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IMBALANCE AND FALL-RISK IMPROVEMENTS IN THE ELDERLY: EFFECTS OF COMBINED STRENGTH AND AEROBIC TRAINING

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Abstract

Background: Falls among the elderly are an important clinical and health problem due to their high incidence and their functional and social repercussions. The aim of this study was to examine the effects of a combined strength and aerobic exercise program (EP) on the fall risk (FR) in older adults by use of a measure of postural stability.

Material and methods: Sixty-two elderly people (69.0 ± 4.3 years, 39 females and 23 males) were assigned to an experimental group (EG) or a control group (CG) and tested using the Biodex Balance System in order to obtain a fall-risk score at baseline (M1), after 4.5 months (M2), and 9 months (M3). Measures of physical activity (use of accelerometers for 7 consecutive days) as well as socio-economic status, clinical problems, and medication were also taken; these factors were identified as potential confounders. The EG underwent a 9-month, three times a week, combined training program consisting of 1-hour sessions of strength (once a week) and aerobic exercise (twice a week).

Results: The combined training program had a large and significant effect on FR (EG vs. CG) ($F(2,120) = 4.519$; $p = 0.013$; $\eta_p^2 = 0.07$; statistical power (π) = 0.76). This was more pronounced from M1 to M2 than from M2 to M3, with a significant improvement ($p < 0.001$) in FR from M1 to M3. In the CG, there was a slight but non-significant functional decline ($p = 0.92$) between M1 and M3.

Conclusions: A 9-month combined EP may have beneficial effects on FR of elderly men and women as a result of improved postural stability.

Key words: Biodex Balance System • fall risk • community programs

POPRAWA RÓWNOWAGI I ZMNIEJSZENIE RYZYKA UPADKU U OSÓB STARSZYCH: EFEKTY ŁĄCZENIA TRENINGU SIŁOWEGO I AEROBOWEGO

Streszczenie

Wprowadzenie: Upadki wśród osób starszych są ważnym problemem klinicznym i zdrowotnym ze względu na ich częstość występowania oraz reperkusje funkcjonalne i społeczne. Celem tego badania było sprawdzenie wpływu połączonego programu ćwiczeń siłowych i aerobowych (EP) na ryzyko upadku (FR) u starszych osób dorosłych za pomocą pomiaru stabilności postawy.

Materiał i metody: Grupa eksperymentalna (EG) i kontrolna (CG) obejmowała sześćdziesiąt dwie osoby w podeszłym wieku (69,0 ± 4,3 lata, 39 kobiet i 23 mężczyzn). Testy prowadzono przy użyciu Biodex Balance System w celu uzyskania oceny ryzyka upadku na początku badania (M1), po 4,5 miesiącach (M2) i po 9 miesiącach (M3). Sprawdzano również aktywność fizyczną (stosowanie akcelerometrów przez 7 kolejnych dni), a także status społeczno-ekonomiczny, problemy zdrowotne i przyjmowane leki; czynniki te zostały zidentyfikowane jako potencjalne czynniki zakłócające. Grupa EG została poddana 9-miesięcznemu, trzy razy w tygodniu, połączonemu programowi treningowemu, który składał się z 1-godzinnych sesji siłowych (raz w tygodniu) i ćwiczeń aerobowych (dwa razy w tygodniu).

Wyniki: Połączony program treningowy miał duży i znaczący wpływ na FR (EG vs. CG) (F (2120) = 4,519; p = 0,013; η_p^2 = 0,07; moc statystyczna (π) = 0,76). Było to wyraźniejsze w zestawieniu M1 do M2 niż z M2 do M3, ze znaczną poprawą (p <0,001) w zakresie FR między M1 a M3. W grupie CG nastąpił niewielki, ale nieistotny spadek czynnościowy (p = 0,92) między M1 a M3.

Wnioski: Łączony 9-miesięczny program EP może mieć korzystny wpływ na FR starszych mężczyzn i kobiet w wyniku poprawy stabilności postawy.

Słowa kluczowe: Biodex Balance System • ryzyko upadku • programy społeczne

Introduction

Impairments of postural stability can result in increased rates of unintentional falls. There is a general consensus that altered postural stability in elderly people is affected by degradation of the sensory channels, i.e., vestibular, visual, and proprioceptive cues, and also by deficits in muscle strength, neuromuscular control, and declining reaction times. These factors make fall events more likely [1].

These age-related conditions have numerous consequences for public health, such as falls, fractures, hospitalisations, institutionalisations, and mortality [2]. Due to the high costs of care, falls among the elderly have a great impact on the quality of their lives, on their relatives' lives, and on the public health system [3, 4]. The prevention of falls and mobility-related disability among older people is an urgent public health challenge [5].

There is now strong evidence for the effectiveness of exercise as a component of a multifactorial intervention in the prevention of falls in community-dwelling older people [6,7]. However, there is little direct evidence about the differential impact of different approaches to exercise as a single intervention in older people. In terms of the effect of combined exercise on postural stability, contrasting findings have been reported.

A combined exercise program (EP) seems to be highly relevant to this problem, and it can slow, halt, or even reverse age-related decline or loss of functionality that leads to an increase in the number of falls [8-10]. In addition, aerobic exercise, such as walking, can improve aerobic capacity and physical function (PF) [11,12]. Furthermore, strength training improves critical elements of physical function, such as mobility and balance [13].

Studies have reported extensively on the effectiveness of multifactorial fall prevention programs involving education, environmental modification, exercises, and psychological intervention [14-17]. Recommendations and guidelines for the prevention of falls which advocate identifying high-risk persons, screening for modifiable risk factors, and the targeting of appropriate interventions have been developed [18-20].

This study is the first to evaluate this specific population with objective tools such as the Biodex Balance System (BBS) Static/Dynamic (SD). Its aim is to investigate imbalance as a key factor related to fall risk, and to study the effects of a 9-month combined EP in older women and men. The results may help us to understand how combined exercise intervention can change the performance of those physiological systems associated with balance and fall risk in older women and men.

Methods

Participants

Elderly people of both genders from the Oporto area, Portugal, aged >65 years, were eligible to participate. A simple random sampling technique was used to distribute participants across the experimental and control groups. To be eligible to participate in the study, participants had to submit medical certification of their state of physical and mental well-being. Participants were excluded if they were not able to walk without a cane or other assistive device, or had had a previous history of peripheral or vestibular abnormalities. Other grounds for exclusion were a history of two or more falls in the previous 6 months, having previous medical and cognitive conditions or musculoskeletal problems limiting safe participation and evaluation, or unwillingness to complete the study requirements.

From the cohort of initial participants, three failed to complete the study. This was due to an injury (broken metatarsals), a case of cancer, and one death from heart disease. The data analysed for this study is based on 62 participants: 39 women and 23 men aged from 65 to 79 years.

Participants were informed about the aims of the study and the study procedures and gave written informed consent before being enrolled. The consent conformed with the International Ethical Guidelines for Biomedical Research Involving Human Subjects [21], the World Medical Association Declaration of Helsinki [22,23], and Harriss et al. [24]. The study was approved by the Ethics Committee, Faculty of Sport, University of Porto (CEFADE.02.2015).

Participants were interviewed in a private facility and self-completed questionnaires to provide information about their clinical and socio-demographic characteristics. These were used to assess their eligibility for the study.

Fall risk

Fall risk (FR) was evaluated by using the BBS SD, a multiaxial device with an unstable balance platform designed to measure postural stability. Under dynamic tests, the device can provide up to a 20º tilt in a 360º range of motion. Subjects were required to stand with their feet slightly apart for three 20-second periods with their eyes open. By measuring the pressures exerted by the subject on the platform, a score for overall stability, anterior/posterior, and medial/lateral stability can be generated, ranging from 0.0 (optimum balance/low fall risk equivalent) to 4.0–5.0 (poor balance/high fall risk equivalent). In healthy people, and according to Biodex Medical Systems, normal score ranges for FR by age are: 2.0–4.0 in the 72–89 years group; 0.9–3.7 in the 54–71 years group; 0.7–3.1 in the 36–53 years group, and 0.7–2.1 in the 17–35 years group [25-33].

The BBS SD was used to provide oscillations from the 12^{th} to the 8^{th} level of difficulty (level 12 being the most stable and level 8 the most unstable). The subject was required to stand up with feet slightly apart in a physiological position for three 20-second periods. Different force plate movements were automatically generated by the equipment and the resulting scores relating to stability were weighted according to the age and height of the subjects [25, 34-38].

Physical activity

Day-to-day physical activity (PA) was assessed over 7 consecutive days using uniaxial accelerometry (GT1M accelerometer, Actigraph, Florida, USA). Participants were instructed to wear the accelerometer over the right hip for a 7-day period (5 week-days and 2 weekend days). Exceptions included time spent sleeping, showering, and participating in water-based activities. Participants were asked to maintain their usual activities, as tracked objectively by accelerometry, and keep written records in a diary. A valid day was defined as at least 10 hours of wear time per day. All non-wear time was excluded from further analysis. Data from the monitors was uploaded by the investigating team using the Actilife Monitoring System v.6.11.3 software and was compared with data from the written diary before the average counts per minute were calculated. This outcome variable was reported in the number of vertical axis counts per minute (CPM), generated based on the magnitude and frequency of movement [39-41].

Exercise intervention

Subjects in the experimental group (EG) (n = 37) submitted to a 9-month combined training course. This involved 1-hour bi-weekly aerobic training sessions (Mondays and Fridays) and a single weekly 1-hour strength training session (Wednesdays) conducted by a physical education instructor with academic specialisation in physical activity for older adults. This was in accordance with ACSM guidelines for exercise for older adults [42-44].

Aerobic training (AT) consisted of a 10-minute warm-up that included walking, calisthenics, and stretching and 30 minutes of aerobic exercises – mainly walking – at an intensity corresponding to 50–70% $HR_{Reserve}$ or a rating of perceived effort (RPE) of 4 to 6 on a 10-point scale [45]. Besides walking, a 10-minute exercise period was devoted to developing muscular endurance, balance, proprioceptive sensitivity, and coordination skills [43]. The session ended with a 10-minute cool-down. The training load was gradually increased by 5 minutes each week during the first 4 weeks until subjects could walk continuously for 30 minutes.

Strength training (ST) consisted of a 10-minute warm-up that included walking, calisthenics, and stretching and a specific resistance training period (30–40 min) consisting of nine exercises (leg press, chest press, leg extension, seated row, seated leg curl, abdominal flexion, biceps curl, low-back extension, and triceps extension) [46]. ST concluded with a 10-minute cool-down. The load increased during the first 2 weeks [47,48], commencing with familiarisation with the machines (for correct breathing and technique) and progressing to 60–70% of one-repetition maximum (1RM) individual strength tests. The 1RM was performed every 15 days for the first month and then every 4 weeks until the final session of the program. Between these tests, the load was increased for those subjects who were able to easily complete 10 for both sets [49].

Attendance of at least 80% of the exercise sessions was required for the training program to be considered complete.

Subjects allocated into the control group (n = 25) were instructed not to change their daily living PA routines or dietary patterns during the study and not to carry out any supervised PA. They were informed that they would receive intervention when the study had ended. After the data collection period, subjects who had been randomised into the CG were invited to participate in specific EPs designed for seniors undergoing FADEUP.

Statistical procedures

Descriptive measures such as mean (M) and standard deviation (SD) were used for data collection and analysis. A Kolmogorov–Smirnov test with Lilliefors correction was used to assess distribution normality while independent sample t-tests were carried out to detect gender differences.

A mixed repeated measures ANOVA was applied to investigate the efficacy of EP over FR by comparing groups (EG/CG) and timeline: baseline (M_1), 4.5 months (M_2), and 9 months (M_3). The assumptions of the method, namely the normal distribution of FR at 3 times and the sphericity of the variance–covariance matrix, were evaluated with a Kolmogorov–Smirnov test ($p > 0.1$ for the 3 times and groups) and with the Mauchly test (W = 0.993; $\chi^2(2) = 0.419$; $p = 0.811$).

Change (Δ) between times was calculated for each pair according to the formula ($M_a – M_{a+1}$). So Δ_1 = change from baseline (M_1) to 4.5 months (M_2), Δ_2 = change from 4.5 months (M_2) to 9 months (M_3), and Δ_3 = change from baseline (M_1) to final (M_3). Between-group differences in pre-intervention was evaluated with unpaired two-tailed Student t-tests by one-way ANOVA.

Analyses were performed with SPSS statistics (v.25; IBM SPSS, Chicago, IL). A significance level of 0.05 was set for all analyses.

Results

The demographic and anthropometric characteristics of the study sample are shown in Table 1. The study population consisted of 62 elderly people, most of whom were female, of age 65–79 years, height 137–175 cm, and with weight ranging from normal to obese Class II [50].

With the purpose of reaching the goal of the present study, a mixed repeated measures ANOVA was used to evaluate the significance of the efficacy of physical activity training on FR and its evolution over the 3 sampled times, as shown in Table 2.

The mean value of FR for participants of the experimental group (M = 1.359, SD = 0.082, n = 37) was significantly different from the value of FR for participants in the control group (M = 1.618, SD = 0.100, n = 25), with high dimension ($F(1,60) = 0.078$, $p = 0.009$; statistical power = 0.799). The size of the effect ($\eta_p^2 = 0.076$) is recommended minimum [51], being the 95% confidence interval for the difference of means of the value of FR of the two groups (0.029; 0.356).

Regarding the time evolution of FR values evaluated, there were highly significant differences between the 3 times ($F(2,120) = 4.928$; $p = 0.009$; = 0.076; statistical power (π) = 0.799).

When considering data from the two groups combined, the values of FR were higher at M_1 (baseline:

Table 1. Demographic and anthropometric characteristics of the study sample divided by EG and CG

Variable	**Total**	**EG**	**CG**	***p***
Participants – *n* (%)	62 (100)	37 (59.7)	25 (40.3)	0.375
Gender – % female	58.1	63.9	52.0	0.102
Age, years – mean (SD)	69.02 (4.27)	68.11 (3.19)	70.36 (5.28)	0.064
Weight, kg – mean (SD)	71.77 (11.47)	70.80 (10.87)	81.45 (17.75)	0.219
Height, cm – mean (SD)	159.04 (10.25)	158.43 (10.50)	165.50 (3.54)	0.550
Body mass index, kg/m^2 – mean (SD)	28.77 (4.12)	28.66 (4.21)	30.80 (3.32)	0.627

Key: EG, experimental group; CG, control group; SD, standard deviation; * statistical significance, $p < 0.05$; *n*, number

Table 2. Mean ± standard deviation of fall risk (FR) in the EG vs. CG at M_1, M_2, and M_3

Group	**M_1**	**M_2**	**M_3**	**Δ_1**	**p**	**Δ_2**	**p**	**Δ_3**	**p**
FR Total (M±SD) (*n* = 62)	1.695 ±0.067	1.499 ±0.065	1.463 ±.065	0.196	**0.007***	0.036	0.608	0.232	**<0.001***
FR EG (M±SD) (*n* = 37)	1.754 ±0.084	1.509 ±0.083	1.359 ±.068	0.245	**0.015***	0.150	0.103	0.395	**<0.001***
FR CG (M±SD) (*n* = 25)	1.608 ±0.109	1.485 ±0.106	1.618 ±.120	0.123	0.235	–0.133	0.216	–0.010	0.919
Δ by Group	0.146	0.240	–0.259						
p	0.287	0.856	**0.049***						

Key: FR, fall risk; M_1, baseline; M_2, 4.5 months; M_3, 9 months (final); M ± SE, mean ± standard deviation; Δ_1, M_1–M_2; Δ_2, M_2–M_3; Δ_3, M_1–M_3; *n*, number of participants; * denotes statistical significance, $p < 0.05$

M = 1.695, SD = 0.67, *n* = 62), decreased at M_2 (M = 1.499, SD = 0.065, *n* = 62), and further decreased at M_3 (M = 1.463, SD = 0.065, *n* = 62).

Finally, the effect of physical activity training on changing the values of FR depended on the group (EG vs. CG) as demonstrated by a significant interaction ($F(2,120) = 4.519$; $p = 0.013$; = 0.070; statistical power (π) = 0.761).

As shown in Table 2, the effect of physical activity training on FR is more pronounced in the experimental group from M_1 (baseline) to M_2, than from M_2 to M_3 (post-intervention), with a clear improvement in FR from M_1 to M_3 ($\Delta_3 = 0.395$, $p < 0.001$). Table 2 also shows that for participants in the control group, the effect of time on FR occurs in the expected direction: that is, between M_1 (baseline) and M_3 (final) there was a slight functional decline, with a variation in FR (**Δ3** = –0.010, non-significant $p = 0.919$).

Comparing the difference between groups (EG vs. CG): at M_1 (baseline), **Δ** = 0.146 (small and non-significant, $p = 0.287$), while at M_3 (final) it was more pronounced (**Δ** = –0.259) and significant ($p = 0.049$).

Showing that PA did not bias the FR results, a mixed repeated measures ANOVA of PA, evaluated objectively by accelerometry, showed that its evolution over the 3 sampled times returned non-significant *p*-values. Table 3 shows that all interactions between group (EG/CG) and time (M_1, M_2, and M_3) gave $p > 0.05$.

Discussion

The objective of this study was to evaluate the effectiveness of a combined (strength and aerobic) exercise-based intervention program on improving observed values of FR in elderly people from the Porto region. To the best of our knowledge, this study is the first to use BBS SD to focus on this population and objectively analyse FR and PA. The EP was found to be safe, with no major incidents occurring. The participants found the EP enjoyable, evident by the high compliance rate and low number of drop-outs.

With regard to accelerometer-determined ambulatory PA, our participants' results (11.02 ± 3.44 CPM) are corroborated by others [4, 52-54] and maintained the same PA during the experimental period, as demonstrated in Table 3.

The observed values of FR of participants were within the normal range for this specific age group [25]. In the EG, the FR values developed favourably over 9 months with the practice of regular physical exercise of combined strength and aerobic training. In comparison, in the CG there was a natural slight functional decline over the same 9 months.

Participation in the EP decreased FR. The changes observed in the EG could be a consequence of muscular strengthening and improvement of the postural control resulting from taking part in the various strength-aerobic training activities as part of EP. Similar results have been reported by others in a series of studies with exercise-based program interventions [5,7, 55-58].

Table 3. Mean ± standard deviation of physical activity (PA, in CPM) in EG vs. CG at M_1, M_2, and M_3

Group	M_1	M_2	M_3	Δ_1	p	Δ_2	p	Δ_3	p
CPM Total (M±SD) (*n* = 62)	11.015 ±3.44	10.788 ±3.49	11.794±3.25	−0.227	0.238	−1.006	0.126	0.779	0.233
CPM EG (M±SD) (*n* = 37)	11.150 ±3.83	11.32 ±3.87	12.308 ±3.88	0.171	0.356	0.987	0.151	1.158	0.142
CPM CG (M±SD) (*n* = 25)	10.880 ±3.02	10.255 ±3.08	11.281 ±2.49	−0.625	0.284	1.026	0.192	0.401	0.239
Δ by Group	0.270	1.066	1.027						
p	0.231	0.136	0.174						

Key: PA, physical activity; CPM, counts per minute; EG, experimental group; CG, control group; M_1, baseline; M_2, 4.5 months; M_3, 9 months (final); M±SD, mean ± standard deviation; Δ_1, M_1–M_2; Δ_2, M_2–M_3; Δ_3, M_1–M_3; *n*, number of participants; * statistical significance, $p < 0.05$

The changes seen in the CG can be considered natural and explained by aging due to the passage of the 9 months between the beginning and end of the study, as reported by Rivolta et al. [59].

The above results show that physical activity in general, and more specifically, combined strength-aerobic training, may have an effect in lowering fall risk. Based on this analysis, we recommend physical activity training to promote a higher quality for daily living activities and a lowering of fall risk in the elderly. This recommendation has also been made by others [11, 60-68].

Strengths and limitations

The strengths of this study include the use of objective instruments to measure PA and FR. This innovative technology can help add to our body of knowledge. Here, BBS-SD was used for the first time for this type of study. Factors that may have played roles in ensuring that the EP was successful included: care was taken to keep the participant's level of interest high in the physical EP; EP was held in venues that were easily accessible; classes were run by graduates trained in running EP; and the rationale for the study and the assessment measures were clearly explained to both the EG and the CG. Also, at the completion of the EP, feedback was provided to all subjects regarding their performances in the tests.

When interpreting the findings consideration should be given to the study's limitations. Subjects in intervention studies with exercise cannot be blinded to group assignment; this study involved a highly physical task that could have led to low compliance if it were considered unpleasant. Ambulatory PA was assessed using an accelerometer worn for just 1 week. The measures of ambulatory PA may therefore have been affected by atypical happenings such as unfavourable weather conditions, random events, or participant's illness. Future studies using randomised controlled experiments should investigate the effect of PA on FR. Future research might examine if greater compliance by participants can be achieved through PA training and also evaluating participant satisfaction through questionnaires and interviews.

Conclusion

Aging causes many changes in the human body which can lead an individual to suffer changes, such as an increase in FR, causing elderly people to become more dependent on help from caregivers. As seen in this study, this functional decline can be halted, or reversed, by PA exercise practice such as a combined (strength-aerobic) exercise-based intervention program.

These findings reinforce a strategy for programs devoted to improving PA in the general population, and especially for elderly people. A PA program can promote physical fitness and lower FR. A decrease in FR is important for enhancing increased autonomy for community-dwelling elderly people. We need to understand that we, as carers for the elderly, can reduce the burden of falls on the broader social economy [18, 69].

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