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RESEARCH

Effectiveness of a multicomponent physical exercise program against older adults' frailty and obesity risk during the COVID-19 pandemic: an experimental, longitudinal, and controlled study with responsiveness analysis

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Abstract

Objective This study assessed the effectiveness of a multicomponent exercise training against old adults' physical fragility and obesity risk during the COVID-19 pandemic.

Methods An experimental, controlled, and longitudinal study was performed in October 2021 (during the pandemic) and after the intervention in March 2023 (during the pandemic), totalizing 16-month intervention. A total of 53 elderly (37 older women and 16 older men), aged 69.2 ± 12.4 years, participated in this study. After some dropouts, 10 participants in the experimental group (EG) and 10 participants in the control group (CG) accomplished the whole intervention and were analyzed after the post test. Bayesian statistical paired tests were applied to analyze the pre–post changes in physical fitness and body composition components. A responsiveness analysis was performed to identify individualized improvements within the follow-up period.

Results The results demonstrated significant benefits, particularly in body composition, with improvements in BMI, VF, and %BF. Training effectively reduced waist circumference and minimized muscle mass loss. For physical frailty, improvements were noted in LLS, while CG showed worsening in UFL but unexpected improvements in static balance measures like APB and the 95% CI ellipse. In addition, training helped mitigate declines in HG strength, ULS, LLS, ULF, LLF, DB, APB, AF, MLB, and balance measures through responsiveness analysis.

Conclusion The multicomponent exercise training improved lower limb strength and reduced BMI, visceral fat, and body fat percentage, with responsiveness analysis showing protective effects across most variables for participants.

Keywords Aging · Physical activity · Pandemics · Prevention and control · Community health

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Introduction

The COVID-19 pandemic emergence by the severe acute respiratory disease coronavirus 2 (SARS-CoV-2) imposed a real threat to human life [1], of which the most common were social isolation and decreased physical activity during the lockdown [2, 3]. As far as older people are concerned, lockdown significantly reduced their physical activity [4]. This led to a high incidence of sarcopenia [5] and metabolic syndrome [6].

The reduced physical activity and the consequent non-communicable disease development (NCD) increase the likelihood of anxiety, depression, and other mental health concerns [7, 8]. Notwithstanding, obesity and physical disability in older ages were reported as the two most dangerous conditions of COVID-19 exacerbation [9, 10]. Two physiologic phenomena (*Immunosenescence* and *inflammaging*) are causes that make older people to be prone to higher risk for COVID-19 severity.

During the pandemic, the lockdown significantly limited older people's movement, aggravating *inflammaging* and *immunosenescence* and increasing SARS-CoV-2 risks [11, 12]. Global decision-makers stressed preventive strategies, promoting healthy lifestyles, and exercise to counteract physical and cognitive decline in older adults [13]. However, due to the SARS-CoV-2's strong transmission capacity, performing exercise outdoors during the pandemic was a challenge faced by everyone [14]. Consequently, some research assessed physical activity levels, sedentary behavior, and mental health during this period [8, 15, 16].

Experimental research that was managed remotely and took 6–24 weeks is also found in the literature [17–21], but evidence on the effects of presential and long-term physical exercise interventions on the older peoples' health and functional parameters during the pandemic is scarce [22, 23].

Altogether, there was a noticeable absence of physical exercise intervention programs, particularly multicomponent ones, addressing functional decline during lockdown. In addition, there is a lack of studies exploring ML tools in this context. Moreover, new COVID-19 variants have been found, such as the variant BA.2.8 [24], with reported rapid growth in France, and the disease deserves concern [25]. The Centers for Disease Control and Prevention stated a growth in 42 USA states and a decrease in zero states [26]. Evidences strengthens physical exercise as a potential protective measure during COVID-19 outbreaks [27].

In this way, the present study's focus was to assess the effectiveness of a multicomponent exercise training program against old adults' physical fragility and obesity risk during the COVID-19 pandemic. It was hypothesized that an intervention enrolling multicomponent exercise training will, first, effectively improve the participants' body composition and reduce obesity risk and second, improve their physical function, consequently reducing the fragility risk in these participants.

Methods

Study design

This was an experimental, controlled, and longitudinal intervention, performing measurements before the pandemic (October 2021), during the pandemic, and after the intervention (March 2023), totalizing 16-months of intervention. Participants were split up into experimental and control groups. The study adopted the CONSORT updated guidelines for reporting parallel-group randomized trials [28].

Participants

In this study, a total of 53 participants (37 women and 16 men) aged 69.2 ± 12.4 years who were participating in a community program were recruited. Following the Cohen's guidelines [8], we set an alpha of 95% for statistical significance and a large effect size for mixed effects of 0.50. The statistical power was calculated a priori considering a 95% confidence interval and a Cohen's d effect size of 0.50 (large in a two-sided hypothesis for the paired *t*-test analysis and minimal sample to retrieve a minimal power of 0.80). Therefore, a total of 64 participants per group were enrolled. But, there was poor statistical power to find real probability in rejecting the null hypothesis (<0.8). This way, we worked with robust statistics which does not require sample size as the main statistical assumption, and it is better described in the statistical analysis session [29].

Inclusion criteria included the consent to participate in the study by signing an informed consent form, have medical consent to participate in the study, have attended at least 75% of all sessions conducted, and not being diagnosed as infected by COVID-19. Exclusion criteria were not agreeing to participate in the study or not signing the informed consent form, not having medical consent to be part of the program, attending less than 75% of the sessions, and having been infected by COVID-19 and diagnosed.

This study was approved by the Ethics Committee of Research from the Douro Higher Institute of Educational Sciences (registration number: 2.576). The study was conducted following the Declaration of Helsinki. All participants were briefed on the research project details and signed an informed consent form. The CONSORT flowchart describes the participant allocation (Fig. 1).

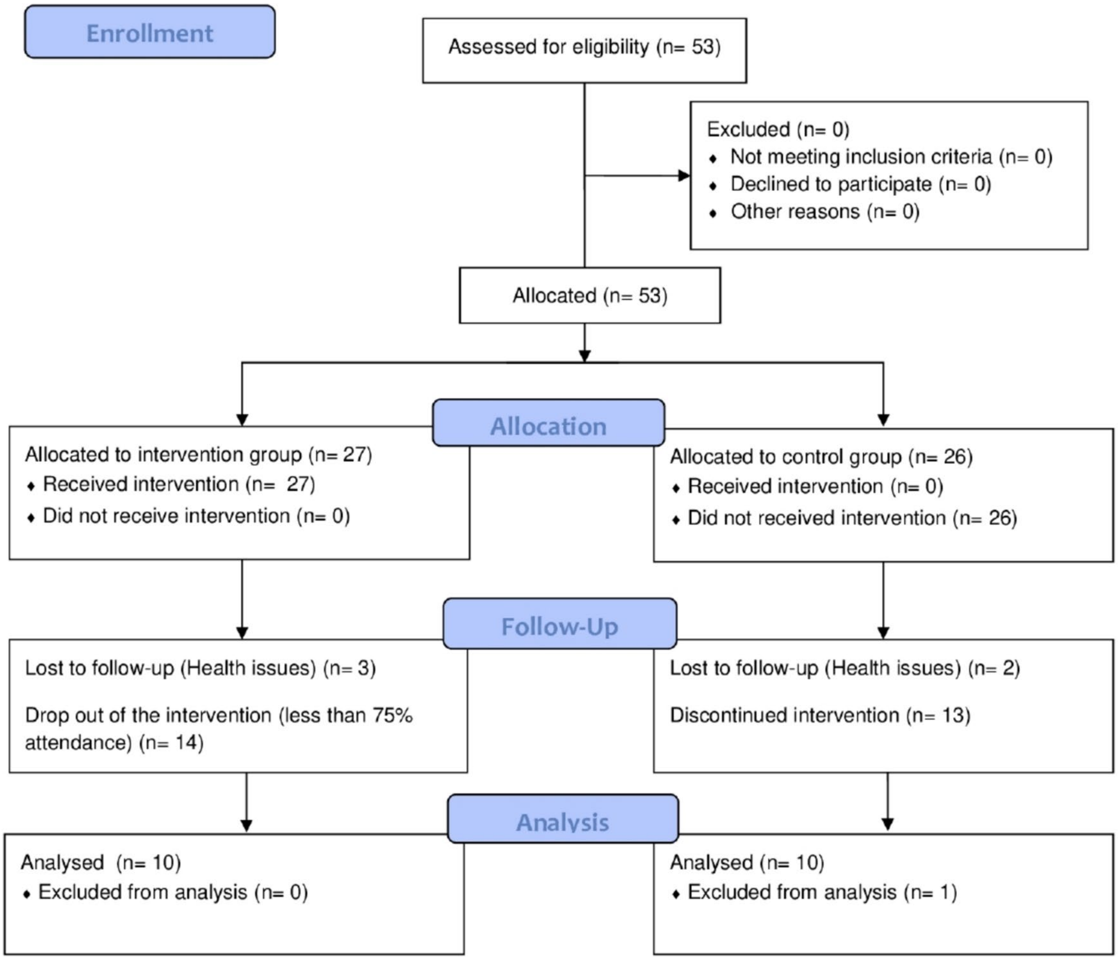

Fig. 1 Flowchart of the study

Multicomponent physical exercise intervention protocol

The experimental protocol lasted for 16 months (64 weeks). Participants were assigned to an experimental group [EG, $n=27$, (20 women and 7 men)] and a control group [GC, $n=26$, (all women)]. A total of 5 participants (9.4% of the total sample) dropped out due to undeclared health issues and 26 (49%) because they did not keep the minimal 75% of attendance at the training sessions. Thus, the data from the remaining 20 older women [10 in EG (9 women and 1 men) and 10 in CG (all women)] were not involved in any physical exercise or similar intervention during the entire follow-up period.

The training sessions were conducted thrice weekly, each with 50 min of duration (Fig. 2). The sessions comprised a 5 min warm-up and a resistance training part encompassing two sets of five functional and multi-joint routine exercises. The resistance training was followed by a balance block involving two sets of three exercises focusing on dynamic and static balance. The final training block comprised two sets of four aerobic exercises characterized by high-intensity interval training (HIIT) stimulus. Finally, a 5 min cool down to stretch and relax was provided after the main training session. The repetitions and time increased by 30% after each 6 month intervention. The training intensity was controlled using Borg's 10-point categorical ratio scale (CR-10). The coaches aimed to work in an intensity range from 3 (moderate) to 5 (intense) [30].

Table 1 shows the progression and intensity load of the multicomponent exercise training session of the 16-month follow-up. The progression was performed with increases in the time of exercise, with periodical increments.

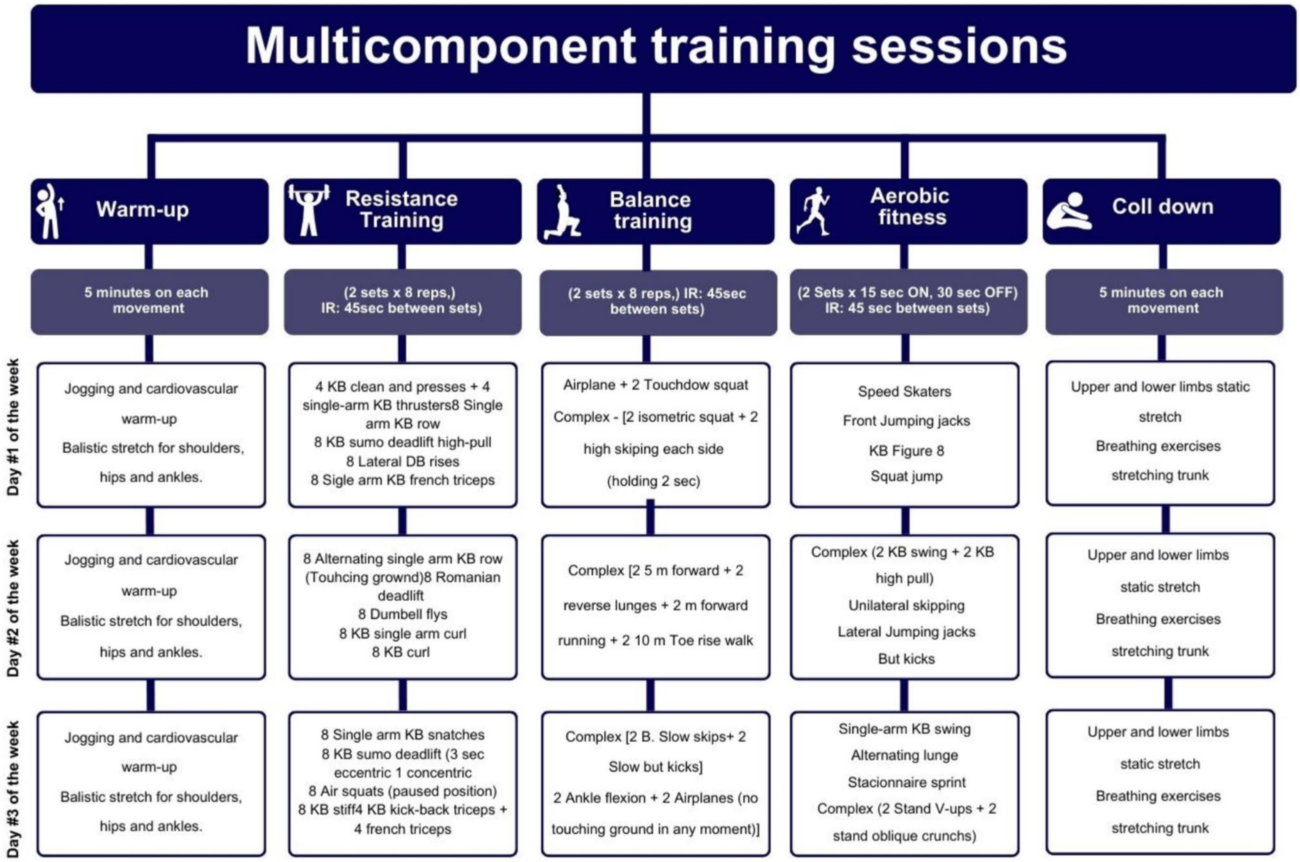

Fig. 2 Structural description of the multicomponent training sessions at the start of the intervention

Table 1 Progression and control of the multicomponent training over the 16-month intervention

Component	Months		
	1–4	5–10	11–16
Resistance training (Set. x Rep.)	2 × 8	2 × 12	3 × 15
Balance training (Set. x Sec. x Rep.)	2 × 5 × 8	2 × 10 × 8	3 × 10 × 8
Aerobic fitness (Set. x Sec.)	2 × 15	2 × 30	3 × 30

Data collection

Anthropometrics and body composition

A Tanita DC430-PMA digital weighing scale with 0.1 g precision and a stadiometer were used for measuring body weight and height. Body mass index was then calculated using the following formula: [body weight (kg)/height (m^2)]. Waist and hip circumference were measured using a Cescorf® measuring tape at the smallest waist circumference. Body composition, including visceral fat, total muscle mass, and body fat percentage, was assessed using a Tanita DC430-PMA phase-sensitive, double-frequency bioelectrical impedance analysis. After fasting and 5-min supine rest, measurements were taken with limbs appropriately positioned.

Muscular strength

Hand grip strength was measured by a digital palmar dynamometer (CAMRY®, Portugal). The subject stays standing, with arms not touching the trunk, and at the signal of the researcher, must exert the maximal hand grip on the dynamometer for over 4 s [31]. Two attempts were provided, and the best result was recorded.

Lower limb strength was measured with the seat-to-stand test from the “Functional Fitness Test Battery” [32]. The participants were positioned standing up in front of a chair 43 cm high. At the evaluator’s signal, the participants performed the movement of sitting and standing up as many times as possible for 30 s. The number of repetitions was recorded.

The assessment of upper limb strength was performed by the arm curl test, as outlined in the “Functional Fitness Test

Battery" by Rikli and Jones [33]. To conduct this test, the participant was seated in a chair of 43 cm in height, gripping a 2 kg dumbbell (standard weight for women). Upon the evaluator's cue, the participant executed as many elbow flexions and extensions as possible within 30 s, and the number of repetitions achieved was noted.

Flexibility

Upper limb flexibility was gauged through the seat-and-reach test from Rikli and Jone's (2013) [32] "Functional Fitness Test Battery." The participants stacked their hands, reaching toward their toes upon a signal. The evaluator measured the distance, noting positive values for fingers surpassing toe tips, zero for reaching precisely, and negative for inability to touch toes.

Aerobic fitness

Aerobic fitness was also assessed using the 2-min step test by Rikli and Jones' (2013) [32] "Functional Fitness Test Battery." The participants were instructed to perform maximal steps in place for 2 min, aiming for maximal effort. The evaluator recorded the number of repetitions for both legs, emphasizing that participants stop only if necessary.

Body balance

Dynamic balance was evaluated with the time-up-and-go test [34], using Rikli and Jones' [33] "Functional Fitness Test Battery." Seated in a 43 cm chair, facing a cone 2.44 m away, the participants walked swiftly, encircling the cone, and returned. Two attempts were made, and the shortest time was recorded.

Static balance was assessed using FOTWORK® pressure platform. The participants stood still in the upright position and barefoot for 20 s, facing forward with open eyes on the platform. Center of pressure sway was measured by the anteroposterior and mediolateral distances covered and the 95% confidence interval (CI) of the ellipse area [35].

Statistical analysis

All statistical procedures were performed on R, a statistical computing language [36]. Since the final sample of analysis did not reach the minimal statistical power of 0.8, we moved on to a more robust statistical analysis. For this purpose, Bayesian two-sample and paired t-tests were applied in the parametric datasets, and the Bayesian Mann–Whitney and Wilcoxon tests were applied in the two-sample and paired non-parametric datasets, respectively [37, 38]. These models are recognized to be robust in scenarios where the minimal statistical power is not reached. The Bayesian statistics is based on the post-prior probability of distributions, thus, it tests new data under the assumption, based on prior probability, that the null hypothesis is true. As a result, the probability of accepting the alternative hypothesis against the null hypothesis is retested after presenting a new dataset for the model (post probability) [37–39]. In this way, as the main output for significance, we considered the results of the Bayes factor, respecting the cutoffs of (≤ 3 = anecdotal evidence, between 3 and 10 = moderate evidence, > 10 = strong evidence). This way, considering Jeffrey's guidelines [38], we considered only stronger-grade evidence to reject the null hypothesis and accepted the alternative hypothesis in a 95% confidence interval of the post-prior probability. To assess the longitudinal effects of the multicomponent intervention, generalized estimating equations (GEE) were used to model changes in body composition and physical fitness outcomes over time. GEE analyses were performed using an appropriate correlation structure and model fit criteria for small samples. Additionally, analyses followed a per-protocol approach, including only participants who completed the intervention and assessments. The models evaluated the main effects of time, group, and, particularly, the interaction between time and group, which captures the differential changes in the experimental group compared to the control group. In addition, a cluster analysis was performed considering individual responsiveness analysis in all variables within the dataset. For this purpose, the typical error, as proposed by Hopkins [40], which is obtained by the standard deviation of the pre-post differences/sqrt(2) and established a value at least two times the typical error of the control group to consider a true responsiveness effect in a subject from the experimental group. In this way, two clusters were built: the first cluster of "responders" formed by those individuals with significant clinical change (improvement or worsening) from to post-test, and the second cluster of "non-responders," composed of those individuals with no significant clinical change from pre- to post-test [40]. The responsive and non-responsive subjects were exhibited in plots.

Results

Results of the baseline comparisons

Table 2 shows the descriptive characteristics of age and body composition of the participants at the baseline. The Bayesian two-sample tests identified that only the variable age exposed significant differences across the groups with the EG (72 ± 4), presenting higher age than the CG (66 ± 4).

Table 3 shows the results of the baseline comparison of the physical fitness between the EG and CG. The Bayesian statistical models did not find any significant differences

Table 2 Descriptive analysis of body composition variables in the baseline

Variable	EG (n = 10)	CG (n = 10)	Bayes factor	Post-prior prob. 95% sig
Age (y)	72.1 ± 3.66	66.2 ± 3.76	15.70744 ± 0%	**Strong**$^{\#}$
BMI (index)	27.4 ± 2.74	26.9 ± 3.32	0.4126905 ± 0%	Anecdotal
Waist (cm)	88.9 ± 7.61	88.0 ± 13.2	0.4130706 ± 0%	Anecdotal
VFat (score)	7.66 ± 1.16	8.06 ± 2.59	0.4188753 ± 0%	Anecdotal
Tot. M.M (kg)	40 (4.75)	39.5 (8.5)	1.659268	Anecdotal
BF (%)	34.2 ± 4.17	32.8 ± 6.52	0.5851108	Anecdotal

Note. The statistically significant changes are highlighted in bold. *Age* chronological age, *BMI* body mass index, *Waist* waist circumference, *VFAT* visceral fat. Tot, *M.M* total body muscle mass, *%BF* percentual body fat mass. #: statistical significance at 95% confidence level with a strong level of evidence (also highlighted in bold)

Table 3 Descriptive analysis of physical fitness variables in the baseline

Variable	EG (n = 10)	CG (n = 10)	Bayes factor	Post-prior prob. 95% sig
HG (kgf)	22.5 ± 3.17	24.6 ± 3.89	0.7262726 ± 0%	Anecdotal
ULS (rep.)	17.1 ± 4.65	19.4 ± 4.72	0.6043855 ± 0%	Anecdotal
ULF (cm)	−5.7 ± 10.1	−6.2 ± 10.8	0.398979 ± 0%	Anecdotal
LLF (cm)	4.6 ± 7.89	2.5 ± 11.2	0.4319764 ± 0%	Anecdotal
DB	6 (0)	5 (1.75)	0.0003562945	Anecdotal
AF (rep.)	163 ± 8.9	142 ± 40.3	0.6383134 ± 0%	Anecdotal
APB (cm)	1.20 ± 3.57	1.34 ± 0.33	1.87	Anecdotal
MLB (cm)	1.09 ± 1.42	1.12 ± 0.52	0.40	Anecdotal
95% CI bal. Ellipse (**cm^2**)	0.767 ± 0.69	0.871 ± 0.87	1.06	Anecdotal

Data are described in mean ± standard deviation and median (interquartile range). *HG* hand grip strength, *ULS* upper limb strength, *ULF* upper limb flexibility, *LLF* lower limb flexibility, *DB* dynamic balance, *LLS* lower limb strength, *AF* aerobic fitness, *APB* anteroposterior static sway distance, *MLB* mediolateral sway distance. 95% CI – Bal.: 95% confidence interval of the sway ellipse area. #: statistical significance at 95% confidence level with a strong level of evidence (also highlighted in bold)

between the two groups in the baseline for any of the analyzed variables ($p > 0.05$).

Experimental results

Table 4 shows the results of body composition from pre-post comparison for the EG and CG. Significant and positive changes were found in EG, favoring reductions in BMI [pre = 27.5 (2.5), post = 25.5 (3.5)], in visceral fat [pre = 8 (1), post = 6 (2.75)] and reductions in the body fat percentage [pre = 34.2 ± 4.39, post = 29.06 ± 10.54]. The CG did not expose any significant change ($p > 0.05$).

Table 5 shows the results of physical fitness from pre-post comparison for the EG and CG. Significant changes were identified in the EG, only for the lower limb strength ($p < 0.05$), while the CG presented reductions in their upper limb flexibility. An unexpected result was found when CG improved in isolation their anteroposterior static balance and the general confidence interval encompassing both pre-post changes in antero- and posterior static balance in the participants.

Generalized estimating equation analysis

The generalized estimating equation (GEE) evaluated the effects of time, group, and the time × group interaction on the study's primary outcomes, as presented in Table 6. The results revealed significant interaction effects for BMI and LLS, indicating that participants in the EG experienced a significant reduction in BMI and an improvement in strength (HG) compared to the CG.

Figure 3 presents the individual responses in the body composition of older adults post the multicomponent physical exercise intervention. BMI (Fig. 3A) revealed that four individuals (40%) were classified as negative responders, indicating a reduction in their obesity susceptibility during

Table 4 Body composition results

Variable	Group	Pre	Post	Bayes factor	Post-prior Prob. 95% sig
BMI	EG	27.5 (2.5)	25.5 (3.5)	21.31813	**Strong**$^{\#}$
	CON	27.5 (5)	27.5 (4.25)	0.01567713	Anecdotal
Waist	EG	89.3 ± 8.55	86.8 ± 9.31	0.4219835 ± 0.01%	Anecdotal
	CON	83.5 (22.75)	90.5 (14)	0.6095392 ± 0.01%	Anecdotal
VFAT	EG	8 (1)	6 (2.75)	11.62263	**Strong**$^{\#}$
	CON	8 (2)	8.5 (2)	0.06685389	Anecdotal
TOT_MM	EG	40 (4.75)	43 (31.25)	0.003965658	Anecdotal
	CON	39.5 (8.5)	39.5 (9)	0.4549449	Anecdotal
%BF	EG	34.2 ± 4.39	29.06 ± 10.54	17.93761	**Strong**$^{\#}$
	CON	33.5 (9)	34.5 (8.25)	0.8387913 ± 0.02%	Anecdotal

Data are described in mean ± standard deviation and median (interquartile range). *BMI* body mass index, *Waist* waist circumference, *FAT* visceral fat, TOT_MM total body muscle mass, *%BF* percentual body fat mass. #: statistical significance at 95% confidence level with a strong level of evidence (also highlighted in bold)

Table 5 Pre to post-changes in functional fitness

Variable	Group	Pre	Post	Bayes factor	Post-prior prob. 95% sig
HG	EG	22.5 ± 3.17	20.9 ± 4.64	0.7124828 ± 0.02%	Anecdotal
	CON	23.5 (3.5)	23.5 (4.25)	0.4571116	Anecdotal
ULS	EG	17.1 ± 4.7	23.5 ± 4.03	5.14666 ± 0%	Moderate
	CON	18.5 (7.8)	20 (3.5)	0.8119597	Anecdotal
ULF	EG	−4.5 (17.5)	−8 (15.5)	0.8936246	Anecdotal
	CON	−5.5 (5.75)	−8 (15.5)	15.03809	**Strong**$^{\#}$
LLF	EG	4.6 ± 7.89	0.8 ± 9.24	0.6393829 ± 0.02%	Anecdotal
	CON	2.5 ± 11.2	2 ± 11	0.3186903 ± 0.01%	Anecdotal
DB	EG	6.3 ± 0.95	5.8 ± 1	0.5724141 ± 0.01%	Anecdotal
	CON	5 (1.75)	5 ± (1)	0.01582758	Anecdotal
LLS	EG	13.5 ± 3.44	21.8 ± 2.82	997.5839 ± 0%	**Strong**$^{\#}$
	CON	19 ± 5	16 ± 5	0.8564583 ± 0.02%	Anecdotal
AF	EG	163 ± 39	176 ± 41.26	0.362853 ± 0.01%	Anecdotal
	CON	157 ± 70	139 ± 26	4.562292	Moderate
APB	EG	138 ± 54	139 ± 50	0.3092349 ± 0%	Anecdotal
	CON	134 (45)	113 (22)	256.5507	**Strong**$^{\#}$
MLB	EG	109 ± 42	189 ± 86	4.440519 ± 0%	Moderate
	CON	112 ± 52	108 ± 48	0.3245117 ± 0.01%	Moderate
95% CI – Bal	EG	121 ± 82	206 ± 134	1.539409 ± 0%	Anecdotal
	CON	126 (120)	90 (72)	49.41277	**Strong**$^{\#}$

Data are described in mean ± standard deviation and median (interquartile range), *HG* hand grip strength, *ULS* upper limb strength, *ULF* upper limb flexibility, *LLF* lower limb flexibility, *DB* dynamic balance, *LLS* lower limb strength, *AF* aerobic fitness, *APB* anteroposterior static balance movements, *MLB* mediolateral static balance movements. 95% CI – Bal.: 95% confidence interval considering anteroposterior and mediolateral static balance. #: statistical significance at 95% confidence level with a strong level of evidence (also highlighted in bold)

the pandemic. Regarding WC (Fig. 3B), all individuals showed neither negative nor positive responses, maintaining stable waist circumference over this period. As for VF (Fig. 3C), three individuals (30%) were classified as negative responders, reflecting a decrease in visceral fat throughout the same timeframe. In MM (Fig. 3D), four individuals

Table 6 Generalized estimating equation results for time × group interaction effects on main study outcomes

Variable	Beta (β)	*p*
BMI	− 2.8	0.019
LLS	11.0	0.001
HG	− 2.8	0.08

BMI body mass index, *LLS* lower limb strength. *%BF* percent body fat, *HG* handgrip strength, *β* estimated coefficient. *p* statistical significance

(40%) were classified as positive responders, showing an increase in muscle mass during the pandemic. Lastly, in BF percentage (Fig. 3E), five individuals (50%) were classified as negative responders, indicating a reduction in fat mass, while only one individual (10%) was classified as a positive responder over the course of the pandemic.

Figure 4 presents the individual responses of older adults in the multicomponent exercise program regarding functional fitness during the pandemic. In HG (Fig. 4A), one individual (10%) was classified as a negative responder, meaning there was a reduction in this variable over the course of the program. For ULS (Fig. 4B), eight individuals (80%) were classified as positive responders, indicating an increase in strength, while one individual (10%) was a negative responder, showing a decrease during the pandemic period. In ULF (Fig. 4C), one individual (10%) was a positive responder and one individual (10%) was a negative responder, indicating increases and decreases in flexibility, respectively, throughout this time.

For LLF (Fig. 4D), one individual (10%) was a positive responder and two individuals (20%) were negative responders, revealing increases and decreases in flexibility, respectively. In LLS (Fig. 4F), six individuals (60%) were positive responders, indicating an increase in leg strength during the pandemic. In AF (Fig. 4G), two individuals (20%) were positive responders, indicating improvement, while one individual (10%) was a negative responder, reflecting deterioration in this variable over the pandemic period.

Regarding APB (Fig. 4H), four individuals (40%) were classified as positive responders, showing deterioration in balance, while one individual (10%) was classified as a negative responder, indicating improvement during this period. In MLB (Fig. 4-I), five individuals (50%) were classified as positive responders, demonstrating deterioration. Finally, for the 95% CI ellipse, four individuals (40%) were classified as positive responders, indicating greater postural sway and, therefore, a deterioration in stability, while six individuals

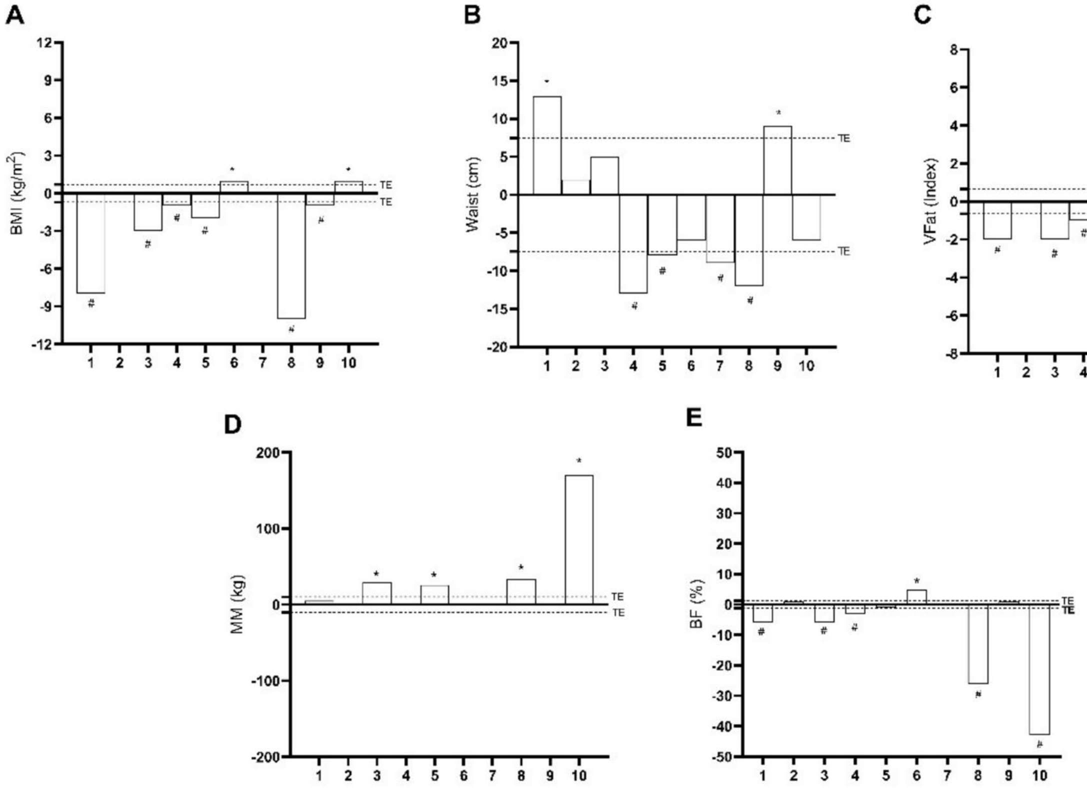

Fig. 3 Individual responses in body composition among older adults participating in a multicomponent physical exercise program. **A** BMI: Body mass index. **B** Waist: waist circumference. **C** VFat: Visceral fat. *MM* total body muscle mass, *BF* body fat mass. * Positive responders; # Negative responders

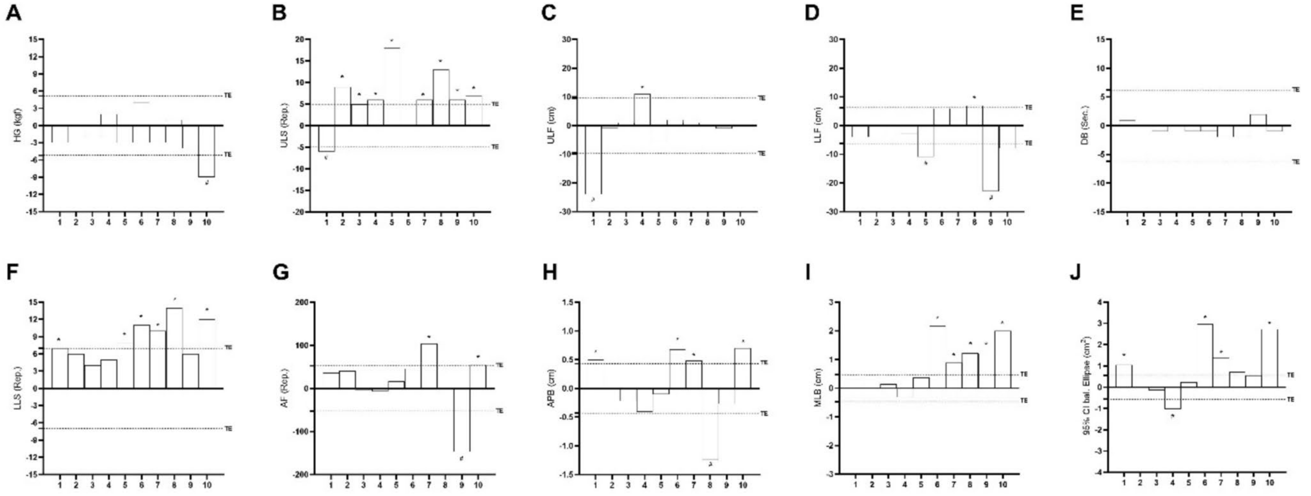

Fig. 4 Individual responses in functional fitness among older adults participating in a multicomponent physical exercise program. **A** HG: hand grip strength. **B** ULS: upper limb strength. **C** ULF: upper limb flexibility. **D** LLF: lower limb flexibility. **E** DB: dynamic balance. **F** LLS: lower limb strength. **G** AF: aerobic fitness. (H) APB: anteroposterior static balance movements. **I** MLB: mediolateral static balance movements. **J** 95% CI—Bal.: Confidence interval ellipse indicating oscillation area. * Positive responders; # Negative responders

(60%) did not show significant changes in this variable over the pandemic period.

Discussion

In the present study, we investigated the effectiveness of multicomponent training in preventing physical frailty and obesity in older adults during the COVID-19 pandemic. The results showed significant benefits, particularly in responsiveness analyses of body composition, with statistically significant improvements observed in BMI, VF, and %BF. These findings were further supported by the GEE analysis, which revealed significant time × group interaction effects for BMI and LLS, indicating that participants in the experimental group experienced a greater reduction in BMI and improvement in strength compared to the control group. When focusing on individual responsiveness levels, the training was also effective in attenuating increases in waist circumference and minimizing muscle mass loss. Regarding physical frailty, there were statistically significant improvements in LLS, whereas the control group worsened in UFL, and an unexpected deterioration in static balance was observed in APB and in the 95% CI ellipse. Moreover, considering individualized responsiveness levels, the training mitigated deterioration in parameters such as HG strength, ULS, LLS, ULF, LLF, DB, APB, AF, MLB, and the 95% CI ellipse for static balance.

Initially, the improvement in body composition observed in this study is consistent with previous research that highlights the effectiveness of multicomponent combined training in promoting favorable changes in body composition [41–43]. These results are even more relevant considering the specific context in which the study was conducted. Particularly during the COVID-19 pandemic, evidence indicates that confinement reduced the physical activity levels of older adults and increased sedentary behavior, as demonstrated by a systematic review [44] and a large-scale study involving 3,052 adults in the U.S. [45]. In this context, marked by restrictions on mobility and access to regular physical activity programs, the findings of this study are especially significant, as they show that the multicomponent combined training used in the present study was able to promote improvements in body composition, even in the face of the adversities imposed by the pandemic.

Moreover, regardless of the pandemic context, aging alone tends to negatively affect the body composition of older adults, leading to an increase in fat mass and a decrease in lean mass, which heightens the risk of conditions such as obesity and sarcopenia [46]. In this regard, interventions that promote a healthier balance between these body composition components become crucial in mitigating the natural impacts of aging. Therefore, the body composition findings from this study highlight the importance of strategies aimed at maintaining an adequate body composition, particularly during stages of life where these changes are more pronounced.

Regarding physical frailty, the results of this study demonstrate significant improvements in upper and lower limb strength, as well as in mediolateral static balance, reinforcing existing literature on frailty prevention in older adults. For example, upper limb strength is essential for daily activities and fall prevention [47, 48]. Therefore, the increase in this physical capacity, especially during the pandemic, was crucial for maintaining the health and mobility of participants, as well as contributing to the preservation of bone mass [49]. Similarly, lower limb strength showed a significant increase, highlighting its relevance for mobility, bone density, and cardiovascular health [50, 51], and it is also associated with a reduced risk of falls and physical decline in older adults [52, 53]. In addition, the improvement in mediolateral static balance underscores the importance of interventions focused on postural stability, as balance is crucial for preventing falls, one of the leading causes of serious injuries in the elderly [54].

In the other variables related to physical frailty (HG, ULF, LLF, DB, and AF), multicomponent physical training proved effective in mitigating impairments, even though it did not promote statistically significant improvements. Several individual responders evidenced the protective effect of the exercise protocol against physical frailty. However, regarding APB, MLB, and the 95% CI ellipse, an unexpected deterioration in static balance was observed in the EG, while the CG showed improvements in these variables. This finding may be explained by several factors, such as the heterogeneity between groups and the influence of uncontrolled external variables. Importantly, the CG had a mean age approximately 8 years lower than the EG. This age disparity is significant because static balance tends to decline markedly with advancing age, mainly due to the progressive loss of hair cells in the inner ear and central vestibular functions. According to Allen et al. [55], these physiological processes impair sensory responsiveness and consequently make postural control more difficult in older adults. Thus, the younger age of the CG may have provided an innate advantage in balance performance, independent of the intervention. In addition, natural vestibular decline and sensory deterioration tend to accelerate in older individuals, potentially contributing to the deterioration observed in the EG [56].

Despite the promising results, this study has some important limitations that should be considered when interpreting the findings. First, the small sample size limits the generalizability of the results, as a larger sample could provide more robust data and better represent the target population on scaling how physical exercise can improve or attenuate frailty and obesity risk over the pandemic period. In addition, the absence of biochemical data, such as inflammatory or metabolic markers, prevents an in-depth analysis of the biological mechanisms involved in changes in body composition and physical frailty. The lack of information regarding the mental health of the participants is also a limitation, as psychological well-being can significantly influence both adherence to the multicomponent combined training protocol and the outcomes in terms of physical function and obesity risk in this uncommon environment. Finally, the specific context of the COVID-19 pandemic, including mobility restrictions and changes in social behavior, may have influenced the results, and their application in post-pandemic contexts should be approached with caution. Moreover, although individual responsiveness was considered, the study did not apply minimal clinically important difference thresholds to assess the clinical relevance of observed changes, which may limit the interpretation of practical significance.

Practical applications

The findings of this study highlight the significant benefits of multicomponent exercise training for older adults, especially during the COVID-19 pandemic. Health professionals, including physiotherapists and fitness trainers, should prioritize promoting multicomponent training as an effective intervention. These programs should incorporate strength, balance, flexibility, and aerobic exercises to comprehensively address physical health and frailty.

Given the individualized responsiveness observed, exercise programs must be tailored to the specific needs and baseline fitness levels of participants, enhancing the effectiveness of interventions. Regular monitoring of body composition and functional performance is crucial to track improvements and adjust training regimens as needed. Finally, fostering a long-term commitment to regular exercise is essential. By providing ongoing support and resources, health professionals and community leaders can help older adults sustain the benefits achieved through training interventions, ultimately enhancing their physical health and overall well-being during challenging times.

Conclusions

A 16-month multicomponent physical exercise program, which was interrupted during the COVID-19 lockdown, improved upper and lower limb muscle strength, flexibility, static and dynamic balance, and aerobic fitness, while preserving body composition. In addition, the responsiveness analysis showed a more observable positive individual response in the EG after the intervention, particularly in terms of body composition and physical frailty. Physical exercise was able to improve, or at least attenuate, the worsening of both parameters, demonstrating its beneficial role in mitigating physical decline and promoting better overall health outcomes in older adults during pandemic periods.

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Declarations

Conflict of interest Pedro Forte serves as section editor for this journal.

Ethical approval This study was approved by the Ethics Committee of Research from the Douro Higher Institute of Educational Sciences (registration number: 2.576). The study was conducted following the Declaration of Helsinki.

Informed consent All participants were briefed on the research project details and signed an informed consent form.

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