Different training programs for improving muscular performance in healthy inactive elderly

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Abstract. The purpose of the present study was to determine whether a general conditioning (callisthenic exercise) versus a machine based resistance-training protocol or an isokinetic exercise program would be similarly effective in improving knee extension muscular performance in healthy inactive elderly. Fifty two individuals, 26 men and 26 women, were randomly assigned to one of four groups: control group (C, \(n = 10\)), the isokinetic strengthening group (ISO, \(n = 12\)), the multi-joint resistance training group (RES, \(n = 15\)) and the calisthenic exercised group (CAL, \(n = 15\)). The training protocol for the ISO included concentric isokinetic extension and flexion of the knee, for the RES included leg extension, leg curls and leg press and for the CAL included aerobic exercise accompanied with music, general calisthenics and activities targeted to reaction time and agility improvement. The isokinetic concentric testing method applied prior to and at the end of the training period to assess peak muscle torque of the right knee extensors. MANOVA repeated measures (2 × 4, time by treatment) revealed that at 60°/s angular velocity there was statistically significant improvement in performance for the RES group in comparison to control group. At 180°/s angular velocity the results revealed, statistically significant improvement in performance for the RES and ISO group also. In conclusion, in older adults isokinetic exercise and resistance training results in larger increases in strength compared with callisthenic exercise.

Keywords: Elderly, isokinetic, muscular performance, strength training

1. Introduction

Physical activity of even moderate intensity decreases cardiovascular disease risk in younger and older adults alike [7,19,26] and can positively impact quality of life outcomes, such as stress responses, depressive symptoms, and sleep quality, which are of particular relevance to older adults. Furthermore, in older adults populations, muscle strength and endurance are extremely important for maintaining quality of life and functional independence. A minimal level of strength is required for acts of daily moving that include tasks of lifting, carrying, pushing, pulling, sitting, standing, walking, and climbing stairs. It has been reported that 28% of men and 66% of women over the age of 75 cannot lift 10 pounds [13]. Quadriceps strength has been identified as the single most important factor in a person’s ability to ambulate as well as sit, stand and climb stairs. The abilities to perform these functional activities are in part determined by one’s muscle strength, range of motion, and balance. Each of these functional parameters can be positively influenced by exercise [16]. In addition to strength, other factors influence the ability to perform functional tasks, including flexibility or range of motion, choice of strategy, vision, balance and postural control, muscular endurance, pathology, and cognitive ability. Although, many factors are involved, several studies have suggested muscular strength to be one of the most important factors limiting the ability to perform many functional tests...
including activities of daily living and instrumental activities of daily living in the elderly population [5,15, 27,38].

Still, there is encouraging evidence that exercise programs can improve strength [5,6,9,18,22,23, 30], gait [9,17,21], balance [22,39] and perhaps decrease falls [4,14,28,30,33,36,37] among healthy, non-impaired adults. Similar results have conducted by others [30] who measured the effects of an exercise intervention on muscle strength, gait, balance, and endurance among elderly men with risk factors for falls. They found that the rate of falls per unit of activity was significantly lower in the exercise group. All these studies concluded that, resistive training could increase strength substantially in adults at any age. According to many investigators, of all the bodily systems, the neuromuscular system can demonstrate the most visibly dramatic difference between a completely sedentary, inactive person and a person who conscientiously trains [31].

Despite the positive health benefits of strength training demonstrated in all of the studies mentioned above, to our knowledge, there is a surprising lack of well-controlled long-term clinical trials reported in the peer-reviewed literature comparing different training regimens, particularly for the adult fitness model. Other studies compared different strength training intensities concluding that high intensity training programs can dramatically increase knee muscle strength in older adults [11,25,29] in comparison to low- or moderate-intensity programs that can also improve strength ranging from 10% to almost 30%.

Others reported important strength gains in older adults after the application of more complex, supervised, progressive strength training. For example [1] in older African American women it was demonstrated that 8 weeks of low frequency strength training, emphasizing free weight, multi joint movements could safely cause significant gains in strength, absolute endurance and flexibility. Also, Rubenstein and co workers [30], applied an exercise protocol focused on increasing strength and endurance and improving mobility and balance in chronically impaired adults. They suggested that group exercise can improve all these parameters and is associated with reduced fall rates when adjusted for level of activity.

Even if many studies proved the efficacy of different kind of exercising, none have compared them in terms of strength gains. The purpose of the present study was to determine whether a general conditioning (callisthenic exercise) versus a machine based resistance-training protocol or an isokinetic exercise program would be similarly effective in improving knee extension muscular performance in healthy inactive elderly. Therefore, it is hypothesized that training using isokinetic or resistance machines would result in larger increases in strength in older adults compared to callisthenic exercise.

2. Methods

2.1. Subjects

Fifty-two individuals (26 men and 26 women, Table 1) volunteered to participate in the present study. All participants gave their written informed consent regarding their participation in the study after being informed of all risks, discomforts and benefits associated with the procedures followed the present study. Procedures were in accordance with ethical standards of the Committee on Human Experimentation at the Institution at which the work was conducted and with the Helsinki declaration of 1975. Selection was based on the following criteria:

1) Subjects were completely inactive prior to the study. Subjects were also required to answer to the Baecke Questionnaire for older adults [35].
2) Subjects did not exhibit anemia, hepatic complications, thyroid disorders or kidney problems.
3) Subjects had their blood pressure measured at rest by auscultation in both arms after sitting in a quiet room during four morning visits. If these blood pressures averaged over 160/100 mmHg, subjects were excluded from the study. Subjects who were on antihypertensive medication (14 men) maintained the same medication regimen throughout the study.
4) A physician examination for potentially damaging orthopedic and neuromuscular problems.

2.2. Measurements of anthropometric variables

Subjects’ body weight was measured while they were wearing underclothes on a balance scale (Seca 707, Hamburg Germany) calibrated to the nearest 0.4 Kg after a 8–10 hour fast (between 7.00–8.00). Barefoot standing height was measured to the nearest 0.1 cm by using a wall mounted stadiometer.
2.3. Isokinetic concentric strength assessments of the callisthenic exercise group.

C indicates the control group, ISO indicates the Isokinetic exercise group, RES indicates the Intensity strength-training group, CAL indicates the callisthenic exercise group.

Peak muscle torque of the right knee extensors was measured using an isokinetic dynamometer (Cybex 6000). Subjects performed the same tasks while in a seated position on a standard dynamometer chair with the subject’s back slightly reclined and thigh well supported on the seat. Stabilization in the seated position was accomplished using pelvic strapping. The subjects were instructed to grip their hands around the chest. The axis of rotation of the knee joint and lever arm were carefully aligned. The tested dominant limb was firmly stabilized at the distal femur, the lower leg at the distal tibia above the ankle joint superior to the medial malleolus. Before the test there was a warm-up session (5 minutes) including cycling (Monark) followed by four sub-maximal and one maximal trial on the isokinetic device. The test protocol included one bout of 5 maximal knee extension/flexion repetitions for each tested speed (60°/s and 180°/s) in a random order, separated by 120 seconds rest intervals. The average of the best 3 tests for each velocity was used as the recorded value. Maximal test efforts began with the leg flexed that is with the knee joint at 100° before flexion and ended at full extension. Correction was applied for the elimination of errors against the effect of gravity on the lower leg and lever arm. During testing there was no visual feedback the verbal instruction at the beginning of the test was “try as hard as you can during flexion and extension of the knee”. The dynamometer was calibrated prior to the testing session according to the procedures prescribed by the manufacturer.

2.4. Training treatments (Table 2)

Subjects were randomly assigned to one of the four groups: a) control group (C, n = 10) the isokinetic strengthening group (ISOG = 12), the multi-joint resistance training group (RES, n = 15) and the callisthenic exercised group (CAL, n = 15). The subjects in the control group did not train and participated only in the measurement procedures. All three-exercise groups trained 3 times a week for 10 weeks. Subjects always completed a 7–10 minute warm up, consisting of either cycling at approximately 40% of their Hrmax before starting their training protocol (for the RES and ISO) or walking and stretching exercises for the CAL. Each training session lasted 45 to 55 minutes. Training sessions were supervised at all times.

2.5. ISO exercise program

Subjects in this training group exercised in a seated position (same as isokinetic test) on the isokinetic device. Concentric isokinetic extension and flexion of the knee were performed. Totally 9 sets (12 repetition of each set) in different angular speed were performed (Table 2). The rest times between sets were 2 minutes.

2.6. RES exercise program

Subjects in the training groups exercised on 3 Universal resistance exercise machines (Irvine, CA, USA), selected to stress the major muscle group of the lower limbs and completed in the following order: Leg extension, leg curls, leg press. One RM on each resistance exercise was measured at the beginning of the training period and every week thereafter until the training period was completed.

The participants exercised at 90% of 1 RM in three sets (12 repetition in each set). Participants were instructed to perform each repetition in 6–9 seconds. They were told to raise the weight in 2 seconds, pause briefly for 2–3 seconds and to slowly lower the weight during the eccentric phase of the contraction for 2–3 seconds [10]. They paused for 5 seconds between repetitions and 2 minutes between sets.

Table 1

<table>
<thead>
<tr>
<th>Groups: C (n = 10)</th>
<th>ISO (n = 12)</th>
<th>RES (n = 15)</th>
<th>CAL (n = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>Male Female</td>
<td>Male Female</td>
<td>Male Female</td>
</tr>
<tr>
<td>Age (years)</td>
<td>69.9 ± 4.3</td>
<td>65.7 ± 4.3</td>
<td>70.7 ± 2.5</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>89.1 ± 11.4</td>
<td>73.4 ± 8.6</td>
<td>90.4 ± 10.2</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.67 ± 0.5</td>
<td>1.62 ± 0.9</td>
<td>1.63 ± 0.8</td>
</tr>
<tr>
<td>Questionnaire</td>
<td>8.03 ± 0.5</td>
<td>8.07 ± 0.7</td>
<td>8.09 ± 0.9</td>
</tr>
<tr>
<td>Score</td>
<td>Low Low</td>
<td>Low Low</td>
<td>Low Low</td>
</tr>
<tr>
<td>Activity level</td>
<td>Low Low</td>
<td>Low Low</td>
<td>Low Low</td>
</tr>
</tbody>
</table>

C indicates the control group, ISO indicates the Isokinetic exercise group, RES indicates the Intensity strength-training group, CAL indicates the callisthenic exercise group.
Table 2

Exercise program for the exercised groups

<table>
<thead>
<tr>
<th>ISO (n = 12)</th>
<th>RES (n = 15)</th>
<th>CAL (n = 15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm up (about 10 min)</td>
<td>Exercising:</td>
<td>15 min low impact aerobics</td>
</tr>
<tr>
<td>Isokinetic knee extension/flexion:</td>
<td>Leg extension 3X12 (90%)</td>
<td>15 min calisthenics for the lower limbs</td>
</tr>
<tr>
<td>3X12, 150°/s</td>
<td>Leg curls 3X12 (90%)</td>
<td>(with 1.5–3 kg weights)</td>
</tr>
<tr>
<td>3X12, 150°/s</td>
<td>Leg press 3X12 (90%)</td>
<td></td>
</tr>
<tr>
<td>3X12, 180°/s</td>
<td>Abdominal crunches and low back exercises</td>
<td></td>
</tr>
<tr>
<td>(2X6 for the first 5 weeks and 3X8 for the last 5 weeks)</td>
<td>Cool down 5–10 min</td>
<td></td>
</tr>
</tbody>
</table>

ISO indicates the Isokinetic exercise group, RES indicates the Intensity strength-training group, CAL indicates the callisthenic exercise group.

2.7. CAL exercise program

Warm up activities were simple steps round a circle combined with arm and trunk movements, stretching exercises while walking and static stretching exercises executed on the floor. Aerobic exercise consisted of various combinations of dancing steps moving to different directions, accompanied with music at a pace that elevated heart rate to the target level. General calisthenics performed mainly using a chair as base of support and after the second week each person used a pair of leg weights, weighted 1.5–3 Kg depending on individuals capacity of respiratory–relaxation and stretching exercises, and activities targeted to reaction time and agility improvement.

2.8. Statistical analysis

Data were analyzed using the SPSS PC (version 10.0) program for windows. Means ± SD were calculated. One-way ANOVA was conducted initially to examine if there were differences among the four groups in the pre-measurements values of each depended variable. MANOVA for repeated measures (2 × 4, time by treatment) was performed on each dependent variable to detect differences in each group for each time point. When F ratios were significant, post hoc comparisons of means were analyzed with Scheffe’s multiple comparisons tests. Statistical significance was accepted at p < 0.05.

3. Results

The results showed that there were no significant differences among the four groups for age, height, weight and activity level (Baecke Questionnaire) (Table 1). Also there found no significant differences in isokinetic concentric right knee strength pretraining values among the four groups at 60°/s (Table 3) and at 180°/s (Table 3).

The statistical analysis showed that in both angular velocities the performance improvement was not the same across the four groups (interaction ‘group’ and ‘test’). Thus, an analysis of variance with repeated measures was used for each group, using the same variables and factors, to validate separately their performance improvement. At 60°/s angular velocity the analysis revealed, statistically significant improvement in performance for the RES group (Table 3) in comparison to control group. At 180°/s angular velocity the results revealed, statistically significant improvement in performance for the RES and ISO group also (Table 3).

4. Discussion

The most notable physical benefit associated with these long-term exercise programs appears to be an overall improvement in strength, as evidenced by significant increases in both the low and high angular velocities. This means that all exercise programs were effective in improving knee extensors muscular performance in healthy older adults. However, comparing the experimental groups with the control, only the isokinetic and the resistance-training groups showed significant performance improvement in both angular velocities. The group that followed a callisthenic exercise program did not show any statistical significant difference with the control group in post-hoc tests.

In spite of many studies that have been conducted to examine the effectiveness of miscellaneous strength training programs in elderly people, comparison of distinct strengthening modes has not been previously explored. Furthermore, it should be noted that it is difficult to compare strength gains among various strength training studies. Muscular strength testing modes and methodologies; muscle group tested; subject’s initial
strength levels; the volume, intensity and frequency of training protocols; equipment used (isokinetic or resistance machines versus free weights or calisthenics) and personalized attention to subjects, all affect outcomes [1].

Nevertheless recent studies refer to the effectiveness of training programs as similar to that described in the present study. More precisely, Rubenstein et al. [30] measured the effects of a group exercise program similar to our calisthenics program on muscle strength, gait, balance and endurance among elderly men with risk factors for falls. The exercise sessions focused on increasing strength and endurance for knee, hip and ankle joint and improving mobility and balance, using elastic bands and small weights. The researchers concluded that the group exercise program improved significantly knee extensors strength that was assessed using the isokinetics (60°/s). However, the difference was not statistical significant compared with the control group in accordance with the results of the present study.

Furthermore, in the same study the results revealed that the above intervention program could improve muscular endurance, as evidenced by significant increases in isokinetic total work in angular velocity 180°/s. This conclusion is also in accordance with our results, since the CAL group showed statistical strength gains for both angular velocities. However, in comparison with the control group we did not find any significant differences in muscular endurance, in variance with Rubenstein et al. [30]. This result may be due to the fact that in our study the participants were sedentary older adults who were healthy and not frail individuals with risk factors for falls, meaning that they needed more intense exercise in order to show more impressive strength gains. On the other hand, the participants of the reported study applied also training focused on endurance and balance training, proving that they had more training stimulus than the participants of the calisthenics group. In parallel, in a recent study of independently living and healthy older adults, no improvement in strength was reported after a low-intensity program of 8 weeks duration [3], meaning that low or moderate exercise might be more effective in partially impaired elderly. In another 2-year study, involving lower intensity training, cardiovascular fitness and flexibility improved, but strength was not affected [24].

Another combined program with free weight and machine weights was applied in sedentary, older African American women, in order to measure knee strength improvement. Training progressed from simple to complex movement (e.g. progressing from body weight movements with support to free standing dumbbells) and machine (plate loaded) exercises were performed, similarly with our RES training group. Exercises included two “primary” exercises (leg press and bench press) and seven “assistance” exercises (dumbbell lunge, hamstring curl, dumbbell incline press, dumbbell row, lat pull-down, triceps press-down, and dumbbell biceps curl). The results showed that supervised, progressive strength training emphasizing free weight multi joint movements caused significant improvement in knee muscular strength. This conclusion can be partially comparable with those of the present study because in both training intensity was progressive and a significant portion of the exercises involved multi-joint, free weight movements that require balance, stabilization, and motor control to perform. However in our study, training speed was similar between subjects of the same group, while in others comfortable, controlled speed was self-selected by the subject.

The efficacy of the RES training group in improving knee strength performance in elderly people has been frequently quoted. Published recommendations on the intensity of exercise in elderly subjects stated

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**Table 3**

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Isokinetic concentric test at 60°/s</th>
<th>Isokinetic concentric test at 180°/s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>C (n = 10)</td>
<td>109.6 ± 10.8</td>
<td>107.9 ± 9.2</td>
</tr>
<tr>
<td>ISO(n = 12)</td>
<td>106.3 ± 12.2</td>
<td>118.3 ± 12.8</td>
</tr>
<tr>
<td>RES (n = 15)</td>
<td>109.0 ± 8.9</td>
<td>128.1 ± 10.8</td>
</tr>
<tr>
<td>CAL (n = 15)</td>
<td>104.4 ± 11.8</td>
<td>113 ± 10.31</td>
</tr>
</tbody>
</table>

C indicates the control group, ISO indicates the Isokinetic exercise group, RES indicates the Intensity strength-training group, CAL indicates the callisthenic exercise group.

1 Significant differences between pre and post training values (p < 0.05).
2 Significant differences with the control group (p < 0.05).
3 Significant differences with CAL (p < 0.05).
4 Significant differences with ISO (p < 0.05).
that approximately 80% of the 1RM load should be used to maximize strength and functional gains following resistive exercise training [8]. There are also numerous studies that reported large increases in maximal strength following high intensity strength training [25,32]. Also, high intensity resistance training is reported to be beneficial in maintaining muscle strength and size in older men following a 12-week progressive resistance training program [34].

Furthermore, the decrease in muscular performance in advanced age is correlated significantly with the decrease in area and size of the FT fibers [20]. Also, this fiber type is selectively recruited during eccentric activation [2]. Apparently, the high-intensity RES training group showed significant strength improvement because it enhanced speed of activation and eccentric function, resulting in better recruitment of FT fibers. Nevertheless the slight superiority of the ISO training group in increasing knee performance, is partially explained by the fact that adaptations in strength are more significant when the testing technique is similar to the training method [12]). Fleck and Kramer [10] reported an average improvement in bench press strength of 23.3% when subjects were tested on the equipment with which they were trained and 16.5% when tested on special variable resistance or isokinetic ergometers. These investigators also reported an average increase in leg strength of 26.6% when subjects were tested with the equipment they trained with and 21.2% when tested with special isotonic or isokinetic ergometers. Furthermore, isokinetic exercise has been shown to be highly effective due to the fact that it accommodates maximal muscle potential throughout the range of motion. Training programs for lower extremity conditions of elderly individuals should include activities to enhance speed of activation. Also, the existing data do support higher velocities and maximal efforts in the application of isokinetic exercise [2]. Ideally, the training sequence can be designed to fit the needs of the individual who is cognizant of his or her special needs.

**References**


