. Early diastolic tissue velocity (E′) was recorded at the lateral mitral annulus. The E/A and E/E′ ratios were then calculated. Left atrial (LA) volume was determined using the biplane method of disks from apical four- and two-chamber views.

- **Resting and 24-h ambulatory blood pressure**

Resting blood pressure was measured in triplicate, with one-minute intervals between measurements, in a standardized seated position[12]. Prior to the installation of the ambulatory blood pressure monitoring, inter-arm systolic blood pressure differences were checked; if the difference was less than 10 mmHg, the device was placed on the non-dominant arm[13]. Ambulatory blood pressure monitoring was conducted using the CardioMAPA device (Cardios, Brazil) over a 24-hour period, with readings taken every 15 minutes during waking hours and every 30 minutes during sleep. For data to be considered valid, a minimum of 16 readings during wakefulness and 8 during sleep were required[13]. Mean systolic and diastolic blood pressure values were calculated for the full 24-hour period, as well as separately for awake and asleep periods.

- **24-h heart rate variability**

Heart rate variability (HRV) was assessed concurrently with ambulatory blood pressure monitoring using the CardioMAPA device and a 24-hour Holter ECG system. Heart rate variability was analyzed in both time and frequency domains. Three ECG leads were recorded continuously, and the data were segmented into 5-minute intervals. Abnormal R-R intervals were excluded from the analysis, and only normal-to-normal (NN) intervals were retained. Participants were instructed to refrain from PA on the day of assessment to avoid external influences on autonomic regulation. Time- and frequency-domain HRV parameters were analyzed using the CardioManager system (Cardios, Brazil). Time-domain metrics included the mean interval between normal beats (NNmd), standard deviation of all NN intervals (SDNN), SDNN index, root mean square of successive differences (rMSSD), and the percentage of successive NN intervals differing by more than 50 ms (pNN50)[14]. Frequency-domain analysis was performed using fast Fourier transform (FFT), with parameters including normalized low-frequency (LF: 0.05-0.15 Hz) and high-frequency (HF: 0.15-0.4 Hz) components, and the LF/HF ratio. HF is indicative of parasympathetic activity, LF reflects sympathetic modulation, and the LF/HF ratio represents the sympathovagal balance[14].

- **Arterial stiffness**

Arterial stiffness was assessed by measuring aortic pulse wave velocity (aPWV) using the DynaMapa AOP device (Cardios, São Paulo, Brazil). This non-invasive oscillometric device captures brachial blood pressure waveforms and estimates aPWV through pulse wave and wave separation analyses using the ARCSolver algorithm (Austrian Institute of Technology, Vienna, Austria)[15]. The aPWV measurements obtained with this device have been validated against invasive intra-aortic catheterization and non-invasive applanation tonometry methods[16,17]. In the present study, aPWV was measured on the left arm with participants in a supine position after 10 minutes of rest in a quiet, temperature-controlled room (24-26 °C). Four measurements were taken at one-minute intervals, following the manufacturer's protocol. Additional hemodynamic variables included: 1) central systolic, diastolic, and mean blood pressure, 2) brachial systolic, diastolic, and mean blood pressure, and 3) central and brachial pulse pressure.

- **Endothelial function**

Endothelial function was assessed via flow-mediated dilation of the brachial artery using ultrasound, following the protocol described by Harris et al.[18] Participants rested for at least 20 minutes in a quiet, temperature-controlled room prior to the assessment. The brachial artery was located using color Doppler imaging, approximately 2-5 cm above the cubital crease. A high-resolution ultrasound device (Vivid I, GE Healthcare, USA) equipped with a 5-10 MHz linear transducer was used to measure arterial diameter and blood flow velocity in duplex mode. Vascular occlusion was performed on the ipsilateral forearm using a cuff placed approximately 5 cm below the cubital fossa and inflated to 50 mmHg above the participant's baseline systolic blood pressure for 5 minutes. Ultrasound images were continuously recorded for 1 minute at baseline, during the occlusion period, and for up to 3 minutes following cuff deflation (reactive hyperemia). All images were stored and later analyzed using flow-mediated dilation Studio software (Quipu, Italy), which automatically identified arterial walls and calculated diameters. The baseline diameter was defined as the 1-minute average before cuff inflation, and the peak diameter was identified as the maximum value recorded after cuff release. Flow-mediated dilation was expressed as the percentage increase from baseline to peak arterial diameter.

- **Cardiorespiratory fitness**

Peak oxygen uptake (VO_2peak) was assessed using a maximal cardiopulmonary exercise testing performed on a treadmill with a ramp protocol[19]. The protocol began at 2.5 km/h with 0% incline for females and 3.5 km/h with 0% incline for males, followed by progressive increases of 0.4 km/h in speed and 0.6% in grade per minute[10]. The test was considered maximal if at least two of the following criteria were met[19]: i) heart rate exceeding 95% of the age-predicted maximum (220 – age); ii) respiratory exchange ratio (RER; VCO_2/VO_2) > 1.15; and iii) rating of perceived exertion (RPE) > 17 on the Borg scale. VO_2peak was defined as the highest 30-second average of VO_2 recorded at the end of the test[20]. The gas analyzer was calibrated prior to each test according to the manufacturer's instructions (VO2000, MedGraphics, USA). Participants were thoroughly briefed on test procedures in advance[19].

- **Accelerometer-measured movement behaviors**

Accelerometer-measured movement behaviors were assessed using the ActiGraph GT3X+ device (ActiGraph LLC, Pensacola, USA). Participants were instructed to wear the device on the right hip for seven consecutive days, including both waking and sleeping periods, and to remove it only for bathing or water-based activities. A diary was provided to record times when the accelerometer was removed during waking hours, as well as bedtime and wake-up times. The device was configured with a sampling rate of 60 Hz and a 60-second epoch length. A default filter was applied to minimize overestimation of daily step counts. Non-wear time was defined as ≥ 90 consecutive minutes of zero counts, allowing for up to 2 minutes of interruptions with counts ≥ 100 counts/min[21]. Data were considered valid if participants had at least three valid weekdays (≥ 600 minutes/day) and one valid weekend day, for a total of at least four valid days[20]. PA intensity was categorized using established cut-offs in counts per minute: SB 0-99, light PA 100-1951, and moderate-to-vigorous PA ≥ 1952 counts/min[22]. Daily step count was calculated as the total number of steps divided by the number of valid wear days. Accelerometer data were processed and analyzed separately for weekdays and weekends using ActiLife software version 6.13.3.2.

- **Body composition**

Body composition parameters, including total body weight (kg), body mass index (BMI, kg/m^2), body fat percentage (%), fat mass (kg), and skeletal muscle mass (kg), were estimated using tetrapolar bioelectrical impedance analysis with an eight-electrode system (InBody 270, Ottoboni®, Brazil), following the standard protocol recommended by the manufacturer and standardized guidelines[23]. Height was measured using a stadiometer integrated into a digital scale (W300, Welmy®, Brazil).

Statistical analysis

Descriptive data for participant characteristics are presented as mean ± standard deviation (SD) for continuous variables and as absolute and relative frequencies (%) for categorical variables. A generalized linear mixed model was used to examine longitudinal changes in the outcomes of interest. In this model, time and relevant covariates were treated as fixed effects, and subject was included as a random effect to account for intra-individual variability. Models were adjusted for age and history of covid-19 infection. For movement behavior outcomes, models were additionally adjusted for accelerometer wear time. Robust estimation was applied for fixed effects. Results are reported as estimated marginal means, regression coefficients (β), and 95% Wald confidence intervals. Residual distributions were evaluated using normal Q–Q plots. All statistical tests were two-tailed, and p-values < 0.05 were considered statistically significant. Analyses were conducted using IBM SPSS Statistics for Windows, version 27.0 (IBM Corp., Armonk, NY, USA).

Results

A total of 15 participants completed all baseline and 15-month follow-up assessments and were therefore included in the final analysis. Baseline characteristics are presented in Table 1. The sample was predominantly composed of older women (73.3%), with a mean age of 66.5 ± 3.9 years and an average hypertension duration of 15.6 ± 10.3 years. Most participants were classified as having normal weight (66.7%). Dyslipidemia was present in 93.3% of the sample, and 40% had a diagnosis of type 2 diabetes. At the time of data collection, 40% reported a previous covid-19 infection, and 73.3% were fully vaccinated.

Cardiac structure/function and vascular measures

After 15 months, a modest yet statistically significant reduction was observed in left ventricular posterior wall thickness (β = −0.5 mm; 95% CI: −1.0 to 0.0; p = 0.046). No significant changes were detected in other cardiac structural parameters, including interventricular septum thickness, left ventricular mass index, ejection fraction, or left atrial volume. As for vascular measures, no significant changes were found over time in aPWV, augmentation index, endothelial function markers, or carotid intima-media thickness (p > 0.05). Conversely, there was a significant reduction in VO_2peak after 15 months (−1.7 mL/kg/min; 95% CI: −3.3 to −0.1; p = 0.034).

Table 1 - Characteristics of participants (n = 15)

Variables	Mean ± standard deviation or n (%)
Female	11 (73.3)
Age, years	66.5 ± 3.9
Living with a partner	7 (46.7)
Post-secondary education	6 (40.0)
Hypertension diagnosis, years	15.6 ± 10.3
Body mass index, kg/m^2	26.7 ± 3.4
Overweight	3 (20.0)
Obesity	2 (13.3)
Ex-smoker	3 (20.0)
Type 2 diabetes	6 (40.0)
Dyslipidemia	14 (93.3)
Antihypertensive medication	
Monotherapy	5 (33.3)
Combination therapy	10 (66.7)
Angiotensin Converting Enzyme inhibitors	1 (6.7)
Angiotensin II receptor blockers	12 (80.0)
Beta–blockers	4 (26.7)
Calcium channel blockers	4 (26.7)
Diuretics	8 (53.3)
Covid-19 infected	6 (40.0)
Covid-19 vaccine	
CoronaVac	10 (66.7)
AstraZeneca/Oxford	4 (26.7)
Pfizer	1 (6.7)
Partially vaccinated	4 (26.7)
Fully vaccinated	11 (73.3)

Values expressed as mean ± standard deviation or absolute (n) and relative (%) frequency. Covid-19 = Coronavirus disease 2019.

Resting blood pressure, 24-hour blood pressure, and heart rate variability

No significant changes were observed in central or brachial systolic and diastolic blood pressure, either at rest or during 24-hour, awake, or asleep periods (p > 0.05). Regarding HRV, no significant differences were found in SDNN, rMSSD, pNN50, or the SDNN index (p > 0.05). In addition, no statistically significant changes were observed in very–low–frequency power, although a small reduction was noted (β = −190 ms^2; p = 0.055).

Accelerometer-measured movement behaviors

Movement behaviors significantly worsened over the 15-month period. Sedentary behavior time increased by 41 minutes per day (95% CI: 12 to 69; before 672 min/day, 648-696 vs after 713 min/day, 687-738; p = 0.007), while light PA decreased by 39 minutes per day (95% CI: –67 to –11; before 324 min/day, 300-349 vs after 285 min/day, 259-311; p = 0.008). Additionally, daily step count declined by 1,343 steps (95% CI: –2,119 to –567; before 5819, 5048-6590 vs after 4477, 3981-4973; p = 0.002). However, no modifications were observed for moderate-to-vigorous PA (before 10 min/day, 6-13 vs after 8 min/day, 5-11; p > 0.05). Figure 1 illustrates the percentage change in movement behavior over time.

Cardiorespiratory fitness

CRF (VO_2peak) significantly decreased over the 15-month period (before 22.1 ml/kg/min, 20.2-24.0 vs after 20.4 ml/kg/min, 19.1-21.7; p = 0.034). In contrast, no statistically significant changes were observed in time to exhaustion (β = 0.1 min; p = 0.562) or peak heart rate (β = −0.5 bpm; p = 0.188). Detailed cardiopulmonary exercise test parameters are presented in Table 2.

Body composition

After 15 months of the covid-19 pandemic, no signifi-

Table 2 – Cardiac structure/function, vascular measures, and cardiorespiratory fitness before and 15 months after the onset of the covid-19 pandemic in older adults with hypertension (n = 15)

Variables	Before	After 15 months		
	Mean (95% CI)	Mean (95% CI)	β (95% CI)	p[a]
Cardiac structure/function				
Interventricular septum thickness, mm	9.6 (8.9 - 10.3)	9.7 (9.1 - 10.4)	0.1 (−0.7 - 0.9)	0.806
Posterior wall thickness, mm	8.8 (8.2 - 9.4)	8.3 (7.7 - 8.8)	−0.5 (−1.0 - 0.0)	0.046*
Left ventricle mass index, g/m^2	80.6 (71.8 - 89.3)	77.8 (65.5 - 90.0)	−2.8 (−9.7 - 4.2)	0.416
Left atrium volume index, ml/m^2	24.7 (22.5 - 26.9)	25.5 (22.6 - 28.4)	0.8 (−1.5 - 3.2)	0.486
E/e´ ratio	1.00 (0.90 - 1.11)	0.98 (0.86 - 1.09)	−0.03 (−0.12 - 0.06)	0.525
Left ventricle ejection fraction, %	63.2 (60.6 - 65.8)	58.7 (51.3 - 66.0)	−4.5 (−13.4 - 4.3)	0.301
Vascular measures				
Augmentation index, %	26.5 (19.5 - 33.4)	27.3 (20.1 - 34.4)	0.8 (−4.0 - 5.6)	0.728
Aortic pulse wave velocity, m/s	9.3 (9.0 - 9.7)	9.4 (9.0 - 9.7)	0.0 (−0.2 - 0.2)	0.680
Brachial diameter, mm	3.8 (3.5 - 4.1)	3.9 (3.7 - .4.1)	0.2 (−0.1 - 0.5)	0.300
Flow-mediated dilation, %	5.2 (2.3 - 8.1)	6.7 (3.7 - 9.7)	1.5 (−0.6 - 3.5)	0.155
Flow-mediated dilation, mm	0.19 (0.08 - 0.29)	0.26 (0.14 - 0.37)	0.07 (−0.01 - 0.15)	0.097
Time to maximum diameter, s	70.6 (56.7 - 84.4)	71.0 (56.1 - 85.9)	0.4 (−21.1 - 22.0)	0.967
Shear area to max ×100^{-1}	111 (87 - 135)	142 (106 - 177)	−31 (−70 - 8)	0.117
Area under the curve of shear rate index ×100^{-1}	131 (99 - 163)	170 (130 - 210)	39 (−9 - 86)	0.108
Flow-mediated dilation / area under the curve of shear rate index ×100^{-1}	0.06 (0.03 - 0.08)	0.07 (0.01 - 0.13)	0.01 (−0.04 - 0.06)	0.685
Carotid intima-media thickness, mm	0.82 (0.73 - 0.91)	0.87 (0.78 - 0.95)	0.04 (−0.05 - 0.14)	0.342
Cardiorespiratory fitness				
VO_2peak, mL/kg/min	22.1 (20.2 - 24.0)	20.4 (19.1 - 21.7)	−1.7 (−3.3 - −0.1)	0.034*
Time to exhaustion, min	10.9 (10.3 - 11.5)	11.0 (10.4 - 11.5)	0.1 (−0.3 - 0.5)	0.562
Heart rate peak, bpm	155.4 (144.1 - 166.7)	150.4 (134.8 - 166.0)	−0.5 (−12.6 - 2.6)	0.188

Values are expressed as mean ± standard error (SE) and coefficient estimates (β) and 95% Wald confidence interval (CI). [a] The models were analyzed using a generalized linear mixed model controlling for age and covid-19 infection. * p < 0.05. VO_2peak: peak oxygen uptake. Abbreviations: E/e' ratio; ratio of early mitral inflow velocity (E) to early mitral annular velocity (e').

cant changes were observed in body composition measures, including BMI (before 26.7 kg/m^2, 25.0-28.5 vs after 26.8 kg/m^2, 25.2-28.3; p = 0.896), fat mass (before 23.7 kg, 21.3-26.2 vs after 24.5 kg, 21.9-27.1; p = 0.282), and skeletal muscle mass (before 23.7 kg, 20.9-26.5 vs after 23.4 kg, 21.0-25.8; p = 0.624).

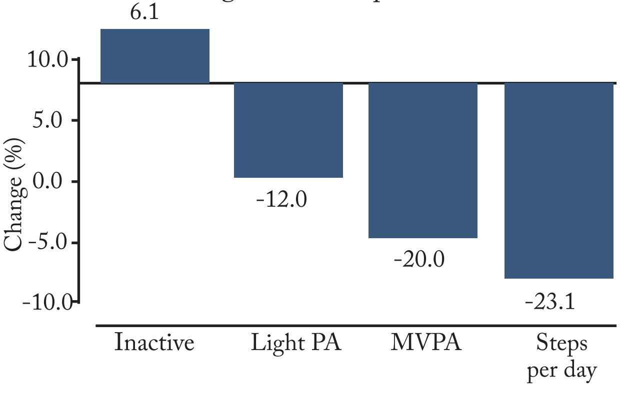

Figure 1 – Movement behaviors before and 15 months after the onset of the covid-19 pandemic in older adults with hypertension (n = 15). *significant change over time (p < 0.05). PA: physical activity; MVPA: moderate-to-vigorous physical activity.

Discussion

The findings of this study indicate that, after 15 months of the covid-19 pandemic, older adults with hypertension experienced: i) no significant changes in most cardiovascular outcomes, such as cardiac structure and function, 24-hour blood pressure and HRV, arterial stiffness, or endothelial function; and ii) a significant decline in movement behaviors, including reduced step volume and light-intensity PA, increased SB, and decreased CRF.

In this cohort of older adults with hypertension, cardiac structure and function appeared largely preserved despite after 15 months of the onset of the covid-19 pandemic. No significant changes were observed in systolic or diastolic function, including ejection fraction, E/e' ratio, and left atrial volume. However, a small but significant reduction in left ventricular posterior wall thickness was detected (β = −0.5 mm), similar changes that have been reported in younger, physically active individuals after detraining[24]. Thus,

Table 3 - Resting and 24-hour blood pressure and heart rate variability before and 15 months after the onset of the COVID-19 pandemic in older adults with hypertension (n = 15)

	Before	After 15 months	β (95% CI)	P[a]
	Mean (95% CI)	Mean (95% CI)		
Resting blood pressure				
Brachial systolic blood pressure, mmHg	123.0 (112.5,133.6)	122.2 (112.9 - 131.4)	−0.9 (−7.4 - 5.6)	0.779
Brachial diastolic blood pressure, mmHg	78.2 (72.2 - 84.2)	75.9 (70.1 - 81.7)	−2.3 (−5.9 - 1.4)	0.208
Brachial pulse pressure, mmHg	44.9 (39.5 - 50.2)	46.2 (40.4 - 52.0)	1.4 (−2.5 - 5.3)	0.475
Central systolic blood pressure, mmHg	115.6 (105.4 - 125.8)	115.1 (105.5 - 124.8)	−0.5 (−6.1 - 5.0)	0.854
Central diastolic blood pressure, mmHg	79.3 (73.3 - 85.3)	77.2 (71.3 - 83.1)	−0.2 (−5.8 - 1.7)	0.271
Central pulse pressure, mmHg	36.1 (31.2 - 41.1)	38.0 (32.2 - 43.8)	1.9 (−1.3 - 5.1)	0.241
24−hour blood pressure				
Systolic blood pressure, mmHg	128.3 (120.3 - 136.3)	128.0 (120.2 - 135.7)	−0.3 (−5.3 - 4.6)	0.885
Diastolic blood pressure, mmHg	69.1 (64.7 - 73.5)	69.3 (65.0 - 73.7)	0.2 (−2.8 - 3.3)	0.877
Awake blood pressure				
Systolic blood pressure, mmHg	129.3 (121.1 - 137.6)	129.9 (122.2 - 137.5)	0.5 (−4.0 - 5.0)	0.811
Diastolic blood pressure, mmHg	70.7 (65.9 - 75.5)	71.5 (67.4 - 75.7)	0.8 (−1.7 - 3.4)	0.507
Asleep blood pressure				
Systolic blood pressure, mmHg	124.1 (116.8 - 131.5)	123.4 (114.7 - 132.1)	−0.7 (−7.4 - 6.0)	0.828
Diastolic blood pressure, mmHg	63.3 (59.4 - 67.1)	64.0 (58.6 - 69.4)	0.7 (−3.9 - 5.3)	0.755
24−hour heart rate variability				
Free of oscillations, ms	4224 (3900 - 4547)	4123 (3810 - 4436)	−100 (−311 - 110)	0.337
Standard deviation of all N−N intervals, ms	71.9 (53.0 - 90.7)	63.8 (55.2 - 72.5)	−0.8 (−28.2 - 12.2)	0.423
Standard deviation of all N−N intervals −index, ms	51.0 (33.3 - 68.8)	42.4 (36.0 - 48.8)	−8.6 (−27.7 - 10.4)	0.361
Root mean square of successive differences between, ms	35.0 (11.0 - 59.1)	24.4 (16.8 - 32.1)	−10.6 (−38.2 - 17.0)	0.437
Percentage of adjacent R−R intervals that vary by more than 50 ms, %	3.9 (1.9 - 6.0)	3.4 (1.1 - 5.6)	−0.6 (−2.5 - 1.3)	0.536
Heart rate, bpm	73.1 (67.9 - 78.3)	70.9 (65.9 - 75.9)	−2.2 (−5.3 - 0.9)	0.159
Very−low−frequency power, ms^2	1058 (713 - 1403)	868 (571 - 1165)	−190 (−384 - 5)	0.055
Normalized low−frequency power, nu	66.4 (60.5 - 72.3)	63.1 (55.2 - 71.0)	−3.3 (−7.8 - 1.2)	0.148
Normalized high−frequency, nu	33.6 (27.7 - 39.5)	36.9 (29.0 - 44.8)	3.3 (−1.2 - 7.8)	0.148
Low frequency/high frequency, nu	3.8 (2.5 - 5.0)	3.9 (2.2 - 5.7)	0.2 (−1.1 - 1.4)	0.787

Values are expressed as mean ± standard error (SE) and coefficient estimates (β) and 95% Wald confidence interval (CI). [a] The models were analyzed using a generalized linear mixed model controlling for age and covid-19 infection.

in this sample, more pronounced reductions in PA or longer exposure may be required for such structural changes to become clinically evident[25]. In addition, it seems reasonable to think that the antihypertensive treatment may have helped maintain cardiac integrity during the follow-up period[26].

While cardiac structure and function remained largely stable, vascular outcomes followed a similar pattern. Arterial stiffness, endothelial function and carotid intima-media thickness, which typically worsen with age[27,28], were unchanged over the 15-month period. Although PA is known to mitigate these age-related vascular declines[29], no significant alterations were observed despite notable reductions in light-intensity PA and step volume. These results diverge from prior studies associating lower step volume with increased arterial stiffness in older adults[30] and from evidence showing that PA improves endothelial function in individuals with hypertension[31]. This discrepancy may be partially explained by methodological differences, particularly sample size, as the present study included only 15 participants, a substantially smaller number than the cohorts evaluated in previous investigations. In addition, differences in participant characteristics and exposure profiles, including the presence of controlled hypertension, the use of antihypertensive medications, and baseline physical inactivity, may have contributed to the contrasting results. Another plausible explanation is the high prevalence of angiotensin II receptor blocker use in our sample (~80%), as these medications enhance nitric oxide bioavailability[32] and reduce endothelial dysfunction and vascular inflammation[33]. Thus, the preservation of vascular function may reflect a protective effect of angiotensin II receptor blocker despite behavioral deterioration.

Consistent with the preservation of cardiac and vascular function, no significant changes were observed in resting brachial or central blood pressure after 15 months. Likewise, 24-hour ambulatory blood pressure monitoring revealed no significant alterations in systolic or diastolic values across awaking, asleep, or 24-hour periods. These findings suggest relative stability in blood pressure control among older adults with hypertension, despite marked reductions in PA and CRF, and increases in SB. This stability is likely attributable to the continued use of antihypertensive medications, which play a critical role in maintaining blood pressure levels[34]. Supporting this, previous studies have shown that individuals in antihypertensive therapy did not exhibit significant changes in resting blood pressure or 24-hour blood pressure during the covid-19 pandemic[35]. These findings reinforce the notion that short- to mid-term reductions in PA and increases in SB may not immediately compromise blood pressure control in pharmacologically treated individuals. In line with this, HRV also remained stable over time. However, a trend toward reduced very–low–frequency power was observed ($p = 0.055$). Since very–low–frequency power is associated with baroreflex sensitivity and parasympathetic modulation[36], and its reduction has been linked to increased cardiovascular risk in older adults[37], this finding may reflect an early sign of autonomic dysregulation. One possible explanation is that 40% of the participants reported previous SARS-CoV-2 infection, a condition associated with autonomic dysfunction in some individuals with post-covid-19 syndrome[38].

A significant decline in CRF was observed 15 months after the onset of the Covid-19 pandemic. Given the well-established relationship between lower PA levels, higher SB, and reduced CRF, our findings suggest that changes in movement behaviors may have contributed to this decline. It is important to acknowledge that a gradual reduction in CRF is an inherent aspect of the aging process[7]. Notably, despite reductions in PA and CRF, as well as the increased SB, no significant changes were found in body composition, suggesting that functional deconditioning may precede detectable alterations in adiposity or lean mass during short- to mid-term periods. In this context, the behavioral deterioration observed characterized by an increase of 41 minutes per day in sedentary behavior, a reduction of 39 minutes per day in light-intensity PA, and a decline of 1,343 steps/day represents a clinically relevant shift in daily movement behaviors, these findings indicate that behavioral changes can lead to a decline in CRF even in the absence of broader cardiovascular alterations, including changes in cardiac structure and function, vascular markers, blood pressure, heart rate variability, and body composition. Furthermore, the observed reduction of 1.7 $mL·kg^{-1}·min^{-1}$ in peak VO_2 (~ 0.5 MET) is clinically meaningful, as even modest declines in CRF have been associated with increased cardiovascular and all-cause mortality risk in older adults[7]. Given that CRF is a strong predictor of cardiovascular and all-cause mortality[7], these results underscore the urgent need to reinforce preventive strategies aimed at preserving movement behaviors and CRF in vulnerable older populations, especially during prolonged periods of societal disruption, such as those imposed by the covid-19 pandemic.

Importantly, although the behavioral changes observed in the present study occurred during a specific and non-modifiable period of the covid-19 pandemic, their persistence over time may have more pronounced implications for cardiometabolic health. Sustained reductions in PA and prolonged exposure to SB have been consistently associated with increased risk of metabolic dysfunction, cardiovascular disease, and functional decline in older adults[8,9,29,30]. From a preventive perspective, these findings highlight that, while the pandemic itself cannot be altered, the maintenance of these unfavorable movement behaviors remains modifiable and represents a critical target for public health and clinical interventions aimed at mitigating long-term cardiometabolic risk in older adults with hypertension.

This study has several limitations that should be acknowledged. First, it was not originally designed to evaluate the impact of social distancing on movement behaviors in older adults with hypertension. The present analysis is exploratory and based on a small sample of individuals initially screened for a clinical trial that was discontinued due to the covid-19 pandemic, in which physical inactivity was an inclusion criterion. Second, the sample consisted of medicated older adults with controlled hypertension aged 60 to 80 years, all without diagnosed cardiovascular diseases such as coronary artery disease or chronic heart failure. Therefore, these characteristics may have influenced the magnitude of the observed changes and should be interpreted with caution and may not be generalizable to other hypertensive populations with differing clinical profiles. Despite these limitations, the study provides valuable insight into the behavioral and physiological responses of a vulnerable group during periods of prolonged social restriction. Nonetheless, this study has important strengths, including: i) a comprehensive assessment of multiple cardiovascular health-related outcomes, such as cardiac structure and function, vascular health markers, 24-hour blood pressure and HRV, CRF, and body composition; ii) the use of accelerometers to objectively measure movement behaviors, reducing the risk of recall bias; iii) the natural experiment context provided by the covid-19 pandemic, allowing for the real-world observation of behavioral and physiological changes.

In conclusion, our main findings indicate deleterious changes in movement behaviors (lower PA, higher SB) and CRF (lower VO_2peak) 15 months after the onset of the covid-19 pandemic in older adults with hypertension, despite the absence of significant changes in a broader range of cardiovascular health-related outcomes.

Conflict of interest

The authors declare no conflict of interest.

Funding

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Author's contributions

Lucena BEB: Conceptualization; Methodology; Software; Validation; Investigation; Data curation; Project administration; Writing – original draft; Approval of the final version. Cabral LLP: Conceptualization; Methodology; Formal analysis; Investigation; Data curation; Supervision; Project administration; Writing – original draft; Approval of the final version. Souto GC: Investigation; Data curation; Visualization; Funding acquisition; Writing – review & editing; Approval of the final version. Fonseca-Araújo MB: Methodology; Investigation; Data curation; Project administration; Writing – review & editing; Approval of the final version. Browne RAV: Methodology; Software; Validation; Formal analysis; Investigation; Data curation; Supervision; Project administration; Writing – original draft; Approval of the final version. Costa EC: Conceptualization; Methodology; Resources; Supervision; Project administration; Writing – review & editing; Approval of the final version.

Declaration regarding the use of artificial intelligence tools in the article writing process

The authors used ChatGPT 5 artificial intelligence tools to assist in the translation process of the manuscript.

Availability of research data and other materials

After publication the data will be available on demand to authors.

Acknowledgments

The authors would like to thank the older adults with hypertension who volunteered to participate in this study.

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Reviewers' assessment

The reviews of this article were originally conducted in Portuguese. This version has been translated using ChatGPT and subsequently reviewed by the Chief Editors.

Reviewer A

Luís Fernando Deresz

Federal University of Rio Grande, Physical Education Program, Rio Grande, Rio Grande do Sul, Brazil.

Title of the Article

- **Title –** After thoroughly reading the manuscript, I believe the title could better reflect the results and be more informative. Although cardiovascular health was assessed, the main findings were observed in variables related to physical activity (step count and VO_2max) and sedentary behavior, rather than in cardiovascular variables per se. Therefore, I suggest directing the title toward these variables. Additionally, such adjustment would better align the manuscript with the journal's scope.

Format

- Does the article comply with the manuscript preparation guidelines for submission to the *Revista Brasileira de Atividade Física e Saúde*?
  Yes
- Regarding formal aspects, is the manuscript well structured, containing the sections: introduction, methods, results, and discussion (with conclusion included in the discussion)?
  Yes
- Is the language appropriate, and is the text clear, precise, and objective?
  Yes
- Was any indication of plagiarism observed in the manuscript?
  No

  Suggestions/Comments:
- Note: Although requested by the journal, I was not provided access to the STROBE checklist, even though most of its items appear to have been addressed in the manuscript.
- Formatting
- The journal requires page numbers in the upper right corner; in the submitted file, they appear in the lower corner. The remaining formatting requirements were met.

Abstract

- Are the abstract and abstract in English adequate (containing objective, participant information, variables studied, main results, and a conclusion) and reflective of the manuscript's content?
  Yes

  Suggestions/Comments:
- Abstract – I suggest exploring effect size data in the presentation of the results (see suggestions in the discussion section).

Introduction

- Was the research problem clearly stated and delimited?
  Yes
- Is the research problem appropriately contextualized in relation to existing knowledge, moving from general to specific?
  Yes
- Are the reasons justifying the study (including the authors' assumptions about the problem) well established?
  Yes
- Are the references used to support the presentation of the research problem current and relevant?
  Yes
- Was the objective clearly presented?
  Yes

  Suggestions/Comments:
- The theoretical foundation is adequate, and the research gap and justification are well presented.

Methods

- Are the methodological procedures generally appropriate for addressing the research problem?
  Yes
- Are the methodological procedures sufficiently detailed?
  Yes
- Was the participant recruitment/selection procedure appropriate and clearly described?
  Yes
- Were instruments used for data collection described, including their psychometric properties

(e.g., reproducibility, internal consistency, validity), and were operational definitions provided when appropriate?
Yes
- Is the data analysis plan appropriate and adequately described?
Yes
- Were inclusion and/or exclusion criteria described and appropriate?
Yes
- Did the authors clarify the ethical procedures adopted for conducting the research?
Yes
Suggestions/Comments:
- The methods are well presented.

Results
- Is the use of tables and figures appropriate and helpful for presenting the results?
Partially
- Is the number of illustrations in accordance with the journal guidelines?
Yes
- Are participant numbers at each stage, including losses and refusals, presented?
Partially
- Are participant characteristics presented and sufficient?
Partially
- Are the results adequately presented, highlighting key findings and avoiding unnecessary repetition?
Partially
Suggestions/Comments:
- On page 4 (Participants section), it is stated that 35 of the initial 41 participants agreed to follow-up (line 14). Line 17 states that all were contacted for reassessment. However, the results present data from only 15 participants. I suggest explaining the loss of 20 participants and discussing its implications for the results.
- Additionally, I suggest including the number of evaluated participants in the text, not only in the table, to improve flow.
- Table 1 – Remove from the legend the abbreviations MVPA and SBP, as they do not appear in the table.
- Figures – I suggest removing grid lines to make them visually cleaner.
- Resting blood pressure and 24-hour blood pressure and heart rate variability (page 10, line 19) – I suggest avoiding the term "trend toward," since the p-value was not significant. If desired, the effect size may be explored in the discussion.
- Cardiorespiratory fitness: Only oxygen consumption values were presented. Although maximal test criteria were described in the methods, I suggest replacing Figure 2 with a table including complementary cardiopulmonary test data (%max HR achieved, RER, and peak RPE). These data would reinforce the validity of the findings. If considered appropriate, the authors may include VO_2 delta values as shown in the original figure.

Discussion
- Are the main findings presented?
Partially
- Are limitations and strengths discussed?
Partially
- Are results discussed considering study limitations and existing knowledge?
Partially
- Are the potential contributions of the findings discussed?
Partially
Suggestions/Comments:
- I suggest further exploring the effect sizes. For example, what does $\beta = -1{,}343$ steps/day represent? Could a reduction of 1,343 steps/day be associated with worse long-term cardiometabolic outcomes? I recommend applying similar reasoning to all significant outcomes: Sedentary behavior $\beta = +41$ min/day; $p = 0.007$; Light physical activity $\beta = -39$ min/day; $p = 0.008$; Step count $\beta = -1{,}343$ steps/day; $p = 0.002$; VO_2max $\beta = -1.7$ mL/kg/min; $p = 0.034$; Left ventricular posterior wall thickness $\beta = -0.5$ mm; $p = 0.046$.
- Additionally, the discussion lacks exploration of long-term implications of maintaining reduced physical activity and increased sedentary behavior. Although data were collected during the pandemic (which cannot be modified), persistence of such behaviors may have greater long-term cardiometabolic consequences.
- For oxygen consumption data, I suggest acknowledging that older adults naturally lose aerobic capacity over time. However, as noted by the authors, the observed reduction may have been exacerbated by changes in movement patterns.

- Limitations - Beyond those already mentioned, consider: 1) The sample was restricted to individuals with controlled hypertension. These individuals may be more compliant, including regarding physical activity, limiting generalizability; 2) Participants were already physically inactive at baseline. The impact of this characteristic on the findings and long-term implications should be discussed.

Conclusion

- Was the conclusion adequately presented and coherent with the objective?
  Yes
- Is the conclusion original?
  Yes
  Suggestions/Comments:
- The conclusion is adequate.

References

- Are references current and sufficient?
  Partially
- Are most references original research articles?
  Yes
- Do references meet journal guidelines?
  Yes
- in-text citations appropriate and accurate?
  Yes
  Suggestions/Comments:
- Most references are current and appropriate.

Comments to the authors

Dear authors and editors,

- Thank you for the opportunity to review the manuscript "Cardiovascular health in older adults with hypertension during COVID-19: a longitudinal study."
- The manuscript presents a longitudinal study investigating changes in cardiovascular health outcomes, movement behaviors, and body composition in older adults with hypertension over 15 months following the onset of the COVID-19 pandemic. This is a relevant and timely topic, particularly considering the potential impact of social restrictions and reduced mobility on cardiometabolic health in vulnerable populations.
- The study stands out for its longitudinal design, objective measurement of physical activity and sedentary behavior using accelerometry, and comprehensive assessment of structural, functional, and autonomic cardiovascular markers. The topic aligns well with the journal's scope and contributes to understanding the indirect effects of the pandemic on lifestyle and cardiorespiratory fitness in older adults with hypertension.
- Overall, the manuscript is well structured and methodologically sound. However, several aspects related to result presentation, interpretation of findings, alignment between title and main outcomes, and specific methodological issues require clarification and refinement to strengthen scientific robustness and clinical relevance. My detailed comments are included in the online form.
- Note: To promote research transparency, I suggest that authors make their dataset available in open repositories such as OSF or Mendeley.

Final decision

- Major revisions required

Reviewer B

Anonymous

Format

- Does the article comply with the manuscript preparation guidelines for submission to the *Revista Brasileira de Atividade Física e Saúde*?
  Yes
- Regarding formal aspects, is the manuscript well structured, containing the sections: introduction, methods, results, and discussion (with conclusion included in the discussion)?
  Yes
- Is the language appropriate, and is the text clear, precise, and objective?
  Yes
- Was any indication of plagiarism observed in the manuscript?
  No
  Suggestions/Comments:
- N/A

Abstract

- Are the abstract and abstract in English adequate (containing: objective, information about study participants, variables studied, main results, and a conclusion) and reflective of the manuscript content?
  Yes

Suggestions/Comments:
- N/A

Introduction
- Was the research problem clearly stated and delimited?
  Yes
- Is the research problem adequately contextualized in relation to existing knowledge, moving from general to specific?
  Yes
- Are the reasons justifying the study (including the authors' assumptions about the problem) well established in the text?
  Yes
- Are the references used to support the presentation of the research problem current and relevant?
  Yes
- Was the objective clearly presented?
  Yes

Suggestions/Comments:
- N/A

Methods
- Are the methodological procedures generally appropriate for addressing the research problem?
  Yes
- Are the methodological procedures sufficiently detailed?
  Yes
- Was the participant selection/recruitment procedure appropriate for the problem studied and described clearly and objectively?
  Yes
- Were details provided about the instruments used for data collection, their psychometric properties (e.g., reproducibility, internal consistency, validity), and, when relevant, operational definitions of the variables?
  Yes
- Is the data analysis plan appropriate and adequately described?
  Yes
- Were inclusion and/or exclusion criteria described and appropriate for the study?
  Yes
- Did the authors clarify the ethical procedures adopted to conduct the research?
  Yes

Suggestions/Comments:
- N/A

Results
- Is the use of tables and figures appropriate and helpful in presenting the study results?
  Yes
- Is the number of illustrations in accordance with the journal's submission guidelines?
  Yes
- Are the number of participants at each stage of the study, as well as the number and reasons for losses and refusals, presented in the manuscript?
  No
- Are participant characteristics presented and sufficient?
  Yes
- Are the results presented adequately, highlighting the main findings and avoiding unnecessary repetition?
  Yes

Suggestions/Comments:
- As written, the Methods section is inconsistent and unclear.
- The quoted sentence states that 35 participants agreed to and took part in the follow-up assessment (accelerometer + telephone questionnaire):
- "Subsequently, in June 2020, 35 of the original 41 participants agreed to take part in a follow-up assessment involving one week of accelerometer wear and a telephone-based questionnaire."
- However, if Table 1 reports data for only 15 participants, this implies that only 15 were actually included in the analyses presented in the table, likely due to exclusions (e.g., incomplete accelerometer data, insufficient wear time, missing questionnaire data).
- You should explicitly state at which stage the sample was reduced from 35 to 15 and why.

Discussion
- Are the main findings of the study presented?
  Yes
- Are the limitations and strengths of the study presented and discussed?
  Yes
- Are the results discussed considering study limitations and existing knowledge?
  Yes

- Are the potential contributions of the main findings to scientific development, innovation, or real-world intervention discussed?
  Yes
  Suggestions/Comments:
- Page 12, lines 7–9:
- “These results diverge from prior studies reporting an association between lower step volume and increased arterial stiffness in older adults[30], as well as from evidence indicating that physical activity improves endothelial function in individuals with hypertension[31].”
- “This discrepancy may be partly explained by methodological differences between studies, particularly sample size. While the present study included only 15 participants, the referenced investigation evaluated a substantially larger cohort (n = 222), which likely provided greater statistical power to detect associations between physical activity and vascular outcomes.”
- What other possible differences exist between these studies?
- Please add more information to this paragraph.

Conclusion

- Was the study conclusion presented appropriately and consistent with the study objective?
  Yes
- Is the study conclusion original?
  Yes
  Suggestions/Comments:
- N/A

References

- Are the references current and sufficient?
  Yes
- Are most references original research articles?
  Yes
- Do the references meet the journal’s requirements (number and format)?
  Yes
- Are in-text citations appropriate (i.e., do statements cite references that substantiate them)?
  Yes
  Suggestions/Comments:
- N/A

Comments to the authors

- I appreciate the opportunity to evaluate this article. The work addresses an important topic, is well written, and the methods are well described. This study examined changes in cardiovascular health-related outcomes, movement behaviors, and body composition in older adults with hypertension 15 months after the onset of the COVID-19 pandemic. The main limitation of this study is the number of participants (n = 15). Despite that, the study deserves to be published. I suggested some revisions before acceptance.

Final decision

- Minor revisions required