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ORIGINAL RESEARCH

Effects of a multimodal exercise program in pedal dexterity and balance: study with Portuguese older adults of different contexts

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Abstract This study investigated the effects of a multimodal exercise program (MEP) on pedal dexterity and balance in two groups of older adult participants (65–92 years of age) from a psychiatric hospital center (HC), a residential care home (RCH), and a daily living center (DLC). The experimental group (EG) trained three times per week for 12 months, and the control group (CG) maintained their normal activities. The Mini-Mental State Examination and the Modified Baecke Questionnaire, as well as the Pedal Dexterity and the Tinetti tests, were applied to all subjects before and after the experimental protocol. Furthermore, the foot preference was controlled using the Lateral Preference Questionnaire proposed by Coren [10]. In the EG, the results from the Pedal Dexterity test showed that both males and females from the RCH and DLC improved their performances after the MEP. In the HC, the males slightly decreased their performance with both feet, contrarily to females. Both males and females from the CG decreased their pedal dexterity performance, namely, with the non-preferred foot. Concerning the Tinetti test, the EG of both males and females from the HC, the RCH (males were better than females regarding the gender factor), and the DLC improved their balance after the MEP. In the CG, no significant effects or interactions were found for any of the context groups.

Keywords Aging · Multimodal exercise program · Pedal dexterity · Balance

The authors declare that this manuscript has never been previously published and submitted simultaneously for publication elsewhere. In addition, its publication has been approved by all coauthors.

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Introduction

Aging is characterized by a series of degenerative changes in the different systems of the organism at the anthropometric, muscular, articular, cardiovascular, pulmonary, and neural levels, with consequences including the decline of the functional abilities and changes in physiological functioning [1, 30, 49]. Mobility problems in older adults are generally associated with deficits in balance, musculoskeletal pain, gait disorders, and a decline in muscular strength of the lower limbs, which are also a factor of fall risk and loss of autonomy for the execution of daily life activities [27, 46].

Compared to the upper limbs, the age-related reduction of muscle strength and mass of the lower limbs is more evident [2, 21]. This fact is important since these muscle changes of the lower limbs have higher correlations with mobility, functionality, and everyday activities of the older adults [7]. Among other characteristics, pedal dexterity is especially important to facing unexpected situations in order to prevent a fall and subsequent fracture or immobilization. Besides a good dynamic balance, it is important that older adults are able to behave quickly and efficiently when faced with these conditions [24].

Dexterity is the ability to solve (precisely, quickly, rationally, and deftly) a motor task in an adequate way using, in general, the limbs and the body. In this context, flexibility, in relation to the changing environment, is an important characteristic [48].

Likewise, balance is the basis of all voluntary motor abilities in this population [22, 33]. Problems with balance control as a result of compromised balance conditions will inevitably affect motor strategies because one cannot activate muscle-response synergies with appropriate timing, force, and muscle-response organization [40]. So, the concept of balance is the ability to maintain the body in equilibrium [41]. If an old person has reduced levels of balance, he or she will become more dependent on others and exposed to a higher risk of fall and fractures [17]. The distinct movement patterns of postural recovery, also referred to as "postural strategies," function to preserve equilibrium following external disruptions by restraining the center of mass within the base of support [41].

Several studies have shown the efficiency of physical exercise programs, not only in the reduction of the risk of fall [14, 17, 36], but also in the reduction of the fear of falling [36].

We point out that a consequence of the aging process leads to a decline in the interference of pedal dexterity with balance. These aspects affect many of the older adults' daily life activities; falls or accidents that often occur could be avoidable if the individuals maintained high levels of motor fitness [25, 28].

Aging is a growing phenomenon in modern-day societies. In fact, the number of older adults (normal or with mental health disorders) accessing rehabilitation and intermediate care services, either in hospitals or at home, is rising and will continue to increase [9].

However, there is not much information or enough systematic investigation about pedal dexterity ability in the Portuguese population, so this subject needs to be further studied in order to better understand the effect of exercise on both abilities (dexterity and balance) in old males and females in different living situations.

With this research, it was our intention to investigate older adults from a wide range of the population as a whole; that is, we sought to include older adults with mental health disorders (from a psychiatric hospital center [HC] and a residential care home [RCH]) and without mental health disorders (namely, from an RCH and a daily living center [DLC]).

The aim of this investigation was to analyze the effects of a multimodal exercise program on the pedal dexterity and balance of older adults from different contexts. The following hypotheses were formulated a priori: (1) a multimodal exercise program improves pedal dexterity and balance and reduces the likelihood for falls in older adults from different contexts, and (2) interventions targeted by a multimodal exercise program (over 12 months in older adults from different contexts) are effective in males and females.

Methods

Subjects

A convenience sample of 136 older adult participants from an HC, an RCH, and a DLC participated in this study. The eligible subject pool was restricted to older adults from both genders with the following characteristics: age ≥65 years, not engaged in any regular exercise training in the last year, older adults from an RCH and a DLC, lack of use of any medication known to affect balance and postural stability, and lack of any diagnosed or self-reported neurologic disorders or orthopedic medical conditions that contraindicate participation in exercise and testing. We point out that the older adults from the HC and the RCH (older adults with mental health disorders) were previously diagnosed with neurological deficits by neurologists and give authorization to participate in the study.

We try to compose the sample with an identical number of older adult participants in each context according to the gender and age. However, in some circumstances, this proceeding was not possible, as was the case of HC and RCH (older adults with mental health disorders), contexts where the number of subjects in each group was different. The sample, in each context, was divided into two groups: an experimental group (EG) with practice of the multimodal exercise program and a control group (CG).

Before conducting the study, all participants received a complete explanation of the purpose, risks, and procedures of the investigation and provided their written informed consent. However, some older adults were excluded due to medical reasons, namely: in the EG, four males and two females from the HC, two males and two females from the RCH, and four males and two females from the DLC. In the CG, one male and one female from the RCH (mental health disorders), two males and three females from the RCH, and one female from the DLC. The characteristics of the participants of the study are shown in Table 1.

Older adults from the EG were submitted to a multimodal exercise program for a period of 12 months, while those in the CG maintained their normal physical activity routine. All measurements and the multimodal exercise program were performed by the same evaluator together with teachers graduated from the University of Porto, Portugal. We emphasize that they were the evaluators prior and after training in both groups (EG and CG).

The investigation was in full compliance with the Helsinki declaration of 1975, as revised in 2004, and all

Table 1 Subject characteristics of experimental and control groups. Contexts, age and gender

Experimental group			Control group		
Subjects	Mean age (years)	Gender	Subjects	Mean age (years)	Gender
HC (n=8)	70.13±4.85	M	RCH (mental health disorders) (n=4)	79.25±8.01	M
HC (n=11)	69.91±4.27	F	RCH (mental health disorders) (n=4)	85.5±4.93	F
RCH (n=9)	80.00±8.27	M	RCH (n=8)	81.88±3.64	M
RCH (n=17)	83.88±5.30	F	RCH (n=8)	81.00±3.16	F
DLC (n=11)	71.73±5.51	M	DLC (n=8)	79.38±7.15	M
DLC (n=16)	72.19±6.45	F	DLC (n=8)	74.25±8.27	F

HC hospital center, *RCH* residential care home, *DLC* daily living center, *RCH* residential care home: older adults with mental health disorders, *M* males, *F* females

methods and procedures were approved by the Institutional Review Board.

Training protocol

The 12-month multimodal training protocol was held three times per week, and each session lasted about 60 min. All sessions were accompanied by appropriate music considered relevant to the required activity and participants' age. A physical education instructor with specialization in older adults' training conducted the sessions. The exercise training was designed to promote the development of abilities, such as visuomotor coordination skills, flexibility, balance, strength, reaction time, speed of movements of the hands and feet, proprioceptive sensitivity, coincidence anticipation, and visuomotor memory, as well as emotional and social aspects and awareness of the benefits of regular physical exercise.

Each training session included three main components: initial, a 10-min light warm-up and stretching exercises; fundamental, 45 min of light- to moderate-intensity exercises for the development of the abilities previously mentioned, such as marching in place, stepping exercise at a speed of 40–60 beats per minute using a 15-cm-high bench, heel drops performed on a hard surface (a heel drop consists of raising the body weight onto the toes and then letting it drop to the floor, keeping the knees locked and hips extended), muscular endurance exercises performed concentrically and eccentrically involving the upper and lower limbs, strength training performed with elastic bands and dumbbells, balance training with static and dynamic exercises (e.g., walking in a straight line, walking heel to toe, using additional resources, such as, balls, balloons, gymnastics parachutes and ribbons, hoops, ropes, and sticks), flexibility training involving the major muscle groups (quadriceps, back, and chest), and agility training (visuomotor coordination) aimed at challenging hand–eye coordination, foot–eye coordination, dynamic balance, standing and leaning balance, and psychomotor performance (coincidence anticipation, proprioceptive sensitivity, visuomotor memory, and reaction time) including ball games, relay races, dance movements, and obstacle courses; and finally, 5 min of stretching. For the exercises in the second part of the session, for all the abilities mentioned above, the repetitions were increased from 8 to 15 and the number of sets increased to three.

Footedness assessment

The footedness assessment was evaluated by applying the Lateral Preference Questionnaire [10]. The older adults were asked to perform five motor tasks, which were associated with the five questions in the questionnaire. After registering the foot with which the subjects performed the activities, a ratio called the laterality quotient, using the following formula, was calculated:

$$\mathrm{LQ} = \frac{(\text{number of tasks with the right foot} - \text{number of tasks with the left foot})}{\text{total number of tasks}} \times 100$$

The older adults were classified as right footed (value greater than zero) or left footed (value lower than zero) based on their score on this questionnaire, which identified 110 strong right footers (mean score of 92.84±11.39, where 100 is maximal right footedness), and 2 strong left footers (mean score of −80.0±0.0, where 100 is maximal left footedness). Both right footers' and left footers' data were included in our analysis, and according to their footedness, the subjects used their preferred foot (PF) and their non-preferred foot (NPF) in the test. It is important to assess the non-preferred foot in order to appreciate—along with the preferred foot—its evolution from pre- to post-training and to observe if this evolution is similar when compared to the preferred foot.

In regard to the Lateral Preference Questionnaire, additional items were added to the Lateral Preference Inventory [11] that provided a measure of handedness, footedness, vision, and hearing. Coren et al.'s measure of lateral preference has demonstrated a 92 % concordance between self-reports and direct behavioral performance [10, 11].

Cognitive function assessment

To assess the subjects' global cognitive function, the Mini-Mental State Examination (MMSE) [15] was applied. MMSE total score ranges from 0 to 30. According to this questionnaire, none of the participants had any cognitive impairment (RCH: mean score of 28.23±2.11; DLC: mean score of 27.53±2.43), except the older adults with mental health disorders of the experimental group and the control group, where the doctors confirmed pathologies like schizophrenia, dementia, and depression.

Daily physical activity assessment

In order to quantify and verify if there was any change in the daily activities of the sample during the research period, the Modified Baecke Questionnaire [4] was completed before and after training. This questionnaire has been shown to generate valid and reliable classification scores for activity in older subjects providing a domestic, a sport, and a leisure-time activity score. The sum of the different scores gives the total activity of the subject. The questionnaires were completed by the same researcher during a personal interview. For ethical reasons, this questionnaire was not applied to all the older adults with mental health disorders of the experimental group and the control group.

Instruments

Tapping pedal test

The tapping pedal test, as an indicator of pedal dexterity, was adapted from the Human Performance Measurement/Basic Elements of Performance apparatus [26]. A chair, a wooden ruler (1 m length, 1 cm width, and 2 mm height) fixed to the floor at the midpoint between the subject's two feet in the longitudinal direction with two signalizing stickers (10 cm× 10 cm), and one chronometer were necessary. The participant sat on a chair, with the lower limbs at a right angle and slightly distant, so that each heel was near each anterior leg of the chair (see Fig. 1).

Fig. 1 Tapping pedal test

The evaluator set the chronometer to 10 s and had it count down. At the command of "ready… start" by the evaluator, each participant was instructed to tap alternately as quickly as possible in the lateral direction (did a sort of tap dance) using one foot at a time. In a period of 10 s, they tapped on the signalizing stickers (the width of the signalizing stickers was 10 cm, and the distance between them was 45 cm) to avoid accuracy errors.

The subjects performed two trials for each foot. The results included the greatest number of taps done by each foot; therefore, this study only considered the better trial by each subject. Finally, the samples were counterbalanced; that is to say, half of the group began the tests with the PF, and the other half started with the NPF. Then, the contralateral foot was assessed. Following this procedure, we avoided the possibility of transfer of learning between feet. The same occurred with respect to the tests; subjects were counterbalanced according to the first test performed, with a time break between both tests.

The functional characteristics of footedness (e.g., the relationship between the preferred limb to execute a manipulative or mobilizing action, such as kicking a ball, and the other foot [non-preferred] that provides stabilizing support) have been studied in children [44] but not in older adults.

Tinetti test

Balance was evaluated using the Performance-Oriented Assessment of Balance and Mobility, also known as the Tinetti test. This instrument was developed by Tinetti [45], and it assesses the predisposition for falls in older adults through the quantitative evaluation of a set of tasks related to balance and mobility that are performed by the subject after being explained by the investigator.

The Tinetti test consists of nine balance items and ten gait items to be scored on a 0- to 2-point scale. The balance items include: (1) sitting balance; (2) rising from a chair; (3) immediate standing balance (first 3–5 s); (4) standing balance; (5) with feet as close together as possible, the examiner pushes lightly with his palm on the subject's sternum three times (nudge); (6) eyes closed in the same position; (7) turning 360°; and (8) sitting down. Static balance is determined by adding up to a maximum score of 16 points. The gait items include: (1) initiation of gait, (2) step length and height, (3) step symmetry and continuity, (4) path direction, (5) trunk sway, and (6) walking stance. This item adds up to a maximum score of 12 points. The total score ranges from 0 to 28 points. Lower scores indicate poorer performance.

Subjects that reach less than 19 points show high risk of fall, and those with scores between 19 and 24 points show moderate risk [40, 45].

Statistical analysis

All data were analyzed with the Statistical Package for the Social Sciences (SPSS: version 19.0). They were checked for distribution, and the means and standard deviation were calculated. Descriptive statistics and tests for normality (Shapiro–Wilk test) were performed for all outcome variables. To analyze the multimodal exercise program effect, a two-way ANOVA 2×2 (time, from pre- to post-training; gender, males and females) was used. This analysis was performed for the two groups (experimental group and the control group) and contexts (HC, RCH, DLC) separately and for each foot (PF and NPF). When ANOVA revealed significant interaction (time × gender), Bonferroni post hoc tests were performed to determine differences between the initial and the final values in each group. Statistical significance was set at $p \leq 0.05$.

Results

Concerning the Modified Baecke Questionnaire data, and regardless of the exercise program, significant increases from pre- to post-training in the experimental group were found in the residential care home and the daily living center ($p<0.001$). The control group maintained the level of daily physical activities from pre- to post-training: residential care home ($p=0.148$) and daily living center ($p=0.248$).

Tapping pedal test: pedal dexterity

Table 2 presents mean and standard deviation values of the tapping pedal test for the experimental group (males and females) of the hospital center, residential care home, and daily living center as a function of times of assessment and foot. In the experimental group of the hospital center, a significant main effect was found for the interaction between time and gender with the PF [$F_{1,\ 11}=8.787$; $p=0.013$] and the NPF [$F_{1,\ 11}=7.007$; $p=0.023$]. More particularly, males had slightly decreased performance with both feet from pre- to post-training (PF: from 18.25±2.36 taps to 17.50±3.31 taps and NPF: from 18.00±2.16 taps to 17.50±2.64 taps), while females improved their performance with both feet from pre- to post-training (PF: from 16.11±4.56 taps to 19.11±3.98 taps and NPF: from 15.00±4.58 taps to 16.77±5.14 taps). No other significant main effect was found.

In the residential care home, a significant main effect was found for time with the PF [$F_{1,\ 19}=31.637$; $p<0.001$] and the NPF [$F_{1,\ 19}=34.027$; $p<0.001$]. Namely, there was a significant improvement in performance from pre- to post-training (PF: from 20.09±2.02 taps to 23.95±3.58 taps and NPF: from 18.85±2.08 taps to 23.80±4.11 taps). No other significant main effect or interactions were found.

In the daily living center, a significant main effect was found for time with the PF [$F_{1,\ 17}=53.901$; $p<0.001$] and the NPF [$F_{1,\ 18}=55.357$; $p<0.001$]. More precisely, there was a significant improvement in performance from pre- to post-training (PF: from 20.57±3.53 taps to 26.52±3.97 taps and NPF: from 19.25±3.99 taps to 25.00±3.97 taps). No other significant main effect or interactions were found. Table 3 presents mean and standard deviation values for the control group's tapping pedal test (males and females) of the residential care home (older adults with mental health disorders), the residential care home, and the daily living center as a function of times of assessment and foot.

In the control group of the residential care home (older adults with mental health disorders), a significant main effect was found for time [$F_{1,\ 4}=9.308$; $p=0.038$], only for the NPF. More specifically, there was a significant decrease in performance from pre- (11.66±1.63 taps) to post-training (9.83±2.78 taps). No other significant main effect or interactions were found.

In the residential care home, a significant main effect was found for time [$F_{1,\ 6}=11.605$; $p=0.014$], only for the NPF. In particular, there was a significant decrease in performance from pre- (18.00±3.42 taps) to post-training (16.37±3.37 taps). No other significant main effect or interactions were found.

In the daily living center, a significant main effect was found for time with the NPF [$F_{1,\ 13}=12.430$; $p=0.004$]. More specifically, there was a significant decrease in performance from pre- (17.93±2.01 taps) to post-training (17.33±1.67 taps). No other significant main effect or interactions were found.

Tinetti test: balance

Table 4 presents mean and standard deviation values of the Tinetti test for the experimental group (males and females)

Table 2 The experimental group's results of the tapping pedal test are shown with mean and standard deviation values of taps from pre- to post-training for each gender and context

Hospital center							Residential care home						
Tests	Males	Females	Total	Factor	*F*	*p* value	Tests	Males	Females	Total	Factor	*F*	*p* value
PF (pre-training)	18.25±2.36	16.11±4.56	16.76±4.04	Time x Gender	8.787	0.013	PF (pre-training)	20.00±1.89	20.13±2.13	20.09±2.02	Time	31.637	0.001
PF (post-training)	17.50±3.31	19.11±3.98	18.61±3.73				PF (post-training)	24.66±4.76	23.66±3.15	23.95±3.58			
NPF (pre-training)	18.00±2.16	15.00±4.58	15.92±4.15	Time × gender	7.007	.023	NPF (pre-training)	18.50±1.87	19.00±2.20	18.85±2.08	Time	34.027	0.001
NPF (post-training)	17.50±2.64	16.77±5.14	17.00±4.41				NPF (post-training)	23.83±5.77	23.80±3.50	23.80±4.11			

Daily living center						
Tests	Males	Females	Total	Factor	*F*	*p* value
PF (pre-training)	22.33±2.80	19.76±3.63	20.57±3.53	Time	53.901	0.001
PF (post-training)	27.00±2.19	26.30±4.64	26.52±3.97			
NPF (pre-training)	20.50±4.13	18.71±3.96	19.25±3.99	Time	55.357	0.001
NPF (post-training)	25.16±3.76	24.92±4.19	25.00±3.97			

Statistical significance, $p \leq 0.05$

PF preferred foot, *NPF* non-preferred foot, *Time × gender* interaction between time and gender

Table 3 The control group's tapping pedal test is shown with mean and standard deviation values of taps from pre- to post-training in each gender and context

Residential care home (older adults with mental health disorders)							Residential care home						
Tests	Males	Females	Total	Factor	*F*	*p* value	Tests	Males	Females	Total	Factor	*F*	*p* value
PF (pre-training)	11.66±2.08	12.00±1.73	11.83±1.72	Time	6.125	.069	PF (pre-training)	18.16±4.62	20.50±2.12	18.75±4.13	Time	2.827	0.144
PF (post-training)	10.00±3.46	11.33±2.30	10.66±2.73				PF (post-training)	17.33±4.50	19.00±1.41	17.75±3.91			
NPF (pre-training)	11.00±1.73	12.33±1.52	11.66±1.63	Time	9.308	.038	NPF (pre-training)	17.50±3.78	19.50±2.12	18.00±3.42	Time	11.605	0.014
NPF (post-training)	9.00±3.60	10.66±2.08	9.83±2.78				NPF (post-training)	16.00±3.79	17.50±2.12	16.37±3.37			

Daily living center						
Tests	Males	Females	Total	Factor	*F*	*p* value
PF (pre-training)	19.14±2.19	18.14±2.26	18.64±2.20	Time	1.875	0.196
PF (post-training)	19.14±1.67	17.42±1.61	18.28±1.81			
NPF (pre-training)	18.37±2.13	17.42±1.90	17.93±2.01	Time	12.430	0.004
NPF (post-training)	17.50±2.64	16.85±1.46	17.33±1.67			

Statistical significance, $p \leq 0.05$

PF preferred foot, *NPF* non-preferred foot

Table 4 Experimental group's Tinetti test is shown with mean and standard deviation values of points from pre- to post-training in each gender and context

Hospital center

Tests	Males	Females	Total	Factor	*F*	*p* value
SB (pre-training)	12.25±2.06	10.33±1.87	10.92±2.06	Time	31.549	0.001
SB (post-training)	15.50±0.57	14.33±2.29	14.69±1.97			
DB (pre-training)	10.00±1.82	8.22±2.38	8.76±2.31	Time	14.489	0.003
DB (post-training)	11.75±0.50	9.77±2.27	10.38±2.10			
TB (pre-training)	22.25±3.86	18.55±3.71	19.69±4.00	Time	29.203	0.001
TB (post-training)	27.25±0.50	24.11±4.45	25.07±3.94			

Residential care home

Tests	Males	Females	Total	Factor	*F*	*p* value
SB (pre-training)	13.50±1.37	9.40±3.26	10.57±3.39	Time	24.091	0.001
SB (post-training)	15.00±0.89	12.33±3.19	13.09±2.98			
DB (pre-training)	11.66±0.51	8.93±2.31	9.71±2.32	Time	6.126	0.023
DB (post-training)	12.00±0.00	10.40±2.38	10.85±2.12			
TB (pre-training)	25.16±1.47	18.33±5.35	20.28±5.53	Time	20.487	0.001
TB (post-training)	27.00±0.89	22.73±5.24	23.95±4.83			

Daily living center

Tests	Males	Females	Total	Factor	*F*	*p* value
SB (pre-training)	12.14±2.85	12.35±2.70	12.28±2.68	Time	53.874	0.001
SB (post-training)	14.85±2.26	15.14±1.23	15.04±1.59			
DB (pre-training)	10.00±3.65	9.85±2.68	9.90±2.94	Time	8.423	0.009
DB (post-training)	11.71±0.75	11.5±0.85	11.57±0.81			
TB (pre-training)	22.14±6.28	22.21±5.11	22.19±5.37	Time	27.262	0.001
TB (post-training)	26.57±2.99	26.64±1.94	26.61±2.26			

TB (SB+DB): maximum 28 points. Interpretation: <19 high risk of falls, 19–24 moderate risk of falls, and 25–28 low risk of falls. Statistical significance, $p \leq 0.05$

SB static balance, *DB* dynamic balance, *TB* total balance

of the hospital center, the residential care home, and the daily living center as a function of times of assessment. In the experimental group of the hospital center, the time factor was significant for the static balance (SB) [$F_{1,\ 11}$=31.549; p <0.001], the dynamic balance (DB) [$F_{1,\ 11}$=14.489; p= 0.003], and the total balance (TB) [$F_{1,\ 11}$=29.203; p< 0.001]. From pre- to post-training, all of the older adults in the sample had a significant improvement of performance in the SB (from 10.92±2.06 to 14.69±1.97 points), DB (from 8.76±2.31 to 10.38±2.10 points) and TB (from 19.69±4.00 to 25.07±3.94 points). No other significant main effect or interactions were found. In the hospital center, after the physical exercise program, the older adults presented a low risk of fall (25.07±3.94 points), but at the beginning, they showed a moderate risk of fall (19.69±4.00 points) as measured by the Tinetti test [45].

In the residential care home, the time factor was significant for the SB [$F_{1,\ 19}$=24.091; p<0.001], the DB [$F_{1,\ 19}$= 6.126; p=0.023], and the TB [$F_{1,\ 19}$=20.487; p<0.001]. We found that from pre- to post-training, all the older adults in the sample experienced a significant improvement of performance in SB (from 10.57±3.39 to 13.09±2.98 points), DB (from 9.71±2.32 to 10.85±2.12 points), and TB (from 20.28±5.53 to 23.95±4.83 points). The gender factor was also significant for the SB [$F_{1,\ 19}$=6.823; p=0.017], the DB [$F_{1,\ 19}$=5.691; p=0.028], and the TB [$F_{1,\ 19}$=6.930; p= 0.016]. Males obtained a better performance in all of the three tests: SB (14.25±1.18 points), DB (11.83±0.25 points), and TB (26.08±1.18 points). In comparison, females performed the tests as follows: SB (10.86±3.23 points), DB (9.66±4.69 points), and TB (20.53±5.29 points). We verified that after the exercise program, females were at a threshold that indicated a moderate risk of fall (22.73±5.24 points), but at the beginning, they showed a high risk of fall (18.33±5.35 points). On the other hand, males showed a low risk of fall in the pre- (25.16±1.47 points) and post-training (27.00±.89 points), as measured by the Tinetti test [45].

In the daily living center, the time factor was significant for SB [$F_{1,\ 19}$=53.874; p<0.001], DB [$F_{1,\ 19}$=8.423; p= 0.009], and TB [$F_{1,\ 19}$=27.262; p<0.001]. More specifically, from pre- to post-training, all the older adults in the sample showed a significant improvement of performance in SB (from 12.28±2.68 to 15.04±1.59 points), DB (from 9.90±2.94 to 11.57±0.81 points), and TB (from 22.19±5.37 to 26.61±2.26 points). No other significant main effect or interactions were found.

In the daily living center, after the exercise program, the older adults had a low risk of fall (26.61±2.26 points), but at the beginning, they presented a moderate risk of fall (22.19 ±5.37 points). In the control group, no significant main effect or interactions were found for any of the context groups or variables, from pre- to post-training.

Discussion

The purpose of this study was to investigate the effects of a multimodal exercise program on pedal dexterity and balance by comparing older adults from different contexts. In the tapping pedal test, the results showed that for the time factor, both genders of the experimental group from the residential care home and the daily living center improved their performance significantly with both feet (preferred foot and non-preferred foot). In the hospital center, a significant main effect was found for the interaction between time and gender, namely males slightly decreased their performance while females improved theirs with both feet (preferred foot and non-preferred foot). In the control group, a significant main effect was found for time in all contexts; that is, both genders decreased their performance with the non-preferred foot.

It should be noted that in our study, all the older adults without mental pathologies of the experimental group (from the residential care home and the daily living center) improved their pedal dexterity with both feet through regular physical exercise. In other words, our results are in accordance with previous studies, which claim that the pedal dexterity of older adults can be improved through the practice of regular physical exercise [23, 32]. On the other hand, low levels of physical activity and weakness of the lower limbs have been identified as risk factors for functional status decline and falls [20, 28].

Literature emphasizes that an active lifestyle, complemented by regular physical exercise programs, can make an old person capable of performing daily tasks, providing meaningful improvement at the physical level [3, 42, 51].

Furthermore, the muscular structure of the lower limbs presents a strong relation with the mobility and functionality of the older adults [7]. It is evident that the training of balance and muscular strength (especially directed to the lower limbs) can improve the physical function and the functional mobility (e.g., walking speed, transferences, climbing stairs, and standing up from the position of sitting down) and reduce the risk of fall [17, 28, 39].

As mentioned above, the males of the experimental group from the hospital center slightly decreased their performance with both feet from pre- to post-training. This means that the effect of the multimodal exercise program was not enough to improve this ability. Additional studies are necessary to elucidate the effects (with respect to this ability) of exercise on men with mental health disorders. In this way, the risk of injury—namely falls and fractures—is even greater among adults with impaired cognitive functioning [6, 29]. Additionally, it is important to recall that due to their impaired motor and mental function, adults with dementia have an increased risk of falling, and those who do fall run the risk of further injuries [31].

On the other hand, the females of the experimental group from the hospital center improved their performance with both feet from pre- to post-training. These results are in agreement with other studies that have shown that structured exercise training leads to an increase in physical fitness and function in daily life in adults diagnosed with dementia [18, 19]. Likewise, exercise in old age is increasingly recognized as an important tool to postpone disability and improve function [6, 38]. Carmeli, Zinger-Vaknina, Morad, and Merrick [8] reported identical results to ours, with females improving their pedal dexterity, that is, an improvement in balance and muscle strength as the result of the applied exercise program.

Furthermore, findings have shown that adults who are generally active have a smaller risk of developing dementia than those who take part in fewer activities. Whether the activity is energy intensive or not plays a minimal role in this context [34]. Even in the oldest subjects (over 85 years), there are indications that regular physical activity protects against the development of dementia [43].

Exercise for adults diagnosed with dementia can yield physiological, psychological, and emotional effects. There is no basis for assuming that the volume and intensity of exercise components, such as muscle strength, flexibility, and balance, act differently in comparison to adults without dementia. When considering the impact of exercise on cognition and emotion, there is little knowledge regarding the amount and type of activity conducive to better results. Studies in the field of motor learning [37] indicate that the most important factors for learning are an adequate volume of practice together with a perceived meaningful and motivating task. However, considering our results, we think that additional studies are necessary to elucidate the effects of exercise on adults diagnosed with mental health disorders.

In our study, a pedal dexterity decrease was verified for the non-preferred foot in the control group (from the residential care home [older adults with mental health disorders], the residential care home, and the daily living center) for both genders, from pre- to post-training. In this sense, our results may suggest that the effect of aging is most visible in subjects who prefer the left foot. Nevertheless, further studies are necessary to confirm this hypothesis.

Concerning the Tinetti test, the older adults of the experimental group from the hospital center, residential care home (gender factor: males better than females), and the daily living center improved their balance from pre- to post-training. The older adults from the hospital center, who had shown a moderate risk of fall before the start of the exercise program, presented a low risk of fall after the program. In the residential care home, the males obtained a better performance than females (gender factor). However, after the training, the females were at a threshold that indicates a moderate risk of fall when, at the beginning, they exhibited a high risk. Otherwise, males showed a low risk. For the daily living center, the older adults displayed a low risk of fall after the training, when at the beginning it was moderate.

In summary, in the experimental group, all participants in this study improved their performance from pre- to post-training. Our results showed that the benefits of the multimodal exercise program are numerous, namely in balance, leading to a decrease of the fall risk [17, 35]. As some studies also confer (e.g., [12, 13]), it is expected that the older adults from our sample will be more autonomous when performing activities like sitting down, taking a bath, crossing a street, or cleaning a window.

Studies have shown that improvements in the proprioception and standing balance control of older adults may be specific to the type of physical training undertaken [47, 50]. It is important to mention that in our 12-month exercise program, we applied some Tai Chi exercises. One activity that has shown a strong relationship with the proprioceptive ability is the traditional Chinese exercise of Tai Chi, which involves slow movements and continuous monitoring of the body position. Tai Chi has been associated with increased joint position sense [47] and a way to enable older adults to feel their joint motion [50].

In the control group, no significant main effect or interactions were found in any of the context groups. These data are not in agreement with the study developed by Demura et al. [13], who find that with aging, balance declines especially after 80 years of age. Supported by these results, the authors suggest that the induced alterations through aging have influences on balance [16]. The loss of motor function is a common consequence of old age, and it is associated with adverse health consequences [5, 12].

The major limitation of our study was the difficulty of finding a sufficient number of older adults with mental health disorders who could perform a 1-year program of regular exercise. A key strength of our study is that, to our knowledge, there is not much information or systematic research on this subject (in the Portuguese population). So we believe that our results can contribute to a better understanding of the effect of exercise in the pedal dexterity and balance in old males and females from different contexts.

As a conclusion, we confirmed our previous hypothesis, noting that from pre- to post-training: (1) in the hospital center, males slightly decreased their performance with both feet while females improved theirs; (2) in the residential care home and the daily living center, the older adults improved their performance significantly with both feet. Furthermore, in the Tinetti test, the older adults from the hospital center, the residential care home (gender factor: males better than females), and the daily living center improved their balance. Finally, we believe that Portuguese society should pay special attention to multimodal exercise programs for older adults because they seem to improve some important motor and functional abilities, such as pedal dexterity and balance, contributing in this way to an increase of the autonomy and a better quality of life for the older population.

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Disclosures

Conflict of interest Guido Schröder, Andreas Knauerhase, Günther Kundt and Hans-Christof Schober declare that they have no conflict of interest.

Informed consent For studies with human subjects All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000. Informed consent was obtained from all patients for being included in the study.

Animal studies Not applicable.

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