

Comparison of multisensory and strength training for postural control in the elderly

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Objective: The objective of this study was to analyze the efficacy of multisensory versus muscle strengthening to improve postural control in healthy community-dwelling elderly.

Participants: We performed a single-blinded study with 46 community-dwelling elderly allocated to strength (GS, n = 23; 70.18 ± 4.8 years 22 women and 1 man) and multisensory exercises groups (GM, n = 23; 68.8 ± 5.9 years; 22 women and 1 man) for 12 weeks.

Methods: We performed isokinetic evaluations of muscle groups in the ankle and foot including dorsiflexors, plantar flexors, inversion, and eversion. The oscillation of the center of pressure was assessed with a force platform.

Results: The GM group presented a reduction in the oscillation (66.8 ± 273.4 cm² to 11.1 ± 11.6 cm²; P = 0.02), which was not observed in the GS group. The GM group showed better results for the peak torque and work than the GS group, but without statistical significance.

Conclusion: Although the GM group presented better results, it is not possible to state that one exercise regimen proved more efficacious than the other in improving balance control.

Keywords: postural control, aging, exercise, multisensory, strengthening

Introduction

Postural control is a key element in the execution of daily activities (eg, walking, sitting and standing from a chair, etc). This complex function requires input from the afferent receptor systems, vestibular, visual, proprioception, and general exterosensibility, in order to generate a motor response allowing the transition between dynamic and static activities.¹⁻³ Aging is associated with a decrease in postural control, which contributes to the increase in falls among the elderly.³⁻⁵

One of the most common interventions to prevent the consequences (eg, fractures and falls) of decreased balance is physical exercise. Besides promoting better health conditions, physical exercise can improve postural control and reduce the tendency to falls in this population.^{6,7} A growing number of studies have demonstrated this association,⁸ and several exercises have been shown to have some effect on the desired outcome.⁹ In particular, multisensory exercises¹⁰⁻¹² are characteristically defined by the stimulation of all three afferent systems and the ones that strengthen body muscles.¹³⁻¹⁶ Although the latter exercises are efficacious in restoring muscle mass and strength, when they are performed in isolation, their effects on postural control have not been well defined.

We believe that interventions that assess how different exercises interfere with postural control will allow a better and customized design of therapeutic programs to achieve a reduction in falls.^{8,15} The objective of this study was to analyze the efficacy

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of multisensory versus muscle strengthening to improve postural control in healthy community-dwelling elderly people.

Methods

Design

The local ethics committee approved the study, and all participants signed an informed consent form. We chose a randomized, single-blinded controlled trial. The study design and procedure for recruitment have been described previously.¹⁷ The study was performed in a rehabilitation center for outpatients in the central area of São Paulo, Brazil.

Subjects

The inclusion criteria were the following: age between 60 and 75 years; body mass index between 20 and 30; and ability to participate in physical activities. The exclusion criteria were the following: regular physical training in the last 3 months; severe clinical musculoskeletal impairments; implanted prosthesis of previous fractures in the axial skeleton or lower limbs; visual impairment without correction; and a recent complaint of dizziness or falls. Furthermore, subjects were discontinued from the study if they failed to participate in at least three consecutive training sessions. Before any intervention, they were evaluated by a physician in order to determine any clinical condition that might hinder participation in the study.

Assessment

Initially, subjects were assessed with the Timed Up and Go (TUG) test, which requires a subject to stand up, walk 3 m (10 ft), turn, walk back, and sit down. The time taken to complete the test is strongly correlated with the level of functional mobility.¹⁸ Afterwards, they were evaluated with a functional balance test using the Berg Balance Scale. This test consists of a range of 14 common tasks that involve both static and dynamic balance, such as reaching, turning, standing, arising, and making transfers.¹⁹

Subjects were evaluated before and after the interventions with a force platform (AMTI Inc, Watertown, MA). Where the oscillation of the body center of pressure area could be defined, we assumed this parameter to represent the whole body oscillation.^{9,10} After calibration, signs of oscillation of the body were recorded with the platform in the on-leg position. Data were captured with Eva software (Hewlett Packard®, Palo Alto, CA), in an acquisition frequency of 100 Hz. The area of movement of the center of pressure was measured in centimeters squared (cm²). We used a routine

developed in Matlab (version 6.5®; MathWorks, Upper Saddle River, NJ) to process the data.²⁰

For the assessment of static balance, subjects remained standing barefoot wearing light clothes on the dominant lower limb with open eyes for 10 seconds. In order to calculate the mean, this procedure was repeated three times sequentially, and the subjects were requested to stare at a fixed point within approximately 1 m at eye level. Illumination, noise, and temperature were kept constant and comfortable for all subjects and sessions. One assessor was positioned beside the subject in order to provide support in the event of a fall.

Isokinetic evaluation of the ankle was performed with an isokinetic evaluator (Cybex Humac Norm®; Computer Sports Medicine, Stoughton, MA). Subjects were positioned supine with the hip fixed in 90° and knee flexion of 80°, and straps were used to keep the lower limb in a fixed position. The movements performed at the heel and foot joints included dorsiflexion, plantar flexion, inversion, and eversion.²¹

Subjects were familiarized with the equipment during three rehearsals with free angular speed in order to get used to the movement to be tested. In order to calculate the mean, testing was performed in five repetitions at an angular speed of 30°/s, with concentric contractions of agonists and antagonists alternately though all ranges of motion. A verbal stimulus during the tests was essential to promote a better effort from subjects. Peak torque (N/m) and total work (J) were recorded.

Interventions

Subjects were asked not to participate in other physical activities and not to change their daily habits during the study. A computer-generated list randomly allocated the subjects to one of two training programs: strength training (GS) or multisensory training (GM). Both groups were subjected to one hour of training sessions on two different days a week. Subjects in both programs remained in training for 12 weeks.^{9,12}

Multisensory exercises program (GM)

Multisensory intervention emphasized the stimuli to sensory systems. A warm-up period before the activity included short walks and games with balls using the hands or feet. These were followed by stretching exercises for hip muscles, flexors, and extensors of the knee, ankle, and paraspinal muscles. Activities were performed both standing and lying down. Resistance exercises for plantar flexors and dorsiflexors as well as squatting and abdominals were performed against gravity in order to strengthen lower limbs and trunk; three series of ten repetitions were performed for each of these exercises.

Subjects also performed activities to stimulate the plantar surface and dynamic balance. They were asked to walk forwards, backwards, and sideways, with eyes both open and closed at different speeds and for various distances. Ground surfaces also varied and included mattresses and different densities of foam rubber. The subjects were also challenged by obstacles, such as ropes, cones, and sticks. Balance training was performed with devices often directed to the following activity in physical therapy: according to the subject's ability, he or she might be asked to remain standing on uni- or bipedal support with eyes open or closed. These sensorial challenges lasted from 20 to 30 minutes. Finally, motor

coordination training was performed by alternate movements of the upper and lower limbs, different positions of the head and neck, both with and without visual stimuli.^{12,17}

Strength exercises program (GS)

The muscle-strengthening program was performed using six different resistance devices with varying resistance: chest press, rowing, leg press, calves, abdominal, and lumbar extension. These devices were chosen because they load the main muscle groups.

At each device, the subjects were oriented to perform three series of exercises with varying loads: the first series

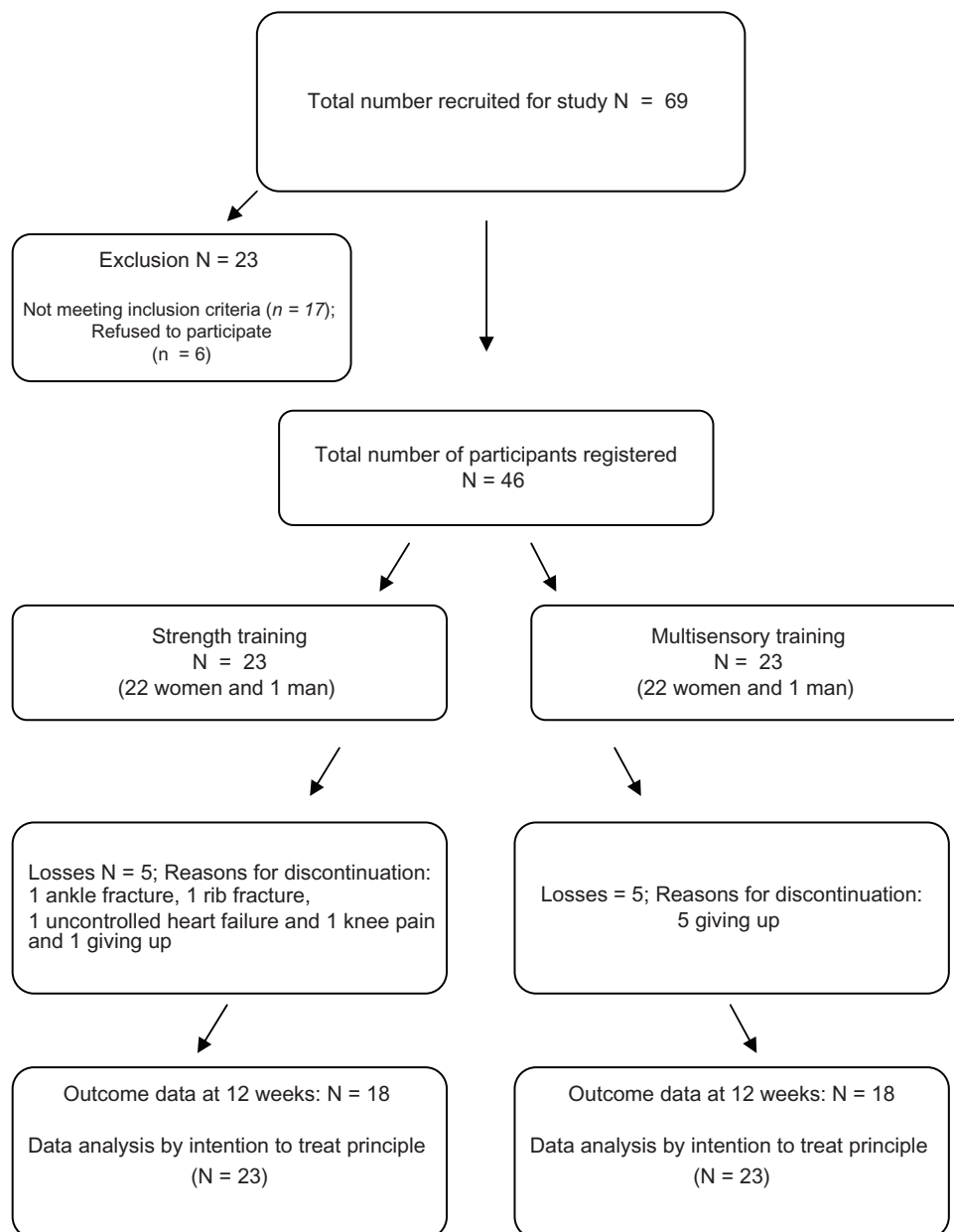


Figure 1 Flow of patients through the study.

of twelve repetitions were performed with a load at 50% of the maximum, the second (ten repetitions) at 75% of the maximum. The third series required eight repetitions at the maximum tolerated load. On the first day of training, the subjects did the exercises with no load in order to get used to the movements and posture. This value was estimated by successive trials and was defined as the load compatible with a complete range of motion, without a slow concentric or eccentric contraction, or sustained apnea. This value was then recorded to set new limits for the next session. The load was increased whenever it was possible to complete the last series of eight repetitions. Complaints of pain and breathing discomfort were actively elicited, and the speed of movements was constantly monitored in both concentric and eccentric phases.^{17,22,23}

Statistical analysis

The analysis considered a two-parallel arm design and an 80% probability of detecting a treatment difference at a two-sided 0.05 significance level. If the true difference between treatments was 1.5 units in TUG, two subjects were added in order to compensate for possible dropouts, which resulted in 46 subjects in the final sample. Data analysis was performed with the statistical package SigmaStat 3.5 for Windows (Systat Software, Point Richmond, CA). We used the principle of intention to deal with possible dropouts, and missing data were input with the mean of the remaining data. This strategy does not change the mean of the sample and prevents reduction of statistical power. However, it reduces the standard deviation and facilitates the identification of statistically significant results. The results were described as means and standard deviations. Comparisons of means at baseline between groups were performed using a two-tailed, independent Student's *t*-test or Mann-Whitney *U* test. Comparisons within the groups after the treatments were performed with a paired Student's *t*-test or Wilcoxon test, according to data distribution. The Mann-Whitney *U* test was used to test the differences in balance outcome variables between the groups in changes during the follow-up. The significance level was 0.05.

Results

From the 69 individuals recruited, 46 were eligible and provided their informed consent to participate. The progress of the participants through the various stages of the study is presented in Figure 1.

There were no statistically significant differences between the groups in terms of the proportion of female and male

Table 1 General characteristics of participants at baseline (Mean \pm SD)

	GS	GM	P
N	23	23	
F/M	22/1	22/1	
Age (years)	70.2 \pm 4.8	68.8 \pm 5.9	0.47*
BMI (kg/cm ²)	28.2 \pm 3.3	26.9 \pm 3.5	0.30*
TUG (s)	8.8 \pm 2.3	9.1 \pm 1.9	0.53*
Berg	55.5 \pm 1.4	55 \pm 1.8	0.51**

Notes: Values are presented as mean (SD). *Unpaired *t*-test; **Mann-Whitney test. **Abbreviations:** BMI, body mass index; F, female; M, male; TUG, Timed Up and Go test; s, seconds; Berg, Berg Balance Scale; GS, group strength; GM, group multisensory; SD, standard deviation.

participants, age, and body mass index (BMI). Clinically, the groups were similar in functional terms before the intervention when TUG, Berg (Table 1), and displacement of center of pressure (Table 2) were compared.

Isokinetic parameters in the right (Table 3) and left (Table 4) ankles were very similar before the interventions in both groups, except for total work during inversion of the right ankles. Although the differences were not statistically significant, the mean peak torque and work were less in GS before the intervention. After the intervention, although GS presented with improvement in peak torque in plantar flexion bilaterally and dorsiflexion in the left side, the improvements in total work were not statistically significant. However, GM presented with improvement in peak torque in plantar flexion and dorsiflexion bilaterally and in inversion and eversion on the right side. The total work improvement was statistically significant for plantar flexion and dorsiflexion bilaterally in GM.

The comparisons after treatment between the groups of gains after the intervention in all isokinetic parameters were not statistically significant (Tables 3 and 4).

Discussion

We compared the benefits of two exercise regimens on postural control of healthy elderly subjects. Although both intervention groups showed statistically significant

Table 2 Displacement of center of pressure (cm²) (mean and standard deviation) within and between groups before and after interventions

	Before	After	P	P
	Group \times Time			
GS displacement	62.7 \pm 269.8	16.6 \pm 30.5	0.75*	0.28**
GM displacement	66.8 \pm 273.4	11.1 \pm 11.6	0.02*	

Notes: *Wilcoxon; **Mann-Whitney.

Abbreviations: GS, group strength; GM, group multisensory.

Table 3 Peak torque (N/m) and total work (J) of isokinetic assessment of right heel and foot movements (mean and standard deviation) at 30°/s, within and between groups: strength (GS) and multisensory (GM) before and after the interventions

	GS			GM			P
	Before	After	P	Before	After	P	Group × Time
Peak torque							
Plantar flexion	28.6 ± 9.0	34.3 ± 13.4	0.03	34.3 ± 13.9	42.7 ± 9.5	0.007	0.55
Dorsiflexion	12.4 ± 4.0	13.7 ± 5.7	0.32	13.6 ± 4.5	15.7 ± 3.8	0.01	0.50
Inversion	12.7 ± 5.2	14.1 ± 5.2	0.38	14.7 ± 4.6	17.6 ± 3.1	0.008	0.46
Eversion	10.2 ± 4.3	11.2 ± 4.0	0.51	11.3 ± 3.3	13.3 ± 3.3	0.007	0.61
Total work							
Plantar flexion	16.5 ± 5.3	18.8 ± 7.7	0.08	20 ± 8.9	24.9 ± 7.2	0.031	0.33
Dorsiflexion	7.6 ± 2.7	8.2 ± 4.2	0.4	8.0 ± 2.9	9.7 ± 2.6	0.002	0.29
Inversion	8.4 ± 3.6	9.4 ± 3.4	0.42	10.7 ± 3.8*	11.4 ± 2.6	0.31	0.85
Eversion	8.3 ± 4.0	9.5 ± 3.5	0.39	9.3 ± 3.4	9.8 ± 2.5	0.47	0.65

Note: *P < 0.05 comparison between GS and GM before the intervention.

improvements in many parameters, and they did somewhat better in the multisensory approach, the differences between the groups were not statistically significant. Thus, although both interventions improved static and dynamic mobility in the healthy elderly subjects, we cannot state that either one is more efficacious.

Static balance is a predictor of independence and risk of falls in the elderly.^{10,24} Similarly, muscle action around the heel is also important because it is responsible for the control of this joint and thus support to the whole body. This outcome was assessed in this study because it is used in situations in which there is little disturbance of balance and the standing surface is stable, which were the conditions in this study.²

Although the improvement of body oscillation in the GM group was not significantly greater than in the GS group, we believe the results obtained by the GM group are clinically important because the subjects in this group might have achieved better postural control.²⁵ Reduced oscillation of the body center of pressure indicates better postural

control, whereas a wide area of oscillation might reflect the deterioration of postural control.² By testing this displacement in a standing position, it was possible to assess the muscle effort to maintain balance,¹¹ which was confirmed by the results of the isokinetic evaluation in the GM group. The reduced oscillation of the body center of pressure observed in the GM group is associated with the strengthening documented by the peak torque and work in the isokinetic assessment. This association was also observed in another study that used multisensory exercises three times a week for twelve weeks, in which improved action in gastrocnemius and tibialis anterioris resulted in the same improvement in balance.^{9,12}

The elderly lose the ankle strategy for postural control due to the muscle weakness and peripheral sensory loss that occur in aging. Improvement of muscle action in this region, which is the first to be used for maintaining balance, can be a contributing factor in the prevention of falls among the elderly.^{2,12,26,27}

Although the results for the two groups were not statistically different, we observed that only the GM group

Table 4 Peak torque (N/m) and total work (J) of isokinetic assessment of left heel and foot movements (mean and standard deviation) at 30°/s, within and between groups: strength (GS) and multisensory (GM) before and after the interventions

	GS			GM			P
	Before	After	P	Before	After	P	Group × Time
Peak torque							
Plantar flexion	27.2 ± 8.8	34.1 ± 7.6	0.001	33.5 ± 15.5	42.0 ± 11	0.01	0.74
Dorsiflexion	12.9 ± 3.2	15.5 ± 3.8	0.001	13.7 ± 3.5	16.8 ± 3.9	0.002	0.71
Inversion	12.8 ± 4.5	14.2 ± 2.7	0.12	13.9 ± 3.5	14.8 ± 4.7	0.4	0.74
Eversion	11.2 ± 3.8	12.4 ± 3.4	0.22	13.2 ± 4.3	14.5 ± 4.7	0.28	0.98
Total work							
Plantar flexion	16.4 ± 6.1	18.6 ± 5.8	0.1	19.5 ± 9.5	24.2 ± 6.9	0.04	0.39
Dorsiflexion	8.0 ± 2.4	9.1 ± 3.1	0.06	8.0 ± 2.5	10.0 ± 2.6	0.004	0.25
Inversion	9.9 ± 4.1	10.2 ± 2.7	0.69	10.7 ± 3.2	10.9 ± 3.5	0.82	0.94
Eversion	8.9 ± 3.0	9.2 ± 3.2	0.68	10.5 ± 3.5	10.6 ± 3.3	0.93	0.84

significantly improved the work of the dorsiflexor and plantar flexor muscles, which are important for the maintenance of static posture.^{2,12} This result led us to believe that the intensity, duration, and frequency of the strengthening exercises performed by the subjects in this study were not adequate to promote changes in the muscular action of the ankle joint.

The fact that multisensory exercises were able to reduce body sway in participants might be because this training provided sensory stimulation of the visual, vestibular, and somatosensory systems through exercises that were performed on different types of surfaces and densities. Furthermore, they used balls, circuits, and other devices that provided stimuli that enhance balance.^{9–11,25,28,29}

On the other hand, when used alone, muscle-strengthening exercises seem to have no effect on the improvement of balance in the elderly. This may be due to a decrease in sensory information because these exercises were conducted in a sitting position and not in an orthostatic posture in which the balance is most evident.^{30,31}

Although strength exercise is often assumed to be beneficial for balance, one review provided evidence that strength exercise used as an isolated intervention is not uniformly effective in improving balance performance.¹⁶ Only 22% of the results of the balance tests examined supported the efficacy of strength exercises as a single modality to improve balance.¹⁶ Although there are significant differences between groups after the intervention, our results corroborate the literature in that stimuli of the sensory systems are required to achieve gains in postural control.^{9,16}

Because it confirmed similar findings in other studies, we believe that the evidence in our study is valid and solid. However, the limitations of this study are the reduced sample size, lack of a comparison group with no training, and the design of the strength exercise programs in terms of load, duration, and frequency performed. These aspects can, however, be used as parameters for new steps in the understanding of the effects of multisensory exercises on postural control.

Conclusion

Although the group that performed multisensory exercises presented with a significant reduction of body oscillation and expressive improvement in isokinetic parameters on the heels after training, we cannot state that any of the exercise programs was superior for postural control.

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Disclosure

The authors declare no conflicts of interest in this work.

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