The impact of proprioceptive exercises on balance and physical function in institutionalized older adults: A randomized controlled trial

Abstract

Objective: The aim of this study was to evaluate the efficacy of a proprioceptive exercise program on functional mobility, musculoskeletal endurance, dynamic and static balance, gait, and risk of falls in institutionalized older adults.

Design: A randomized, single-blind, controlled trial.

Setting: A Spanish nursing home from the Autonomous Community of Extremadura, Spain.

Participants: An initial sample was created by recruiting 148 older adult volunteers. The final sample (n = 42) was randomly divided into two groups.

Intervention: Both the control and experimental group received physical therapy treatment based on a combination of adapted exercises and other physical therapy techniques (physical therapy intervention program) for a period of 12 weeks. This program consisted of 45 minutes (group intervention) plus 100 minutes (individual intervention) a week, for a total of 36 sessions (29 hours). The experimental group also received a proprioceptive training program during the same intervention period, which was conducted twice weekly (24 sessions), each session lasting 55 minutes.

Main Outcome Measures: The TUG, Cooper, Tinetti, One-Leg Stance and MORSE scales were used.

Results: ANOVA analysis showed a time x group interaction in TUG scores (F=10.41, P=.002), Cooper test (F=5.94, P=.019), Tinetti scores (F=6.41, P=.015) and MORSE scores

(*F*=5.24, *P*=.028). Differences between groups were achieved for TUG scores (*d*=0.76), Tinetti scores (*d*=1.12), One-Leg Stance test scores (*d*=0.77) and MORSE scale scores (*d*=0.85). In the experimental group, within-group analyses showed pre-post-treatment differences for TUG scores (*d*=0.72), Cooper test scores in meters (*d*=0.18), Tinetti scores (*d*=0.60), One-Leg Stance scores (*d*=0.55), and MORSE scores (*d*=0.42).

Conclusions: A proprioceptive exercise program produced significant improvements compared to the control group in areas such as functional mobility, musculoskeletal endurance, balance, gait, and risk of falls in institutionalized older adults. This study may help to enhance our understanding of the impact of a specific protocol for a proprioceptive rehabilitation program.

Key Words:

Proprioceptive; rehabilitation; physical activity; mobility; physical performance

List of abbreviations:

TUG Timed Up and Go test

SEM Standard Error of Measurement

MDC_{95} Minimum Detectable Change at the 95% confidence level

OLS One-Leg Stance test

Aging is defined as a natural process characterized by structural and functional changes that can be accelerated by disease or other factors, such as inactivity.[1] The worldwide population is progressively aging and this is commonly associated with a deterioration of physical health, functional performance and autonomy.[2] Functional impairments may be associated with alterations in balance and are an important predictive factor in various health conditions.[3] About one-third of adults aged 65 years and over experiences a fall at least once a year.[4] Moreover, people who have fallen once are at a higher risk of falling again, increasing the healthcare costs of national health systems in several countries.[5,6] Low levels of physical exercise are associated with poor postural control, which is another major factor linked to an increased risk of falling. Hence, physical decline in terms of balance, postural control and gait typically lead to the institutionalization of older individuals, increasing demand for long-term care.[1-6]

Health care centers belonging to private and public health systems usually provide assistance to older adults in residential care facilities, hospitals or nursing homes.[7] Long-term residential care is increasingly demanded once the patient is discharged from hospital and before they are able to return to a community setting.[8] Therefore, prevention plans and health promotion schemes for older adults have become increasingly important in recent decades, while reducing age-related disability has become an essential public health goal.[9] Previous literature provides evidence of rehabilitation programs using therapeutic physical exercises in the recovery process of common disorders in older people.[10-11] Various therapeutic approaches have shown their efficacy in improving health and functional movement in older adults.[6, 12-13]

Proprioception is defined as “the perception of joint and body movement as well as position of the body, or body segments, in space” [14] while kinesthetic sense is defined as “the

65 sense of position and movement of our limbs".[15] Although proprioception and kinesthesia are
66 involved in maintaining position, balance and movements when the eyes are both opened and
67 closed, these functions must be evaluated and trained with the eyes closed. Proprioceptive
68 exercises performed with the eyes closed reinforce the information sent and processed by the
69 central nervous system. The reception (on a sensory and perceptual level) and processing of
70 this information in older adults may be altered. If physical therapists stimulate these functions
71 through exercises with closed eyes and they actively direct attention toward body positions
72 and movements, the synaptic system that organizes this information at the neuronal level may
73 specifically be stimulated. In addition, these exercises likely integrate the proprioceptive
74 inputs with other balance components such as the vestibular system (the inner ear), the body
75 scheme (cognitive), base of support, body (trunk) symmetry, trunk sway, and the center of
76 gravity. In line with this, although proprioception is an essential aspect of balance,
77 proprioceptive exercises may specifically be used to improve proprioceptive and kinesthetic
78 integration in the brain, that is, the increase of synaptic connections for the perception of
79 static and dynamic positions in space.[14,15]

80 The lack of scientific evidence and conclusions on the efficacy of physical
81 rehabilitation on health variables has led to a wide variety of different experimental
82 protocols.[6] For example, cardiovascular training or exercises to enhance strength, flexibility
83 and balance have been shown to significantly improve physical and mental health, as well as
84 having positive effects on various body functions.[13,16] Nevertheless, to our knowledge,
85 research on the independent effects of proprioceptive exercises on functions such as general
86 mobility, balance, gait, or on the risk of falls in institutionalized older adults is still inadequate
87 to date. Findings in this specific area of rehabilitation are needed to provide clinical

knowledge for the appropriate design and planning of physical exercise interventions in this population.

The main objective of this randomized controlled trial is to evaluate the efficacy of a proprioceptive exercise program on functional mobility, musculoskeletal endurance, dynamic and static balance, gait, and the risk of falls in comparison with a control group in institutionalized older adults.

Methods

Design

This study is a randomized, single-blind, controlled trial. This trial was registered on ClinicalTrials.gov (NCT number: 02541305). CONSORT statements were used to conduct and report the trial.

Participants

An initial sample was created by recruiting 148 older adult volunteers from a Spanish nursing home. Convenience sampling was used for recruitment (i.e. any participants that were qualified for the trial were accepted). The final sample (n = 42) was randomly divided into control and experimental groups, each comprising 21 participants. The control group (15 females, 6 males) only received a physical therapy intervention program. The experimental group (14 females, 7 males) participated in the physical therapy program plus a proprioceptive training program. Fig 1 depicts a flowchart of participant recruitment during the study.

The inclusion criteria were: 1) adults over 65 years old, 2) living in an institutionalized setting, 3) participating voluntarily in the study, 4) who had had a previous fall in the last year (documented by the medical staff of the center in the twelve months before the inclusion of

111 the participant in the study), 5) physician's prescription that the rehabilitation intervention
112 would be appropriate and potentially beneficial. The exclusion criteria were: 1) patients with
113 cognitive decline (score ≥24 in the official Spanish version of the Mini-Mental Status
114 Examination for older adults) [17] or those unable to understand or take part in the measurement
115 process, 2) patients unable to tolerate moderate physical activity due to cardio-vascular or
116 respiratory illness, 3) patients with disorders affecting balance different from those caused by
117 aging such as dizziness or vestibular disorders that require medication with a potential effect
118 on balance, as well as balance disorders secondary to taking any medication or other medical
119 causes, 4) patients with a high risk of falls (≥ 51 points on the MORSE scale).

120 The Ethics Research Committee from the University of Extremadura (Spain) approved
121 the study protocol (number: 17//2013). This protocol complied with all the principles of the
122 Declaration of Helsinki as amended in 2013.

123 **Randomization**

124 Participants were randomly allocated to the experimental or control groups. The
125 randomization was performed by asking the participant to pick a number out of an envelope.
126 A researcher, aware of the study design, conducted enrolment and group assignment. The
127 primary outcome measure was the Timed Up and Go (TUG) test. Participants from both
128 groups were assessed both at the beginning of the first session (baseline evaluation) and after
129 the last session (post-treatment evaluation). The researcher conducting the evaluations was
130 blinded to the group assignment/allocation.

131 **Interventions**

132 The interventions were carried out at the Puente Real II nursing home in the city of Badajoz,
133 in the Autonomous Community of Extremadura, Spain (see supplementary material). Both

control and experimental groups received physical therapy treatment based on a combination of adapted exercises and other physical therapy techniques. The experimental group also received a proprioceptive training program during the same 12-week intervention period. The interventions were supervised by two physical therapists, with more than ten years of experience with older adults. An adherence rate to the interventions of 75% was established as a minimum for participants to be included in the final analysis.[18]

Physical therapy intervention program (Control group)

This program was based on a multicomponent physical therapy intervention with a combination of exercises adapted to older adults (in-group) and other physical therapy techniques (individually). In previous studies, multicomponent physical therapy protocols have been used as control groups (a 'standard' package) to evaluate the impacts of different novel physical therapy interventions in various older adult populations.[19,20] On the other hand, the standard physical therapy services provided in nursing homes, aged care facilities and other related services in Spain are based on providing these multifaceted interventions[21], which are similar to the physical therapy protocol used in the previous studies. [19,20]

The physical exercise was divided into different sections that were performed in the following order: warm-up, general mobility exercises in sitting and standing positions, games, stretching and return to rest. Exercise sessions were performed once a week (Mondays) for a duration of 45 minutes per session.[22,23] Individually, participants from the control group received infrared thermotherapy, neuromuscular electrical stimulation and manual therapy across a range of motion exercises on the spine and upper and lower limbs twice a week (Wednesdays and Fridays) for a duration of 50 minutes per session.[22,23] Hence, the control group had 45 minutes (group intervention) plus 100 minutes (individual intervention) a week, with a total of 36 sessions (29 hours) (see supplementary material).

158 *Physical therapy intervention program + Proprioceptive exercise program (Experimental*
159 *group)*

160 Both the experimental group and the control group received the physical therapy intervention
161 program. Although it was conducted on Mondays, Wednesday and Friday (at the same time)
162 for both groups, the therapy was administered in different rooms for each group to avoid any
163 possible risk of contamination between them in the institutional setting. In addition to the
164 physical therapy intervention program of the control group, the experimental group
165 participated in a proprioceptive training rehabilitation program during the same 12-week
166 period, two days per week (Tuesdays and Thursdays), for a total of 24 sessions (22 hours).
167 Each exercise session had a duration of 55 minutes with three phases: 15 minutes of warm-up
168 with slow walking, mobility and stretching exercises, followed by a 30-minute proprioceptive
169 exercise program, and 10 minutes to cool down using muscle stretches and relaxation
170 exercises (see supplementary material and fig 2). [21] Since only the experimental group
171 participated in a proprioceptive training rehabilitation program during the same 12-week
172 period, the participants from both groups were encouraged not to discuss the intervention
173 outside their cohort.

174 **Outcome Measures**

175 All instruments were applied in a single day for each participant and the times for baseline
176 and post-treatment testing were consistent for each individual participant. The rater was
177 blinded to group allocation and was the same researcher who collected the baseline clinical
178 data. Demographic, anthropometric, and clinical data were collected using a self-assessment
179 questionnaire developed for this study. The primary outcome was functional mobility
180 measured by the Timed Up and Go (TUG) test,[25,26] exhibiting a standard error of measurement
181 (SEM) of 1.27 s for the current sample study, and a minimum detectable change at the 95%

confidence level (MDC_{95}) of 3.12 s. The secondary outcome measures were: Cooper test[27], showing a SEM of 2.14 m, and a MDC_{95} of 4.01 m; Tinetti scale[28,29], with a SEM of 0.41 points, and a MDC_{95} of 1.79 points; One-Leg Stance (OLS) test[29,30], reported a SEM of 2.03 points, and a MDC_{95} of 3.96 s; and MORSE scale[31], showing a SEM of 1.11 s, and a MDC_{95} of 2.92 points. For a more extended instruments description, please see the supplementary material.

Statistical Analysis

Data analysis was performed using SPSS version 20.0 (SPSS Inc., Chicago, IL, USA). A descriptive analysis of each of the variables was performed. The normality of the variables was evaluated using the Shapiro-Wilk test, which showed a normal distribution for all the variables and, thus, parametric tests were appropriate. Data are reported as mean ± SD. The demographic and clinical variables of the groups at baseline were compared using the chi-square test for categorical data and the independent-samples t test for quantitative data. A two-way repeated measure ANOVA was performed to analyze the interaction effects of time (at baseline and 3 months post-treatment) in the two intervention groups (experimental and control group). The independent and paired-samples t tests were used for comparisons between and within-groups, respectively. The effect size for between-group and within-group mean differences was calculated using Cohen's d coefficient. A significance level of $P<.05$ was used.

Sample Size Estimation

G*power 3.1 software was used to calculate the sample size required to detect changes in the primary outcome (Timed Up and Go Test). Assuming an effect size (f) of 0.4 for between-group differences, an alpha level of .05 and power of 80%, a total sample size of 40

participants was estimated. The sample was inflated by 5% to account for potential dropouts, giving a final target sample size of 42. This calculation showed that a sample size of 21 participants per group was needed for a confidence interval of 95%, with a power of 80%, assuming a bilateral significance (a) of .05.

Results

Of the 45 older adults who volunteered to participate in the study, three did not meet the inclusion criteria. There were no significant baseline differences between the treatment groups in any of the sociodemographic or clinical characteristics ($p \geq .05$ for all comparisons). Sociodemographic and clinical characteristics at baseline are shown in Table 1. There were no differences between groups (proprioceptive training program vs. control group) in the outcome measures at baseline (see table 2).

The 2x2 mixed ANOVA revealed a time x group interaction for TUG (F=10.41, P=.002), Cooper test (F=5.94, P=.019), Tinetti (F=6.41, P=.015) and MORSE scores (F=5.241, P=.028). The post-hoc analyses showed significant differences between the experimental and control groups at post-treatment for mean scores of TUG (Mean experimental = 15.74, versus Mean control = 22.50; Cohen d = 0.76), Tinetti scores (Mean experimental = 23.05, versus Mean control = 19.88; Cohen d = 1.12), mean scores of OLS (Mean experimental = 25.15, versus Mean control = 15.42; Cohen d = 0.77), and mean scores of MORSE (Mean experimental = 13.00, versus Mean control = 25.57; Cohen d = 0.85). Pre- and post-treatment means, SD and differences between groups are shown in table 2.

In the experimental group, within-group analyses showed pre-post-treatment differences for TUG scores (Mean pre-treatment = 20.68, Mean post-treatment = 15.74, Cohen d = 0.72), Cooper scores in meters (Mean pre-treatment = 416.79, Mean post-treatment = 449.42, Cohen d = 0.18), Tinetti scores (Mean pre-treatment = 21.47, Mean post-treatment

= 23.05, Cohen *d* = 0.60), OLS scores (Mean pre-treatment = 17.94, Mean post-treatment = 25.15, Cohen *d* = 0.55) and MORSE scores (Mean pre-treatment = 19.10, Mean post-treatment = 13.00, Cohen *d* = 0.42). However, in the control group, within-group differences were not achieved (p>.05), except for Cooper test scores with a decline in musculoskeletal endurance. Pre- and post-intervention means, SD and differences for each group are shown in table 2.

Discussion

The objective of this study was to evaluate the efficacy of a proprioceptive exercise program on physical performance factors such as functional mobility, musculoskeletal endurance, dynamic and static balance, gait, and the risk of falls in institutionalized older adults. The proprioceptive exercise program combined with a physical therapy intervention program produced significantly higher improvements in all physical functions compared to the control group, except for postural steadiness. The effect sizes for the between-group differences ranged from moderate to high. In the experimental group, the magnitude of post-intervention improvements ranged from low to moderate. Although studies can be found in the literature on the effect of rehabilitation interventions on these physical components in older adults, to our knowledge, this is the first clinical trial that uses a specific proprioceptive program for a sample of institutionalized older adults. These findings may provide novel insights and practical information for professionals in the clinical and research fields, and may also help to design and implement future rehabilitation sessions and additional studies on this population.

This study revealed a significant improvement in the primary outcome (functional mobility) for the experimental group. After intervention, the mean difference between groups was 6.76 s in TUG, which was interpreted as significant in terms of the time to execute the test. Additionally, the pre-post differences in TUG scores after experimental intervention were

253 higher than those reported by Kristensen et al.[25] in older adults (4.95 s vs. 1.8 s), while also
254 achieving the MDC_{95} established for the current sample (3.12 s). Consistent with this finding,
255 musculoskeletal endurance, measured in total walking distance with the Cooper test,
256 significantly improved after experimental intervention, with a mean difference of 32.63 m
257 compared to pre-treatment values (this being higher than the 4.01 m reported for the current
258 sample as the MDC_{95}). These findings may be the result of the movements included in the
259 intensive proprioceptive training program. These movements were similar to those naturally
260 inherent to the performance of the basic and instrumental activities of daily living [32], which
261 probably reinforced the vestibular and proprioceptive systems, kinesthetic awareness and
262 attentional resources. These results are consistent with previous studies conducted with
263 institutionalized older adult population samples.[13,33] However, these studies differed from the
264 present study. Here the selected sample was different (institutionalized older adults), other
265 outcome measures were included, and the proprioceptive intervention program used in this
266 study is a specific protocol designed for this specific research (including different
267 proprioceptive exercises compared to other studies).

268 It is likely that the improvements in dynamic balance observed after the proprioceptive
269 program are due to the fact that this intervention addresses sensorimotor components and
270 processes involved in balance. These components usually include proprioceptive and
271 vestibular systems, body scheme, base of support, body symmetry, or trunk sway.[34,35] Several
272 studies have concluded that proprioceptive training in older adults can enhance inter- and
273 intra-muscular coordination, enabling a correct dynamic balance.[24] Regarding postural
274 steadiness as measured by the OLS test, although this is an essential component or phase of
275 walking patterns, the time x group interaction was not found to be significant. However, the
276 results of our study reported a significant increase pre-post-treatment of 7.21 s for the single-
277 leg stance position in the experimental group (this being higher than the MDC_{95} for the

current sample of 3.96 s). These improvements were also greater than the clinically significant improvement reported by Maribo et al [36] (6.88 s). Previous interventions based on several physical exercises significantly improved static balance when balance was assessed with the OLS test.[37,38] Several factors may account for the differences between this study and the aforementioned clinical trials. They may have used samples with a lower or higher mean age, the interventions were not conducted individually as in this study, and the older adults included in these studies were not institutionalized.[37,38] Similarly, the optimization of posture control depends not only on variables analyzed in a controlled situation, but also on the integrated response during a specific task and other parameters such as sight, cognitive-spatial mapping, or muscle fatigue.[37]

With regard to the risk of falls, significant between-group differences and improvement after the experimental group intervention were obtained (6.10 points), above the MDC_{95} for the current sample (2.92 points). Many different types of interventions have been conducted to prevent and reduce the risk of falls.[6] Giordano et al[39] achieved a reduced incidence of falls in older adults discharged from hospital in a community context after implementing a home tele-management program. In addition, the systematic review performed by Cadore et al.[13] reported that seven trials displayed fewer incidences of falls after physical training in comparison to a control group. However, although there is evidence supporting the effect of multifactorial interventions on reducing the risk of falls, specific proprioceptive training programs for Spanish institutionalized older adults have not yet been implemented.[6]

Study Limitations

This study presents some limitations. Firstly, the sample was recruited from a single institution and it may not be suitable for extrapolation to other populations. Future studies

should include other contexts such as retirement homes and outpatient hospital settings to extrapolate the results to the overall population of older adults. Second, the long-term efficacy of the proprioceptive exercise program was not measured, which could be used to derive clinical implications from the study. Thirdly, the assessors who collected the data were blinded to the group allocation; however, it was not possible to conceal the group assignment from the researchers involved in the intervention. Fourthly, the outcome measures used did not specifically target improvements in proprioception, but the effect on standard measures is an important finding. Although the study intervention protocol was based on proprioceptive aspects, we focused on physical functional improvements since these allow older adults to live more independently. Proprioceptive and kinesthetic functions are directly involved in maintaining position, balance, and movements performed with and without visual inputs. Some instruments for evaluating proprioception do exist, but they are usually costly, the evidence regarding their validity is limited or unknown, and they normally evaluate proprioception of isolated joints. Finally, although participants were advised not to discuss the intervention outside their cohort, there is always some risk of contamination between the groups in an institutional setting.

Conclusions

From a clinical perspective, the inclusion of proprioceptive exercises in rehabilitation sessions, twice a week for at least 12 weeks, has the potential to benefit functional mobility, musculoskeletal endurance, dynamic and static balance, gait, and to reduce the risk of falls in institutionalized older adults.

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Figure legends

Fig 1 Flow diagram of patient recruitment following CONSORT guidelines.

Fig 2 Images of the proprioceptive therapeutic exercises illustrating the proprioceptive program protocol (main phase - proprioceptive exercise session).