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The effects of stretching on the flexibility, muscle performance and functionality of institutionalized older women

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Abstract

Stretching has been widely used to increase the range of motion. We assessed the effects of a stretching program on muscle-tendon length, flexibility, torque, and activities of daily living of institutionalized older women. Inclusion/exclusion criteria were according to Mini-Mental State Examination (MMSE) (>13), Barthel Index (>13) and Lysholm Scoring Scale (>84). Seventeen 67 ± 9-year-old elderly women from a nursing home were divided into 2 groups at random: the control group (CG, N = 9) participated in enjoyable cultural activities; the stretching group (SG, N = 8) performed active stretching of hamstrings, 4 bouts of 1 min each. Both groups were supervised three times per week over a period of 8 weeks. Peak torque was assessed by an isokinetic method. Both groups were evaluated by a photogrammetric method to assess muscle-tendon length of uni- and biarticular hip flexors and hamstring flexibility. All measurements were analyzed before and after 8 weeks by two-way ANOVA with the level of significance set at 5%. Hamstring flexibility increased by 30% in the SG group compared to pre-training (76.5 ± 13.0° vs 59.5 ± 9.0°, P = 0.0002) and by 9.2% compared to the CG group (76.5 ± 13.0° vs 64.0 ± 12.0°, P = 0.0018). Muscle-tendon lengths of hip biarticular flexor muscles (124 ± 6.8° vs 118.3 ± 7.6°, 5.0 ± 7.0%, P = 0.031) and eccentric knee extensor peak torque were decreased in the CG group compared to pre-test values (-49.4 ± 16.8 vs -60.5 ± 18.9 Nm, -15.7 ± 20%, P = 0.048). The stretching program was sufficient to increase hamstring flexibility and a lack of stretching can cause reduction of muscle performance.

Key words: Homes for the aged; Muscle stretching exercises; Muscle strength; Flexibility; Activities of daily living

Introduction

The Brazilian Institute of Geography and Statistics (1) has estimated that 8.6% of the Brazilian population (14.4 million) are composed of elderly citizens. According to the Institute, the growth experienced during the last 10 years was of 17% and projections indicate that this population may reach 55.0 million people (27% of the total population) by the year 2040. As the aging population increases so also will the number of people living in nursing homes (2). The institutionalized elderly have a different profile than non-institutionalized persons (3). For instance, physical disability, functional loss and autonomy, psychosocial context, stress,

family support, and loss of an identity role in the community cause difficulties in basic daily activities and cognitive skills and increase the risk of falling (2-4).

It has been shown that independence is closely related to the ability to sustain the functional status of the neuromuscular system (5). Furthermore, exercise programs have shown a reduction in the rate of falling and improved balance and mobility (4,6).

In general, most physical activity and exercise programs are designed to improve the force-generating characteristics of skeletal muscles, specifically by increasing strength or

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power in the active elderly (7). In fact, increasing muscle strengthening has been confirmed to be one of the most effective ways to reduce the debilitating effects of ageing on functional performance (4). However, a major part of the current literature has only reported the effect of multi-component exercise interventions and lacks studies assessing the effects of stretching alone (4,8).

For example, some outcomes have shown that the elderly benefit from a stretching program in which the gains in range of motion were translated into better performance over a number of gait-related variables (9,10).

Therefore, muscle-tendon alterations associated with the ageing process especially affect the bi-articular muscles, such as knee flexors and extensors, limit the range of motion, and change torque distribution around joints (11-15). Thus, stretching exercises can be an important tool in minimizing these losses.

To the best of our knowledge, no more than one study has reported strength gains after a stretching program using proprioceptive neuromuscular facilitation in the institutionalized aged (16). Other investigators have also found an increase in torque after a stretching program in a standing position, but performed by non-institutionalized older women (17,18).

Consequently, musculoskeletal adaptation induced by active stretching exercises in the institutionalized elderly, who experience difficulties in engaging in more strenuous training programs, needs to be further explored. In addition, the studies that analyzed the effects of stretching programs designed to improve flexibility did not fully assess muscle strength changes (14,19). Thus, there is limited information about the effects of stretching on the torque-producing ability of institutionalized older women. Assessment of muscle strength provides information about the extent of muscle weakness caused by ageing conditions. Hence, muscle strength is a component of human performance and is an important measure for the characterization of the functional capability of an individual (15).

For these reasons, the objective of the present study was to investigate the effects of an active static stretching program (3 sessions per week for 8 weeks) on the hamstring muscle in a group of institutionalized older women. Peak eccentric and concentric torques of agonist and antagonist knee muscle groups, muscle-tendon length of uni- and biarticular hip flexors, hamstring flexibility, and activities of daily living were used to investigate the influence of the stretching program on female nursing home residents.

Material and Methods

Subjects

Initially, 142 women were contacted via the administration of a long-term care facility. Sixty-one women were excluded from the study as they were limited in their mobility (use of a wheel chair, cane or other walking device),

10 were found to experience health problems and 52 had physical restrictions in performing physical activities. Thus, 19 women (67.0 ± 9.0 years old; 72.4 ± 17.1 kg, and 1.54 ± 0.08 m) volunteered and were eligible to participate in the study. Age, weight and height were similar for all subjects ($P > 0.05$). All participants had been living in the facility care unit for at least 22.0 ± 16.0 years and were medically stable. The recruitment and selection criteria are described in Figure 1. All procedures used in the present study were approved by the Ethics Committee of the Federal University of Paraná (CAAE-0003.0.91.000-09) and written informed consent was obtained from all participants after a detailed explanation of the procedures and requirements of the experiments.

After recruitment, subjects were randomly assigned to either the control group (CG; $N = 9$), which received educational talks about healthy habits and cultural activities, or to the group enrolled in a stretching program (SG; $N = 10$) (20). Both groups (CG and SG) attended sessions three times per week for 8 weeks, for a total of 24 sessions. Unfortunately, 2 participants were excluded from the SG due to cellulitis in the lower limbs.

A brief warm-up of 10 min of ludic activities and walking was carried out before the stretching exercises (21). Then, the stretching exercises for hamstring muscles were performed in a sitting position with an extended knee with a thick non-elastic band (1 m in length) placed around the foot of the stretched limb to allow subjects to pull themselves forward with both hands. The lower segment was gradually extended with the trunk leaning forward to a position in which participants felt discomfort for a period of 60 s. The corresponding limb maintained knee and hip joint flexed and with the foot flat on the floor. Four consecutive repetitions of 60 s each were performed and an interval of 60 s was allowed before exercising the opposite limb (19,22,23).

Before starting the interventions, all participants underwent two assessment sessions. The first assessment session was used to familiarize the elderly women with the peak torque measurements in the isokinetic dynamometer (Cybex NORM, division of Lumex, Inc., USA). In addition, participants underwent the following evaluations: Mini-Mental State Examination (MMSE), Barthel Index and Lysholm Scoring Scale. The MMSE questionnaire was applied to determine the cognitive ability of the subjects according to educational level, and the score had to be more than 13 (24). The Barthel Index was applied to establish the activities of daily life and the score also had to be more than 13 (25). The Lysholm Scoring Scale was applied to assess knee functional status and the presence or absence of signs of instability. Thus, to be included in this trial, the subject had to receive a minimum score of 84, i.e., knee function fair to good (26).

The flexibility, muscle-tendon length, isokinetic eccentric and concentric peak torques of the knee flexor and extensor muscles were determined in the second assessment

session. Specific procedures are reported below in detail. The same tests (stretching training/ludic activities) were applied after the intervention period (i.e., 8 weeks later) and followed the same sequence.

Assessment of muscle-tendon length and flexibility

The muscle-tendon length and flexibility were determined by the Photogrammetric Method using a digital camera (Canon, model Power A95, Japan) positioned perpendicularly at ~2.7 m to the sagittal plane of the subjects. The focus of the camera aimed at the center of the relevant joints and the following landmarks were identified: greater trochanter (GT), lateral epicondyle (LE) of the femur, and malleolus of the fibula (MA). These points defined the thigh (GT-LE) and shank (LE-MA) segments. The angle between

these segments was determined using the angular dimension tool, which is available in commercial image processing software (Corel Drawl, version 13) and followed the recommendations proposed by Sarraf et al. (27). Initially, the modified "Thomas" test was applied (27). The test is used to determine muscle-tendon length of the hip uni- and biarticular flexor muscles. A comprehensive description of the test can be obtained elsewhere (27). Briefly, the participant was positioned in the supine posture with the knee joint of the tested segment flexed, with the thigh supported on the table and the shank hanging down from the edge of the table. The experimenter actively flexed the opposite segment until the hip reached 125° of flexion, while the tested segment hung free. Thus, the angle between the initial and final positions of the thigh with respect to the horizontal line

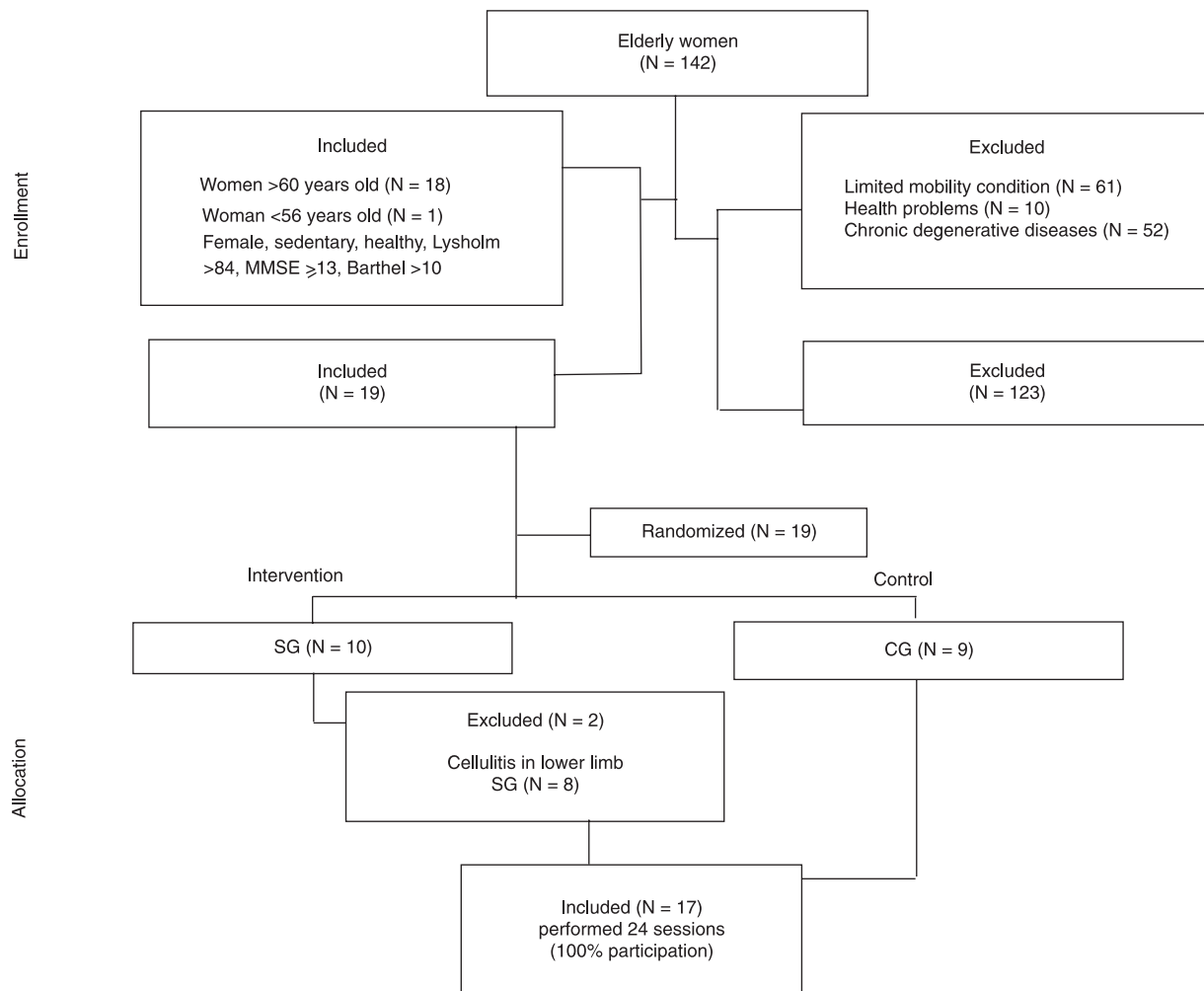


Figure 1. Study design. Flow of participants through the study. Nineteen institutionalized female elderly nursing home residents were randomized to the stretching group (SG, N = 10) or to the control group (CG, N = 9). A total of 17 participants completed the study. MMSE = Mini-Mental State Examination.

(Table 1) and at the knee joint was measured.

After the Thomas test, the flexibility of the hamstrings was assessed by the passive straight-leg-raising test (28,29). The tested segment was slowly lifted by the experimenter until some discomfort was felt in the popliteal region and the other segment was stabilized in an extended position using adjustable straps. The initial and final positions were photographed and the angle between the elevated thigh and the horizontal line (Table 1) was quantified. Values above 65° were deemed as normal, and lower values were considered to indicate decreased flexibility.

Torque assessment

Peak torque was measured using an isokinetic dynamometer (Cybex NORM, division of Lumex, Inc.). Assessments were performed according to the guidelines of the manufacturer and the procedures are described elsewhere (30). Gravity correction was calculated using the procedures established in the software equipment (Cybex Software, version 2.06). Each participant sat secured by adjustable straps and was requested to fold her arms in front of the chest region. Participants received verbal encouragement and visual feedback was provided by the PC monitor in an attempt to obtain maximal performances.

The eccentric and concentric actions of the knee flexor and extensor muscles were tested at 60°/s. Initially, a set of three submaximal attempts was allowed prior to the proper test to permit the participants to familiarize themselves with the demands and requirements of the assessment. Then, tests were repeated three times with an interval of 2 min between trials. The order of the tests was randomly assigned. Blood pressure (Premium - G-Tech sphygmomanometer, China) was monitored throughout the test.

Statistical analysis

Standard descriptive statistics were calculated for all

variables. The normality of the data was determined using the Shapiro-Wilk test and homogeneity was assessed by the Levene test. When the results were homogeneous and normally distributed, two-way analysis of variance for independent samples was applied. The Fisher test was applied to determine where differences occurred. Wilcoxon and Mann-Whitney tests were used where normality or homogeneity was not found. The level of significance was set at 5% for all comparisons and all analyses were performed using a specific software (Statistica, version 7.0®, USA).

Results

The 8-week stretching training program improved hamstring flexibility with respect to the initial condition ($P < 0.05$). The SG experienced a hamstring flexibility increase of 30% compared to the values found before intervention ($76.5 \pm 13.0^\circ$ vs $59.5 \pm 9.0^\circ$, $P = 0.0002$). In addition, the SG also showed greater increases in the flexibility of knee flexor muscles when compared to the CG ($76.5 \pm 13.0^\circ$ vs $64.0 \pm 12.0^\circ$, $P = 0.0018$).

The ability to stretch the hip biarticular flexors of the CG was reduced when compared to initial values ($124.0 \pm 6.8^\circ$ vs $118.3 \pm 7.6^\circ$; $P = 0.031$). Table 1 demonstrates the data for flexibility and muscle-tendon length changes that occurred in response to the stretching program.

No peak torque differences in knee extensor or flexor muscle groups were found in the SG ($P > 0.05$), irrespective of the contraction type (eccentric or concentric). However, the knee extensor eccentric peak torques of the CG decreased (15.7%) after the experimental period (post = -49.4 ± 16.8 vs pre = -60.5 ± 18.9 Nm, $P = 0.048$; Fisher test).

The Lysholm Knee Score, Barthel Index and MMSE showed no differences between groups ($P > 0.05$). In addition, results were stable across the intervention period ($P > 0.05$).

Table 1. Photogrammetry of hamstring flexibility and muscle-tendon lengths of the uni- and biarticular hip flexors of institutionalized older women.

Test	Group	Pre-intervention dominant leg (°)	Post-intervention dominant leg (°)	Relative difference (%)
Hamstring flexibility	CG	58.6 ± 7.0	64.0 ± 12.0*	9.2 ± 14.3
	SG	59.5 ± 9.0	76.5 ± 13.0 ⁺	30.0 ± 18.0
Hip uniarticular flexors	CG	18.1 ± 3.0	18.4 ± 4.0	-1.7 ± 22.7
	SG	15.5 ± 3.5	20.1 ± 8.5	31.4 ± 74.0
Hip biarticulars flexors	CG	118.3 ± 7.6	124.0 ± 6.8 [#]	5.0 ± 7.0
	SG	118.6 ± 9.4	121.1 ± 10.9	2.3 ± 7.6

Data are reported as means ± SD. CG = control group; SG = stretching group. Relative difference was calculated through the following equation: $(\text{post-intervention values} - \text{pre-intervention values}) / \text{pre-intervention values} \times 100$. * $P = 0.0018$ compared to SG post-intervention. ⁺ $P = 0.0002$ compared to pre-intervention. [#] $P = 0.031$ compared to pre-intervention (Wilcoxon and Mann-Whitney tests).

Discussion

The active stretching protocol performed only three times per week induced an increase in hamstring flexibility in nursing home women residents. Therefore, the main findings of the present study were: i) decreased flexibility in all institutionalized older women studied before the experimental period; ii) increased flexibility of knee flexors after the stretching exercise program; iii) declined muscle-tendon length and eccentric torque of knee extensor of the non-trained group.

All participants from both groups showed below normal flexibility values ($<65^\circ$) before the study (29) that could be attributed to a decrease in the magnitude of maximal passive resistive force, which indicates a marked decrease in the maximal length associated with the aging process (12). These muscle-tendon changes can be caused by an increase in type I collagen and/or a decrease in type III collagen (12,31).

However, it was interesting to observe in the present study that active static stretching training, performed only three times per week, was sufficient to induce an increase in hamstring flexibility above normal values in institutionalized older females. This result was better than that obtained by other investigators who submitted aged people to a daily passive stretching program for 6 weeks (19). The increase observed in the present study can be attributed to the active characteristics of the stretching technique, the longer duration of the training program, i.e., 8 weeks, and also the profile of the participants. It has been documented that active protocols are more effective in providing a greater gain than passive exercises (31).

Other factors may have contributed to the changes observed in the present study, such as Golgi tendon organs and muscle spindle adaptation (32), which may have allowed increased tolerance to stretching (33) and a possible addition of sarcomeres in series (34).

Moreover, the group that performed stretching exercises (SG) did not show as marked a reduction of flexibility of the knee extensor muscles during the course of the experiment as CG. This outcome could be explained by an increase in antagonist coactivation, which could have reduced the elastic rigidity of the passive viscoelastic elements of the muscle-tendon unit (12,31,35).

The elderly women who did not exercise showed a further flexibility decline during the period of the experiment and once again demonstrated the negative effects of the lack of physical activity, which is generally found in the institutionalized elderly (4,36,37). Although the loss of flexibility and muscle strength deficit are common among institutionalized elderly subjects, the stretching training performed in the present study was sufficient to prevent reduction of flexibility even in the antagonist muscles (4).

Peak flexor or extensor torques remained unchanged after the stretching training despite the changes observed in

hamstring flexibility. These results agree with other studies in which peak torque did not respond to a program of stretching exercises (8,38). On the other hand, the group that did not exercise experienced a decline in the eccentric peak torque of the knee extensor muscles, which can be related to the reduction of muscle-tendon length in the hip bi-articular flexor muscles. In addition, the increasing loss of muscle strength beginning from the 4th decade is more pronounced after the 6th decade and is further accelerated by the lack of physical activity induced by institutionalization (31,36,37).

Although the stretching program did not cause an increase in peak torque, nonetheless it was successful in preventing a further loss of muscle function, which can contribute to mobility. Consequently, this outcome is very relevant because strength of lower extremity muscles is an important determinant of mobility-based functional activities as rising from a chair or stair negotiation (15). The unchanged peak torque found in the present study may be attributed to institutionalization and/or the stretching technique performed (17,18,37).

To the best of our knowledge, this is the first report that has investigated the effect of stretching on isokinetic peak torque in older women living in a nursing home. Therefore, when the peak torque of non-institutionalized elderly of other studies is compared to the results of the present study, a clear difference is noticed (17,18,39). It is interesting to observe that the peak torques of the institutionalized elderly women found in the present study were lower than those of active elderly subjects aged 70 to 80 years (39).

All elderly women analyzed were independent in their daily life tasks. The Barthel index remained unchanged after 8 weeks. The subjects showed good knee functionality (Lysholm Scoring Scale), and the training program did not interfere with the cognitive aspects (MMSE).

The present study has some limitations, specifically the reduced size of the sample per group (SG, $N = 8$ and CG, $N = 9$), which may have influenced the impact of the investigation. Using the equation of Luiz and Magnanini (40) to calculate the sampling size, we found that 16 subjects per group would be the number needed to test the hypothesis of the present study. However, on the basis of the eligibility criteria, it was not possible to include this number in each group, especially because of the profile of institutionalized elderly women to be enrolled in the stretching program. Hence, future studies should include more than one nursing home to obtain a suitable sample size.

Additionally, other studies should include passive torque and analysis of the length-tension muscle-tendon properties, which may provide a better understanding of the effects of stretching training on muscle adaptation in institutionalized older subjects. Nevertheless, we should emphasize the important contribution of active stretching exercises, performed three times per week, to increase flexibility and to prevent loss of muscle performance in female nursing home residents.

We believe that an active stretching program should be added to the routine of institutionalized elderly subjects because it has been shown here to be effective not only in increasing knee flexor flexibility but also in preventing loss of knee extensor performance.

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