Positive effects of resistance training in frail elderly patients with dementia after long-term physical restraint

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Abstract This study investigated the effects of a multicomponent exercise intervention on muscle strength, incidence of falls and functional outcomes in frail elderly patients with dementia after long-term physical restraint, followed by 24 weeks of training cessation. Eighteen frail elderly patients with mild dementia (88.1 ± 5.1 years) performed a multicomponent exercise program, which consisted of 4 weeks of walking, balance and cognitive exercises, followed by 4 weeks of resistance exercise performed twice weekly [8–12 repetitions at 20–50 % of the one-repetition maximum (1RM)], combined with walking, balance and cognitive exercises. Before and after training, as well as after

24 weeks of training cessation, strength outcomes, Barthel Index, balance, gait ability, rise from a chair ability, dual task performance, incidence of falls and Mini-Mental State Examination were assessed. After the first 4 weeks of training, there was a significant improvement only in the balance test, whereas no additional changes were observed. However, after the second part of the training, the participants required significantly less time for the time-up-and-go test ($P < 0.05$), and improved the isometric hand grip, hip flexion and knee extension strength, as well as the leg press 1RM ($P < 0.01$). A significant reduction was also observed in the incidence of falls ($P < 0.01$). After 24 weeks of training cessation, abrupt decreases were observed in nearly all of the physical outcomes ($P < 0.05$). The exercise intervention improved strength, balance and gait ability in frail elderly patients with dementia after long-term physical restraint, and these benefits were lost after training cessation.

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Introduction

Dementia is a syndrome that represents a major public health problem because it impacts the capacity for active

daily living and impairs social and occupational functions (Heyn et al. 2004). With the progression of dementia, elderly individuals with cognitive disorders generally become frail and institutionalised patients (Heyn et al. 2004; Singh 2002). One of the major negative consequences of dementia is the severe decline in physical activity, which can be attributed to several causes, including the use of physical restraints to prevent falls (Gulpers et al. 2010; Berzlanovich et al. 2012). Physical restraints, which are commonly used in elderly individuals who require long-term nursing care (Zwijnen et al. 2011), may be defined as any limitation of an individual's freedom of movement (Hantikainen 1998; Hamers and Huizing 2005) and include restraints worn by the person (belt, chest and arm/leg) and those attached to beds (full-enclosure bed rails) or chairs (locked table) (Gulpers et al. 2010). The restraints are associated with adverse social, physical and psychological outcomes, such as loss of freedom and autonomy, humiliation, incontinence, demoralization, depression, aggression, exacerbated sarcopenia, loss of strength, impaired ability to stand and walk and overall decreased functional status and quality of life (Gulpers et al. 2010; Berzlanovich et al. 2012; Zijwen et al. 2011).

Dementia and frailty may coexist in elderly persons because both diseases share several pathophysiological mechanisms and phenotypes and are different entities in the same disease spectrum (Hantikainen 1998; Robertson et al. 2013). Long-term physical restraint of elderly individuals as a consequence of dementia and institutionalisation may accelerate sarcopenia (Gulpers et al. 2010), which, in addition to strength and muscle power loss, results in an accelerated decline in aspects of overall function including gait ability in addition to other physical hallmarks present in frail elderly patients (Campbell and Buchner 1997; Walston and Fried 1999; Stewart et al. 2005; Bergman et al. 2007; Rockwood and Mitnitski 2007; Morie et al. 2010; Theou et al. 2010; Rodríguez Mañas et al. 2012). The frailty syndrome may accelerate the trajectory of decline in patients with dementia because individual components of frailty, such as impaired grip strength, slow gait, low level of physical activity and body weight loss, have been shown to predict the development of dementia and are associated with the incidence of mild cognitive impairment (MCI) (Buchman et al. 2007; Yaffe et al. 2009; Boyle et al. 2010; Watson et al. 2010; Garcia-Garcia et al. 2011; Mhaoláin et al. 2012; Robertson et al. 2013).

Exercise intervention (e.g. resistance, walking and balance training), which is designed to improve the physical domains of frailty, may also benefit elderly patients with dementia (Hauer et al. 2012). Additionally, physical exercise, such as endurance and resistance training, has been shown to improve cognitive function in subjects with MCI and dementia (Heyn et al. 2004; Hauer et al. 2012). However, to the best of our knowledge, no study has investigated the effects of exercise intervention in frail subjects with dementia after long-term physical restraint. Dual-task walking, such as “walking when talking”, has become an interesting method to assess the interaction among cognition, gait and falls because results in dual-task walking tests are associated with the incidence and risk of falls (Lundin-Olsson et al. 1997; Maquet et al. 2010; Montero-Odasso et al. 2012). However, the effects of an exercise program on dual-task performance have not been investigated in frail elderly patients with dementia.

Physically frail patients with dementia often experience interruptions in training sessions because of illness, injury or other factors that may result in a reduction or cessation of their normal physical activity. Reports have shown that cessation of training results in a loss of strength and that the magnitude of this reduction may depend on the length of the detraining period (Izquierdo et al. 2007; Pereira et al. 2012a), together with the subject's pretraining physical level. However, little is known about the regressive effects of training cessation in frail elderly patients with dementia once the training intervention has ended (Henwood and Taaffe 2008). Therefore, the extent to which the residual effects of power or strength training promote physical independence after a period of interruption needs to be elucidated.

It is important to determine the effectiveness of a multicomponent exercise intervention, which consists of resistance, gait and balance exercises, on functional outcomes in this population because improved muscle strength, gait ability and balance are key factors for reducing the incidence of falls and increasing independence in frail elderly patients with dementia and with severely impaired physical condition. However, the extent to which these individuals retain their capability to improve their strength and functional outcomes remains to be determined. The purpose of this study was to investigate the effects of 8 weeks of multicomponent exercise intervention on muscle strength and functional outcomes in frail patients with dementia. Our second purpose was to evaluate the physical outcomes of these

participants after 24 weeks of detraining. We hypothesized that these individuals would demonstrate improved muscle strength and functional outcomes even after long-term physical restraint.

Methods

Experimental design

The total duration of the present study was 34 weeks. The first part of the trial was designed to investigate the effects of a 4-week exercise intervention that consisted of gait, balance and cognitive exercises. The second 4-week training period included a multicomponent exercise, which consisted of resistance training with loads for optimizing muscle power output, combining this resistance exercise with the gait, balance and cognitive exercises performed in the first 4 weeks. To investigate the effects of this exercise intervention on physical function in older patients with dementia after long-term physical restraint, we assessed muscle strength, functional outcomes, incidence of falls and dual-task performance. After a follow-up period of 12 and 24 weeks of training cessation, we investigated the sustainability of the physical gains. To provide the exercise intervention to all of our participants with dementia, we chose to use a period control (2 weeks) rather than a control group of elderly with dementia. Thus, despite of the short period control, we assessed the physical parameters twice before the exercise intervention to test the stability and reliability of these variables in this population. Before data collection, the individuals participated in a familiarization procedure for each test. Both before and after the intervention, each specific test was overseen by the same investigator, and each test was conducted on the same equipment with identical subject/equipment positioning. Each subject performed the tests at the same time of day throughout the study.

Subjects

The participants were institutionalized elderly patients from the Tudela (Spain) area and were included in the study if they met the following criteria: age 75 years or older, diagnosis of dementia, several months of physical restraint and fulfillment of Fried's criteria for frailty, which was determined by the presence of three or more of the following components: slowness, weakness,

weight loss, exhaustion and low level of physical activity (Fried et al. 2001). In the individuals who met the inclusion criteria for cognitive impairment [Mini-mental state examination (MMSE) score of 17–26] (Hauer et al. 2012; Hueger et al. 2009), a dementia diagnosis was confirmed according to the international standards for Alzheimer's disease, multifactorial cause or vascular dementia. The diagnosis was based on medical history, clinical examination, cerebral imaging and an established neuropsychological test battery [Consortium to Establish a Registry for Alzheimer's Disease (CERAD)], the Trail-Making Test 31 and a Clinical Dementia Rating (CDR) (Morris 1993) of 1, thus allowing a diagnosis of different types of dementia. Before the study, all of the participants underwent a medical assessment. The CDR of the patients of the present study was between 1 and 2. Physical restraint was defined as any limitation of an individual's freedom of movement (Hantikainen 1998; Hamers and Huizing 2005) including restraints those worn by the person (belt, chest and arm/leg) and those attached to beds (full-enclosure bed rails) or chairs (locked table) (Gulpers et al. 2010). All of the patients had experienced at least 9 months of physical restraint (14 ± 3 months). The exclusion criteria were the absence of frailty, dementia, recent cardiac arrest, unstable coronary syndrome, active cardiac failure, cardiac block or any unstable medical condition. Of the 29 frail elderly patients with dementia who were approached, 21 patients with the approval of their legal guardians agreed to participate in the trial after completing an informed consent form. From the initial sample of 21 elderly patients who volunteered to take part in this study and who met the inclusion criteria, 18 (age of 88.1 ± 5.1 years; $n=18$) completed the pre- and post-training measurements (Fig. 1). During the intervention, one subject died of causes unrelated to the exercise intervention, and two participants dropped out of the study because of medical complications. During the follow-up period, 11 participants completed the physical evaluations at 12 and 24 weeks after the cessation of the exercise intervention. Six participants died during the follow-up, and one dropped out of the study because of a medical complication. Dementia was caused by Alzheimer's disease in most of the patients (10 of 18), but vascular disease (one patient) and a multifactorial cause (seven patients), primarily Alzheimer's disease with a vascular component, were also present. In addition to frailty and dementia, several comorbidities were diagnosed with a mean of

Fig. 1 Flowchart for screening, recruitment, allocation, intervention and post-intervention period

“7” diagnosed per patient. The most usual comorbidities were type II diabetes (seven patients), chronic renal failure (seven patients), hypertension (six patients), depression (four patients), osteoporosis (four patients), ischemic heart disease (three patients), dyslipidemia (three patients) and osteoarthritis (three patients). Women accounted for 55 % of the patients with dementia (10 of 18 patients). The patients were assessed for all of the functional outcomes, dual-task performance and muscle strength. The study was conducted according to the Declaration of Helsinki, and the protocol was approved by the local Institutional Ethical Committee Board.

Functional outcomes and incidence of falls

Gait ability was assessed using the 5-m habitual (GVT) gait and time-up-and-go (TUG) tests. In the 5-m habitual gait test, the subjects were asked to walk at their habitual speed on a flat 5-m course with an initial distance of 2 m for acceleration that was not included in the calculations of gait assessment. The TUG test

consisted of measuring the time required to perform the task of standing from a chair, walking 3 m, turning, going back to the chair and sitting down on in the chair.

The dual-task performance was assessed using both verbal and arithmetic methods in the 5-m habitual gait test. Gait velocity was measured during simultaneous performance a verbal or counting task (verbal GVT and counting GVT, respectively) in two separate trials. During the verbal fluency dual-task condition (verbal GVT), we measured the gait velocity as the participants named animals aloud; during the arithmetic dual-task condition (counting GVT), we measured the gait velocity while the participants counted backward aloud by ones from 100.

Balance was assessed using the FICSIT-4 tests of static balance (parallel, semi-tandem, tandem and one-legged stance tests), and the subjects progressed to more difficult tests only if they had succeeded on easier tests. The chair rise test was performed to determine the maximum number of chair rises that the subjects were able to perform in 30 s. The functional outcomes have been described in detail elsewhere (Casas-Herrero et al. 2013). The reliability of these functional outcomes in

people with dementia have been previously shown (Tomas and Hageman 2002; Hueger et al. 2009).

Data on the incidence of falls were assessed retrospectively using questionnaires to nurses. These data were assessed in periods of 4 weeks: before the start of the exercise intervention (from week -4 to week 0), 4 weeks after the start of exercise intervention (week 5 to week 8) and at 12 weeks after training cessation (week 12 to week 15).

Functional status was assessed using the Barthel Index (BI), which is an international and validated tool of disability. The scores ranged from 100 (complete independence shown in daily living activities) to 0 (severe disability). The MMSE was used to measure general cognitive function.

Maximal isometric and dynamic strength

Isometric upper (right hand grip) and lower limb (right knee extensors and hip flexors) muscle strength was measured using a manual dynamometer. The maximal dynamic strength was assessed using the 1RM test with a bilateral leg press exercise. The bilateral leg press 1RM was performed using an exercise machine [Exercycle, S.L. (BH Group), Vitoria, Spain]. On the test day, the subjects warmed up with specific movements for the exercise test. Each subject's maximal load was determined with no more than five attempts, with a 4-min recovery between attempts.

Exercise intervention (strength, balance and walking program)

The total duration of the exercise program was 8 weeks. During the first 4 weeks, the participants began a short daily walk inside the nursing home, along routes normally traveled in a wheelchair, for example, going to the dining room, chapel or bathroom, or walking along the corridors of the nursing home. The participants walked using canes and walker devices, if necessary, with the assistance of a physical therapist. At all times, the participants were encouraged to increase the distance walked and to try to walk without aid. The distance was gradually increased according to the physical ability of the participants. Subjects who were in the worst physical condition ($n=8$ subjects) started by walking 15.2 ± 3.2 m per day and progressed to 33.3 ± 14.6 m per day during the 8 weeks of intervention, whereas subjects who were in better physical condition ($n=10$

subjects) started by walking approximately 60.3 ± 4.3 m per day and progressed to 144.5 ± 37.1 m per day. Balance and gait retraining exercises that progressed in difficulty were also implemented: semi-tandem foot standing, line walking, stepping practice, walking with small obstacles, proprioceptive exercises on unstable surfaces and altering the base of support and weight transfer from one leg to the other. Furthermore, occupational therapy with exercises for executive and cognitive functions were also performed individually and in groups; these exercises addressed stimuli for eating and dressing, space-time orientation, reasoning, memory, language, attention and perception. In the last 4 weeks of the multicomponent exercise intervention, the participants added a twice-weekly resistance training to their walking and balance exercise program. The resistance training workloads were progressively increased (2 sets, 8–12 repetitions, 20–50 % of 1RM) using a leg press machine [Exercycle, S.L. (BH Group), Vitoria, Spain]. During the progressive resistance training, the participants were instructed to perform the exercises at a high speed to optimize the power output. However, care was taken to ensure that the exercises were executed appropriately. In each session, the subjects performed a specific warm-up with one set of very light loads for the upper and lower body. All of the training sessions were carefully supervised by at least one experienced physical trainer. Attention was paid to emotional aspects, such as reassurance, respect and empathy toward the participants as described in patient-centered techniques that were developed for communication with individuals with dementia (Kitwood 1990). The simple structure of the instructions, haptic support and use of mirror techniques rather than complex oral instructions supported the progress of training and created a familiar, empathetic training atmosphere in the study group. To reduce participant dropout, music was played during all of the sessions, and adherence higher than 90 % was observed in all of the subjects. Sessions were deemed completed when at least 90 % of the prescribed exercises had been successfully performed.

Training cessation

After 8 weeks of the multicomponent exercise intervention (4 weeks of balance and gait retraining+4 weeks of resistance, balance and gait retraining), the subjects interrupted their exercise routine. They maintained their cognitive exercises in occupational therapy and also

walked short distances, such as going to the bathroom and walking with assistance, but they no longer engaged in systematic physical activity. No physical restraint device was used after the training cessation.

Statistical analysis

The SPSS statistical software package was used to analyse all of the data. The normal distribution of the data was evaluated using the Shapiro-Wilk test. Statistical comparisons in the control period (from week -2 to week 0) were performed using Student's paired *t* tests. The results were reported as the mean $\pm$ SD. The training-related effects were assessed using an analysis of variance (ANOVA) with repeated measures (0, 4 and 8 weeks). When a significant *F* value was obtained, LSD post hoc procedures were used to evaluate pairwise differences. Comparisons among values before and after 8 weeks of training and 12 and 24 weeks of training cessation were also performed by ANOVA with repeated measures and LSD post hoc tests in participants who were assessed during the follow-up period. $P < 0.05$ was considered to be statistically significant.

Results

Control period

During the control period, there were no changes in the intervention group in any of the physical outcomes assessed: 5-m gait velocity ($0.37 \pm 0.24 \text{ m s}^{-1}$ vs. $0.30 \pm 0.16 \text{ m s}^{-1}$); TUG ($44.7 \pm 58.7 \text{ s}$ vs. $49.7 \pm 50.1 \text{ s}$); rising from a chair (1.47 ± 3.14 times vs. 1.45 ± 2.74 times); balance (0.29 ± 0.46 vs. 0.35 ± 0.48); gait ability with verbal task ($0.21 \pm 0.14 \text{ m s}^{-1}$ vs. $0.22 \pm 0.14 \text{ m s}^{-1}$); gait ability with arithmetic task ($0.26 \pm 0.19 \text{ m s}^{-1}$ vs. $0.25 \pm 0.17 \text{ m s}^{-1}$); MMSE score (15.1 ± 6.3 vs. 16.2 ± 5.1); Barthel Index (27.9 ± 17.0 vs. 29.2 ± 16.9); isometric hand grip strength ($12.3 \pm 5.3 \text{ kg}$ vs. $12.4 \pm 5.8 \text{ kg}$); isometric knee extension strength ($11.7 \pm 6.1 \text{ kg}$ vs. $14.4 \pm 6.2 \text{ kg}$) and isometric hip flexion strength ($11.3 \pm 7.4 \text{ kg}$ vs. $14.4 \pm 5.3 \text{ kg}$).

Functional outcomes and incidence of falls

After the first period of training (i.e. 4 weeks of gait and cognitive exercises), there were no changes in the 5-m gait velocity test, TUG, dual-task performance or rising

from a chair, whereas a significant enhancement of balance was observed (Table 1). However, after the second part of the training period (i.e. 4 weeks of multi-component exercise including resistance training with loads that optimize muscle power output), the intervention group required significantly less time for the TUG test ($P < 0.05$) and tended to have a higher gait velocity in the 5-m test, although the difference did not reach significance ($P = 0.07$) (Fig. 2). A significant reduction was also observed in the incidence of falls ($P < 0.01$). No changes were observed in the intervention group in the BI score, MMSE, dual-task performance and rising from a chair, and no additional change was observed in balance.

Maximal isometric and dynamic strength

After the first period of training (i.e. 4 weeks of gait and cognitive exercises), there were no changes in the isometric hand grip, knee extension and hip flexion strength, or in the maximal dynamic strength (1RM). After the second part of the training period, the intervention group showed significant increases in isometric hand grip, hip flexion and knee extension strength ($P < 0.01$) (Fig. 3). Significant changes were also observed in the lower body 1RM in the intervention group.

Follow-up period (12 and 24 weeks post-exercise intervention)

After 12 and 24 weeks of training cessation, significant decreases were observed in nearly all of the variables assessed (Table 1). Regarding the strength variables, the isometric hand grip, knee extension and hip flexion strength were lower after 12 and 24 weeks of detraining compared with before training and after 8 weeks of intervention ($P < 0.05$) (Fig. 3), with the values after 24 weeks being lower than those after 12 weeks of detraining ($P < 0.05$). The leg press 1RM strength after 24 weeks of detraining were lower than that after 8 weeks of exercise intervention ($P < 0.05$). Regarding functional outcomes, the gait speed with single and dual tasks (both verbal and arithmetic tasks) was lower after 12 and 24 weeks of detraining compared with that before training and after 8 weeks of intervention ($P < 0.05$). TUG performance was significantly decreased post 12 and 24 weeks of training cessation when compared with pre- and post-8 weeks of exercise intervention ($P < 0.05$) (Fig. 2). Additionally, the TUG performance tended to be lower after 24 weeks of detraining compared with

Table 1 Functional and strength outcomes pre- and post-intervention and follow-up period (mean±SD)

	Exercise intervention group (n=18) and follow-up group (n=11)				
	Intervention period			Follow-up period	
	Pre-	Post-4 weeks of intervention	Post-8 weeks of intervention	12 weeks of detraining	24 weeks of detraining
Gait velocity (m s ⁻¹)	0.36±0.18	0.32±0.21	0.42±0.21	0.30±0.20*†	0.25±0.17*†\$
TUG (s)	43.4±16.3	49.4±55.7	31.2±10.9*	55.4±32.6*†	62.7±38.5†
Number of rises from a chair in 30 s	2.3±3.5	1.4±3.4	2.7±4.0	2.2±2.8	1.8±2.2
Balance	0.30±0.5	0.82±0.8*	0.80±0.7*	0.90±0.8	0.70±0.8
Gait velocity arithmetic task (m s ⁻¹)	0.27±0.21	0.28±0.24	0.29±0.17	0.18±0.14*†	0.17±0.12*†
Gait velocity verbal task (m s ⁻¹)	0.27±0.17	0.24±0.19	0.27±0.17	0.21±0.16*†	0.19±0.14*†
Incidence of falls	1.1±1.4	—	0.16±0.5*	0.30±0.60†	—
Barthex index	35.0±18.1	29.6±18.1	30.3±17.7	23.3±16.3*†	18.3±14.1*†
MMSE	15.1±6.3	15.6±6.7	15.9±7.1	12.6±4.2†	10.6±3.1*†\$
Hand grip (kg)	11.9±4.6	12.9±5.8	13.8±5.3*	10.7±4.8*†	9.4±4.2*†\$
Knee extension strength (kg)	14.3±5.9	15.7±5.5	17.3±4.5*	11.1±3.7*†	8.5±2.6*†\$
Hip flexion strength (kg)	13.9±4.7	12.5±5.1	16.7±4.5*	11.0±2.9*†	9.0±2.0*†\$
Leg press 1RM (kg)	33.5±13.4	31.4±15.6	43.9±16.4*	37.0±15.7	32.5±12.0†

TUG time-up-and-go test, 1RM one maximum repetition, MMES Mini-mental state examination

* $P<0.05$, significant difference from pre-training values; † $P<0.05$, significant difference from post-8 weeks of training; \$ $P<0.05$, significant difference from post-12 weeks of detraining

12 weeks of detraining, although the difference did not reach significance ($P=0.06$). The incidence of falls significantly decreased after 12 weeks of detraining ($P<0.05$). Moreover, significantly lower values were observed in the BI score after 12 and 24 weeks of training when compared with pre- and post-8 weeks of exercise intervention values ($P<0.05$). Furthermore, significant

reductions in the MMSE score were observed after 12 and 24 weeks of training when compared with pre- and post-8 weeks of exercise intervention values ($P<0.05$). No changes were observed in chair rise performance or balance during the detraining period.

Fig. 2 Time-up-and-go (TUG) (s) and gait velocity tests (metres per second) (mean±SD) pre-, post-8 weeks of training, post-12 weeks of detraining, and 24 weeks of detraining. Significant differences from pre-training values * ($P<0.05$) and significant difference from 8 weeks of training, † $P<0.05$

Fig. 3 Knee extension, hand grip and hip flexion isometric strength (Kgf) (mean±SD) pre-, post-8 weeks of training, post-12 weeks of detraining and 24 weeks of detraining. Significant differences from pre-training values * ($P<0.05$); significant difference from 8 weeks of training, † $P<0.05$ and significant difference from 12 weeks of detraining \$ $P<0.05$

Discussion

In the present study, the primary finding is that, after several months of physical restraint, a multicomponent exercise intervention program composed of walking, muscle power training, cognitive and balance exercises provides an optimal stimulus for improving muscle strength, balance and gait ability and for reducing the incidence of falls in frail patients with dementia. Additionally, the changes in muscle strength and gait ability occurred primarily after the second half of the intervention (last 4 weeks), during which resistance training with a special emphasis in power output development was included. However, after the interruption of the exercise intervention, marked performance decreases were observed in nearly all of the outcomes assessed, and the patients showed worst physical condition compared with the pretraining status. These results suggest that even after long-term physical restraint, frail elderly patients with dementia and disability maintain their capability to improve strength and functional capacity and that a multicomponent exercise intervention that includes muscle power training seems to be effective in providing these changes.

Dementia and institutionalisation may drastically reduce the elderly physical activity levels and accelerate sarcopenia, muscle strength and power losses, resulting in an accelerated decline in aspects of overall function including balance, gait ability and other physical hallmarks present in frail patients (Campbell and Buchner 1997; Stewart et al. 2005; Rockwood and Mitnitski 2007; Rodríguez Mañas et al. 2012). On the other hand, physical exercise seems to be an effective intervention to counteract this process (Heyn et al. 2004, 2008). Hauer et al. (2012) found that 3 months of progressive resistance and functional training resulted in significant increases in maximal strength and functional performance in elderly patients with dementia. However, in this study, the patients with dementia were capable of walking 10 m without a walking aid (Hauer et al. 2012), which suggests that the patients in these studies had a better functional status than the patients in the present study. Thus, although previous studies have shown positive effects of strength and endurance training in elderly patients with cognitive impairment and dementia (Heyn et al. 2004, 2008), this report is the first to investigate frail patients after several months of physical restraint. Physical restraints, which are often used in elderly individuals who require long-term nursing care (Zwijnsen

et al. 2011), limit the freedom of movement (Hantikainen 1998; Hamers and Huizing 2005), which results in severe adverse outcomes, such as exacerbated sarcopenia, decreased muscle quality, rapid strength loss, impaired ability to stand and walk and overall decreased functional status and quality of life (Suetta et al. 2007; Gulpers et al. 2010; Zwijsen et al. 2011; Berzlanovich et al. 2012). Thus, effective strategies to increase physical activity and independence with a low risk of falls are required. In the present study, only 8 weeks of a multicomponent exercise program composed of resistance training, walking and cognitive exercises improved strength, balance and TUG performance, and reduced the incidence of falls. The TUG test is a simple and classic test for evaluating the risk of falling in elderly patients. In frail elderly patients, a cut-off point of 12 s has been suggested, with no clear references for dementia patients. In our study, the participants in the intervention group showed a significant decrease in the time required to perform the TUG, which suggests a decreased risk of falls in this sample of very old frail patients with dementia. This finding is remarkable, considering that this population has a high incidence of falling and a significant risk for falling (Casas-Herrero et al. 2011; Robertson et al. 2013).

The participants' physical improvement occurred primarily after the inclusion of twice-weekly resistance training with a special emphasis on power output development. Resistance training performed with high-speed motion in the concentric phase has been shown to be effective in improving the functional capacity of healthy younger elderly patients (Bottaro et al. 2007; Correa et al. 2012; Pereira et al. 2012b), which suggests that this type of training may improve the functional capacity in subjects with a poor physical condition, as demonstrated in the frail elderly patients with dementia in the present study. The absence of changes in other fall risk predictors, such as the dual-task performance, or in functional measurements such as the Barthel Index and rising from a chair suggests that a longer exercise intervention or greater volume of resistance, walking and balance exercises may be necessary to stimulate additional changes.

In the present study, the walking program consisted of a daily walk on routes previously traveled in a wheelchair, such as going to the bathroom and to the dining room, and in the corridors of the nursing home. The subjects increased their amount of walking; therefore, this walking program was an important parameter related to functional capacity. Additionally, most of the

patients changed from using a wheelchair to using canes and walker devices, which also represented a relevant subjective parameter related to their level of independence, functional status and total amount of physical activity.

The purpose of the present study was to investigate a follow-up period with no systematic physical activity after the exercise intervention because it would be interesting to determine the capacity of this population to retain strength and functional gains. Another important finding of the present study was that the intervention group showed severely decreased physical and cognitive outcomes after the cessation of training. At several weeks after cessation of high-speed resistance training, healthy elderly patients retained a portion of their functional capacity gains (Pereira et al. 2012a), which was not observed in the patients with dementia and disability in the present study. In addition to their clinical condition, the absence of residual training effects most likely resulted from their physical status as a consequence of the long-term physical restraint used in their nursing care. This poor clinical condition became more evident after 3 and 6 months of detraining, during which the frail patients presented values lower than those in the pre-training period. These results are in agreement with the observed decrease in physical outcome performance after interruption of the exercise intervention in the frail elderly (Hauer et al. 2012; Zech et al. 2012). After analysing the follow-up data, we suggest that, in addition to the improvements observed in the strength outcomes, balance, incidence of falls and TUG performance, the exercise intervention was also responsible for maintaining the overall physical function in this population because during the detraining period, the physical performance deteriorated to a lower level than the pre-training value. Along with their poor initial physical status, it is possible that the low-intensity physical activity performed after the resistance training cessation (i.e., cognitive exercises, walking short distances) was not sufficient stimuli to prevent the exacerbated decline of their physical function. These results reinforce the need for this population to be involved in an exercise intervention composed of high-speed resistance training together with gait and balance retraining (i.e. a multicomponent exercise program).

The present study has several limitations. A control period rather than a control group was used because we chose to allocate all available frail older patients with dementia to the intervention group because the number

of participants (21 at the beginning of the study) with these very special characteristics was too small to allocate into two groups, taking into consideration the possible losses that would occur in the sample. Additionally, because of the absence of a control group, blinded measurements were not available. Nevertheless, the results of the present study are unique because this report is the first to use an exercise intervention consisting of walking, balance and cognitive and resistance exercises with a special emphasis on power output development (concentric phase performed as fast as possible) in a group of elderly patients with very particular physical conditions.

In summary, the systematic multicomponent exercise intervention produced improvements in muscle strength, balance and gait ability and decreased the incidence of falls in frail elderly patients with dementia after long-term physical restraint. We should emphasize that the physical enhancements observed in the participants of the present study occurred primarily after the inclusion of twice-weekly resistance training with a special emphasis on power output development. Additionally, the absence of changes when patients rose from a chair or in dual-task performance or the Barthel Index scores suggests that a longer intervention or perhaps a higher volume of resistance exercises may be necessary to stimulate more changes. After 12 and 24 weeks of exercise interruption, frail patients with dementia presented worse values than in the pretraining period, which reinforces the need for this population to be involved in a multicomponent exercise intervention that consists of resistance training in addition to gait and balance retraining.

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