

Effects of Maximal Isometric and Isokinetic Resistance Training on Strength and Functional Mobility in Older Adults

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Background. The aim of the present study was to compare the changes in voluntary strength (isometric, concentric, and eccentric) and functional mobility in response to maximal isokinetic eccentric-only resistance training to those elicited by maximal isometric-only or maximal isokinetic concentric-only resistance training in older adults.

Methods. Twelve women (73 ± 7 years) and 18 men (73 ± 5 years) completed a 12-week training program (three times per week) using a Biodex System 3 dynamometer. Primary outcome measures included peak isometric and isokinetic (concentric and eccentric) knee extensor strength, concentric work, concentric power, stair ascent and descent, and gait speed. Participants were randomly assigned to one of three training groups: isometric-only, isokinetic concentric-only, or isokinetic eccentric-only.

Results. All three training groups demonstrated an increase in peak isometric and isokinetic concentric and eccentric strength following 12 weeks of training ($p < .01$). Step time was positively influenced ($p < .03$) by all three training modes; however, gait speed was unchanged following 12 weeks of training. All three training groups experienced a significant increase in peak concentric work and concentric power ($p < .01$) with the concentric training group demonstrating the largest increases in both peak concentric work and concentric power when compared to the isometric and eccentric training groups.

Conclusions. It was clear that all three resistance training programs (isometric, concentric, and eccentric) in older adults were effective in increasing strength, concentric work, and concentric power over the 12-week training period. Furthermore, 12 weeks of resistance training resulted in improved stair ascent and descent performance.

PROGRESSIVE resistance training has been shown to alleviate the age-related reduction in maximal voluntary strength usually experienced by older adults (1–3). The benefits of such programs were further corroborated by the recent conclusions of Latham and colleagues (4) from their systematic review of the resistance training literature. A notable feature of effective programs is the adherence to the overload principle of providing a relatively intense signal to the neuromuscular system, yet it is known that sedentary older people may have dramatic reductions in maximal isometric (5) and concentric (6) force-generating capacity. These reductions, which have been linked to sarcopenia in older adults (7), thus appear to provide a potential limit to the overload stimulus possible with isometric or concentric exercise movements.

The preservation of maximal eccentric (muscle lengthening) force-generating capacity in older adults is well documented (8–10). Therefore, using this preservation of maximal eccentric force-generating capacity might be advantageous as it has been hypothesized that the higher mechanical loading offered by maximal eccentric contractions could result in larger gains in maximal voluntary strength than would the loading offered by traditional concentric training (11). Studies using the higher mechanical forces generated by eccentric

muscle contractions in their training protocols have found significant increases in voluntary strength (isometric, concentric, and eccentric) (12,13). However, these studies also used training protocols that combined both a concentric muscle action and a near maximal or maximal eccentric muscle action. Therefore, it is uncertain whether the increases in voluntary strength are the result of the high forces generated by the eccentric muscle action or a combination of concentric and eccentric muscle actions.

LaStayo and colleagues (14) recently demonstrated that eccentric-only cycle ergometry resulted in significant increases in isometric strength in frail elderly persons; however, they did not explore changes in concentric or eccentric strength. Therefore, one aim of the present study was to compare the changes in voluntary strength (isometric, concentric, and eccentric) in response to maximal isokinetic eccentric-only resistance training to those elicited by maximal isometric-only or maximal isokinetic concentric-only resistance training in healthy community-dwelling older adults.

The loss of maximal voluntary strength, particularly in the lower limbs, can dramatically reduce functional mobility such as gait speed, balance, stair climbing, and chair rising performance (15). The study by LaStayo and colleagues (14) is also one of only two studies to our knowledge that has

examined the effects of eccentric overload resistance training on functional ability in older adults. They found improved stair descent, improved balance, and increased isometric strength following eccentric-only cycle ergometry training. Similarly, Nichols and colleagues (16) found that resistance training (including an eccentric overload training group) improved stair climbing and balance. However, they combined their training groups (traditional resistance training group and eccentric overload group) when exploring the effects of training on functional tasks, thereby making it impossible to establish whether the eccentric overload training had a greater impact than the traditional training did on functional tasks. Therefore, a second aim of this study was to compare the changes in functional mobility in response to maximal isokinetic eccentric-only resistance training compared to those elicited by maximal isometric-only and isokinetic concentric-only resistance training in healthy older adults.

METHODS

Participants and Design

Thirty-seven healthy adults at least 65 years old (19 females aged 65–87 years; 18 males aged 65–85 years) were recruited from newspaper advertisements. Participants indicated that they were free of any debilitating cardiovascular, lower limb musculoskeletal, or neuromuscular limitations and had not participated in resistance training for a period of at least 6 months. Informed written consent was obtained prior to participation, and all experimental procedures were in accordance with The University of Western Ontario's Research Ethics Committee.

Participants were randomized (random selection with continuing replacement method) into three training groups: concentric (CON-TG), isometric (ISO-TG), and eccentric (ECC-TG). All groups participated in four testing sessions: familiarization, Week 0, Week 6, and Week 12. Both the dominant and nondominant lower limbs were assessed; the starting limb was chosen by a random draw. The design and sample size were planned to identify a robust difference between training groups of at least 25% (17) in a relatively homogeneous group of healthy older adults. With limited personnel involved, it was not possible to have all assessors blinded to randomization, but the multiple training groups and outcome variables served to eliminate expectation bias. Seven female participants were unable to complete the study; reasons given were: knee discomfort ($n = 5$), bruising ($n = 1$), and personal reasons ($n = 1$). Of these participants, five were from the ECC-TG, one was from the ISO-TG, and one dropped out following Week 0 testing; therefore, an overall total of 30 older men and women completed the study.

Participant Positioning

All torque measurements were assessed using a Biodex Multi-Joint System 3 dynamometer, and the data were analyzed using Biodex System 3 Advantage Software (version 3.2; Biodex Medical Systems, Shirley, NY). Participants were seated in an upright position (seat back angle $\approx 85^\circ$), and the lateral femoral epicondyle was aligned with the center of

the dynamometer shaft. To minimize the use of muscle groups other than the knee extensors, participants were stabilized with two shoulder straps, a waist strap, and a thigh strap.

Isometric and Isokinetic Testing

Before the start of the strength testing, a 5-minute warm-up was performed on a stationary cycle ergometer at a low rate (≈ 50 rpm) and low work load (1 kilopond). The sequence of strength testing was standardized for all participants: first, concentric torque at $90^\circ \cdot s^{-1}$, followed by isometric torque at $0^\circ \cdot s^{-1}$ (5 s hold, knee angle $\approx 90^\circ$), and lastly eccentric torque at $-90^\circ \cdot s^{-1}$. Three submaximal (50%–65%) warm-up contractions were performed, followed by five maximal voluntary contractions. A 5-second rest period was given between each contraction, during which time the lower limb was passively returned to the starting knee angle of $\approx 85^\circ$ (CON-TG and ECC-TG) or $\approx 90^\circ$ (ISO-TG). A 15-second rest period was given between each isometric contraction to compensate for the longer contraction duration (5 s). A 2-minute rest period was given between each strength test. All strength measurements were corrected for the influence of gravity using the Biodex software. Primary outcome measures included peak isometric and isokinetic (concentric and eccentric) strength, concentric work (work is the product of force and degrees of rotation), and concentric average power (the rate of work, total work divided by time).

Functional Mobility Testing

Functional mobility was assessed with a self-paced step test (18) and a self-paced 80-m walk test (19). The step test was performed on a standard two-step stair ergometer (20 cm high \times 30 cm deep \times 60 cm wide). Participants were asked to perform 20 two-step cycles (step-step-up, step-step-down) at their own natural pace and the time to completion was recorded. The 80-m self-paced walk test required participants to walk at their natural pace around two laps of a 20-m course marked off by two pylons. The time to turn around the pylons was not included. Gait speed was determined by dividing the 80-m walk test distance by the total time (seconds).

Training Protocol

Training took place over a 12-week period, during which the participants were required to train three times per week, and each training session was separated by a minimum of one rest day. The total possible number of training sessions was 35 (one session was lost due to Week 6 testing), and the mean number of training days missed was 3.5 ± 2.4 (10%). Both the dominant and nondominant lower limbs were trained. Training was performed on the same Biodex dynamometer used for the strength testing.

All training sessions included a 5-minute cycle ergometer warm-up (≈ 50 rpm; ≈ 1 kp load), followed by three sets of 10 maximal voluntary contractions of the knee extensor muscles using the specific contraction type of the training group to which the participant was assigned. A 5-second rest period between each contraction was allowed, during which time the lower limb was passively returned to the starting position. A 2-minute rest period was provided between each set. This process was repeated for both the dominant and nondominant leg, and the starting leg was randomly chosen by draw for

Table 1. Physical Characteristics of the Participants

Characteristics	CON-TG (N = 10)	ISO-TG (N = 11)	ECC-TG (N = 9)
Age, y	71.8 ± 3.1	74.8 ± 7.6	70.5 ± 5.2
Height, cm	168.9 ± 10.3	165.8 ± 10.3	166.1 ± 9.1
Mass, kg	78.5 ± 11.2	77.3 ± 15.6	80.7 ± 11.6

Note: Values are means ± standard deviation.

N = number of subjects; CON-TG = concentric training group; ISO-TG = isometric training group; ECC-TG = eccentric training group.

each training session. A target torque marker, which was established from baseline testing, was provided for each participant on the Biodex computer screen. The participant was instructed to try and reach or exceed the target torque marker. The target torque was adjusted at the beginning of each test session if a new peak torque (highest peak torque value obtained during the previous straining session) was established.

Statistical Analysis

For the purpose of statistical analysis, peak scores from the participant’s dominant and nondominant lower limbs were averaged to determine one peak score. Statistical analysis was performed using SPSS (version 9; SPSS, Inc., Chicago, IL). Changes in voluntary strength were analyzed using a two-factor repeated measures analysis of variance with one between-subjects factor (training group—three levels) and one repeated measures factor (time—three levels). When a significant training group effect was found, Tukey’s Honestly Significant Difference test was used for post hoc analysis. Separate one-way analyses of variance were used to determine if significant between-group differences existed prior to training for age, height, mass, peak isometric and isokinetic concentric and eccentric torque, peak concentric work, and peak concentric power. Statistical significance for all analyses was set at $\alpha = 0.05$.

RESULTS

Physical Characteristics

Physical characteristics for the three training groups are presented in Table 1. No statistical differences were found between groups for baseline age, height, and mass ($p > .05$). There were also no significant differences between the three training groups at Week 0 for peak values of isokinetic concentric torque, isometric torque, isokinetic eccentric torque, concentric work, and concentric power, as well as step time or gait speed.

Peak Isometric and Isokinetic Strength

Peak isometric and isokinetic concentric and eccentric strength increased across the 12-week training period for all three training groups ($p < .01$) (Table 2). Specificity of training was present with the greatest gains in peak isometric, isokinetic concentric, and isokinetic eccentric strength generated by the training group that trained using that specific muscle contraction. However, no main effect for training group was found as no one training group differed significantly from its counterparts for either isometric or iso-

Table 2. Peak Torques (Nm) at Weeks 0 and 12 for the Three Training Groups

Group	Week 0	Week 12	Mean % Change
Peak Concentric Torque			
CON-TG	93.6 ± 40.4	113.9 ± 48.3	22.1*
ISO-TG	91.4 ± 35.3	104.2 ± 40.7	15.1*
ECC-TG	107.5 ± 30.7	116.3 ± 26.1	10.0*
Peak Isometric Torque			
CON-TG	130.6 ± 54.0	151.8 ± 61.2	17.3*
ISO-TG	122.9 ± 47.0	153.7 ± 57.2	27.7*
ECC-TG	142.0 ± 39.8	176.0 ± 44.7	25.5*
Peak Eccentric Torque			
CON-TG	161.9 ± 62.6	191.4 ± 76.8	17.9*
ISO-TG	151.1 ± 45.9	176.4 ± 58.4	16.5*
ECC-TG	168.5 ± 40.0	207.1 ± 35.6	26.0*

Note: Values are means (± standard deviation) in Nm.

*Significant difference between Weeks 0 and 12 ($p < .01$).

CON-TG = concentric training group; ISO-TG = isometric training group; ECC-TG = eccentric training group.

kinetic concentric or eccentric strength over the 12-week training period.

Peak Concentric Work and Concentric Power

All three training groups experienced a significant increase in peak concentric work and concentric power over the course of the 12-week training period ($p < .01$) (Table 3). The CON-TG demonstrated the largest increases in both peak concentric work and concentric power when compared to the ISO-TG and the ECC-TG (Figure 1). There was a main effect for training group for peak concentric work ($p < .01$) and concentric power ($p < .03$). Post hoc analysis revealed significant differences between the CON-TG and the ISO-TG ($p < .02$) and the CON-TG and ECC-TG ($p < .02$) for peak concentric work. With regard to peak concentric power, the CON-TG differed from the ISO-TG ($p < .03$) but not from the ECC-TG.

Functional Mobility Measures

Step test time decreased significantly ($p < .03$) for all three training groups following training (Figure 2) with no

Table 3. Peak Concentric Work (J) and Concentric Power (W) at Weeks 0 and 12 for the Three Training Groups

Group	Week 0	Week 12	Mean % Change
Peak Concentric Work			
CON-TG	99.7 ± 47.8	138.3 ± 63.7	45.2*
ISO-TG	97.7 ± 39.0	109.2 ± 39.5	14.9*
ECC-TG	114.1 ± 33.4	127.3 ± 35.3	12.7*
Peak Concentric Power			
CON-TG	75.5 ± 37.2	104.4 ± 41.0	51.8*
ISO-TG	76.2 ± 40.3	87.2 ± 41.9	20.8*
ECC-TG	83.5 ± 32.8	98.1 ± 28.7	23.3*

Note: Values are means (± standard deviation) in Nm.

*Significant difference between Weeks 0 and 12 ($p < .01$).

CON-TG = concentric training group; ISO-TG = isometric training group; ECC-TG = eccentric training group.

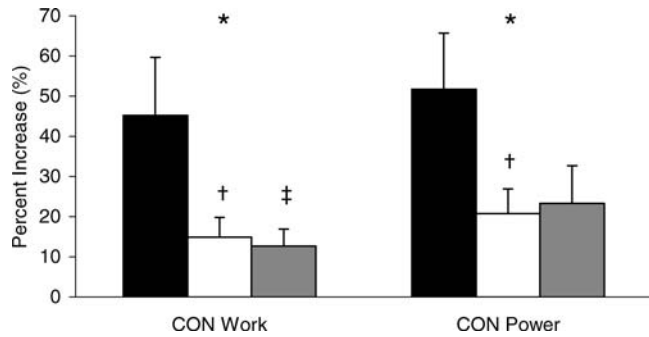


Figure 1. Mean (\pm standard error) percentage increase in concentric work and concentric power following 12 weeks of isometric and isokinetic concentric and eccentric resistance training. Black bars, concentric training group; open bars, isometric training group; gray bars, eccentric training group.*Significant difference between Week 0 and Week 12; †significant difference between the concentric training group and the isometric training group; ‡significant difference between the concentric training group and the eccentric training group.

between-group differences. There were no changes in gait speed (Week 0, ≈ 1.4 m/s; Week 12, ≈ 1.3 m/s).

DISCUSSION

Isometric and Isokinetic Strength

Considerable strength gains were found following the 12 weeks of resistance training for all three training groups. However, contrary to previous research (12,14,17) isolated eccentric resistance training in our study did not result in significantly greater gains in isometric and isokinetic concentric strength. One caveat is that the sample for our study consisted of a relatively small and homogeneous group of healthy older adults, so these results should not be generalized broadly to the elderly population. Hortobagyi and DeVita (12) found that eccentric overloaded training elicited significantly greater posttraining gains in concentric strength (16%) compared to traditional isotonic resistance training (7%). A possible explanation for this difference in concentric gain is the use of contraction-specific training in the present study, i.e., the ECC-TG trained only with eccentric contractions. Conversely, the eccentric overload training group in the Hortobagyi and DeVita study (12) performed both concentric and eccentric contractions during training. The lack of specific training in concentric contractions by the ECC-TG could account for the smaller gains found in posttraining concentric strength.

We observed no difference in isometric strength gain between training groups. LaStayo and colleagues (14) and Hortobagyi and DeVita (12) found significant increases in isometric strength (60% and 16%, respectively), whereas their traditional isotonic resistance training groups only demonstrated 15% and 5% increases in posttraining isometric strength, respectively. Neither LaStayo and colleagues (14) or Hortobagyi and DeVita (12) used isometric contractions during their training. Based on the results of the present study (isometric strength: ECC-TG = 27.7% vs ISO-TG = 25.5%) and the significant gains in isometric strength in the two previously mentioned studies, it appears that eccentric training results in considerable gains in isometric strength. Therefore, it seems plausible that by adding an overload

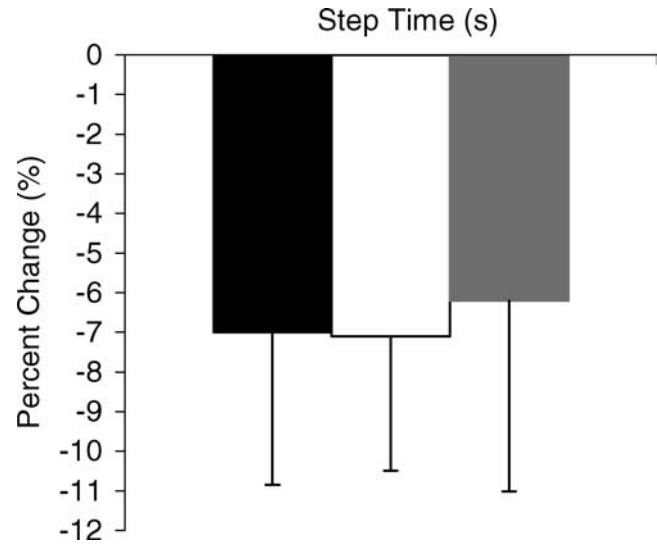


Figure 2. Mean (\pm standard error) percentage decrease in step time following 12 weeks of isometric and isokinetic concentric and eccentric resistance training for all three groups. Black bars, concentric training group; open bars, isometric training group; gray bars, eccentric training group.

eccentric phase to traditional isotonic resistance training programs of older adults, the potential result could be increases in all three types of strength.

Concentric Work and Concentric Power

Concentric power, whether peak (20) or average power (21), has been shown to increase following resistance training of various intensities. The results of the present study confirm these findings as 12 weeks of maximal isometric and isokinetic concentric and eccentric resistance training resulted in increased concentric power. Furthermore, our results demonstrate the task-specific nature of these increases, with the CON-TG generating the greatest gains. This finding has potential implications on future training programs of older adults. Bean and colleagues (22) demonstrated that there is a significant relationship between leg power and the physical performance of tasks such as stair climbing, chair stand, habitual gait, and maximal gait. Therefore, training regimens should incorporate a concentric contraction component to optimize the potential of increasing concentric power and the possible translational effect(s) on the performance of functional activities.

A similar trend was found for concentric work, with the CON-TG showing the greatest gains compared to the ISO-TG and the ECC-TG. Correlation analysis was carried out to determine if these training-induced increases in concentric work and concentric power were related to improved step test times. Only the training-induced increases in concentric work for all three training groups were correlated with improved step time ($r = -0.45$; $p < .02$). Additionally, when the increases in concentric work were analyzed by training group, only the increases from the CON-TG were associated with improvements in step time ($r = -0.76$; $p < .02$). The evidence for transfer to improved functional performance as a result of increased power is inconclusive, and data pertaining to concentric work is scarce. Further exploration of the

relationship between concentric work and concentric power and functional performance is warranted.

Functional Mobility

Maximal isometric and isokinetic resistance training had a significant impact on self-paced stair stepping, with step time decreasing by about 6% for all groups. Our results are in agreement with previous research that found significant improvements in stair descent (21%) (14) and stair ascent (11%) (16). Nichols and colleagues (16) used participants with similar physical characteristics to those used in the present study, but they used a timed 20-step stair test with participants carrying 20% of their total body weight in a backpack. They believed for their study, as we do for ours, that greater decreases in step time would have been observed had less active and mobile participants been used. This appears to be a plausible prediction based on the findings of LaStayo and colleagues (14), who reported a 21% improvement in stair descent in frail elderly participants. Despite these differences, it is important to note that training composed of isometric and isokinetic concentric and eccentric muscle actions all transferred into improved stair climbing and descending performance.

Gait speed was not influenced by 12 weeks of maximal isometric and isokinetic resistance training. Latham and colleagues (4) recently compiled a systematic meta-analysis of the effects of progressive resistance training for this age group, and reported that there was limited effect size of 0.07 m/s in gait speed. However, Worm and colleagues (23), following a 12-week study, observed a more sizeable gain of approximately 0.20 m/s (tested over 10 m). There was a sizable difference in baseline ambulatory function between our participants (1.4 m/s) and those of Worm and colleagues (0.8 m/s). Furthermore, their study incorporated aerobic, rhythmic, and balance exercise in addition to resistance training (23).

In summary, the eccentric isokinetic training group did not demonstrate gains in voluntary strength superior to those of the isometric and concentric groups; it was clear that all three resistance training programs in older adults were effective in increasing concentric, isometric, and eccentric strength. Training, particularly with concentric contractions, had a significant impact on concentric work and concentric power. Functional mobility was only partially affected by training with improved stair ascent and descent performance.

ACKNOWLEDGMENTS

This research was supported by a Pharmacia/Pfizer Research Grant on Physical Activity & Musculoskeletal Injury Prevention from the American College of Sports Medicine Foundation and by the Natural Sciences and Engineering Research Council of Canada.

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Received March 4, 2004

Accepted April 12, 2004

Decision Editor: John E. Morley, MB, BCH