

1-1-2000

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Citation of this paper:

Connelly, D. M. and Vandervoort, A. A., "Effects of isokinetic strength training on concentric and eccentric torque development in the ankle dorsiflexors of older adults" (2000). *Physical Therapy Publications*. 162.
<https://ir.lib.uwo.ca/ptpub/162>

Effects of Isokinetic Strength Training on Concentric and Eccentric Torque Development in the Ankle Dorsiflexors of Older Adults

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This study quantifies concentric and eccentric dorsiflexor muscle torque at various movement velocities and determines the neuromuscular effects from short-term practice of repeated maximal voluntary contractions using an isokinetic resisted exercise program in older adults. Twenty-eight subjects (76.3 ± 4.6 years) trained concentric and eccentric dorsiflexion 3 days per week for 2 weeks at 30°, 90°, and 180°/s through 40° of dorsiflexion range of motion. Peak torque, rate of torque development, surface electromyography, and strength curves at each velocity were compared before and after training. Increases were found for concentric (27%) and eccentric (20%) dorsiflexor peak torque and concentric rate of torque production (20%–53%) across all movement velocities ($p < .01$). Training also significantly increased dorsiflexor concentric (64%) and eccentric (55%) surface electromyography; taken together, this is evidence of apparent adaptation of neural factors in older adults with short-term training. These findings support that eccentric and concentric strength training enhances the control and production of ankle muscle dorsiflexor torque in older adults, with implications for improving functional mobility of the ankle joint.

PRODUCTION of absolute maximal torque is known to be reduced by aging (1–4). Less is known regarding the ability to produce explosive torque in a timely fashion, although fast, forceful contractions may be critical to maintain balance and to prevent trips and falls in an older adult. In normal postural control, the time taken to produce a submaximal force may sometimes be as important as the absolute force level itself (5,6). For example, the age-related loss of high muscle torque levels in the ankle (7–9) may be restrictive to the fast, forceful muscle contraction responses needed to respond effectively to perturbations of posture. In addition, diminished sensorimotor conduction might produce significant delays of long-loop reflexes in response to challenges to balance (6,10).

Previous analyses of torque-time, torque-velocity, and length-tension curves for isometric or concentric (CONC) contractions of the ankle dorsiflexor muscle group (8,9,11) and of torque-angle isokinetic curves at 30°/s for CONC and eccentric (ECC) dorsiflexor muscle actions (7) indicate that explosive torque production capacity of this muscle group decreases in older people. These findings support the concepts that age-related atrophy effects may be greater on fast-twitch than on slow-twitch fibers, that there is a loss of fast-twitch fibers, or that the maximal rate of voluntary neural activation of the muscles might also be reduced by aging (5,12). The type II muscle atrophy observed in elderly persons has been associated with a greater decrease in torque at higher isokinetic velocities and with lower maximal peak knee extension velocities (13,14), but a similar study was not found for the dorsiflexor muscle.

Observations that aging limits the ability to produce fast,

forceful muscle contractions at higher velocities of movement prompt the question: Can training these movements over time promote a neural adaptation to improve peak torque and power at faster movement speeds? Evidence suggests that ECC torque is preserved to a greater extent than CONC torque (7,15,16) in older persons, leading to the possibility that training with ECC loading is an effective approach for this age group (17). Nevertheless, the effects of aging on ECC dorsiflexor strength over faster velocities have also received insufficient attention to date. Thus, the purposes of this study were to quantify CONC and ECC dorsiflexor muscle strength at various movement speeds and to determine the neuromuscular effects from short-term practice of repeated maximal voluntary contractions using an isokinetic resisted exercise program in older adults.

METHODS

Subjects

Twenty-eight men and women ranging in age from 70 to 85 years participated with informed, written consent. The subjects, fifteen women and thirteen men, were healthy, active, community-living older adults (Table 1). None of the subjects had sprained or fractured either ankle within the past 2 years and were not limited in walking or other daily activities by other medical conditions. Subjects were habitually involved in recreational exercise as quantified using the Yale Physical Activity Survey for Older Adults (18).

Exclusion criteria for participation in the study included uncontrolled hypertension, heart failure, unstable angina, requirement for supplemental oxygen, known recent (<3

Table 1. Summary of Subject Characteristics

Subjects	Age (y)	Height (cm)	Mass (kg)	Recreational Activity (h/w)
Group (<i>N</i> = 28)	76.3 ± 4.6	163.7 ± 9.2	71.2 ± 12.1	4.5 ± 3.6
	70–85	142.1–178.9	47.1–99.5	0–14.0
Women (<i>n</i> = 15)	74.7 ± 3.8	158.3 ± 7.5	67.3 ± 11.8	4.1 ± 3.5
	70–83	142.1–175.0	47.1–87.0	0–10.0
Men (<i>n</i> = 13)	78.2 ± 4.9	169.8 ± 7.0	75.6 ± 11.1	5.0 ± 3.7
	71–85	156.8–178.9	61.1–99.5	1.0–14.0

Note: Values are mean ± *SD* and range for each subject characteristic.

months) myocardial infarction, previous isokinetic exercise training, or current resisted strength training of the ankle dorsiflexor or plantar flexor muscle groups. Subjects did not have conditions or take medications that have known major effects on neuromuscular function or on the ability to perform maximal voluntary contractions (MVCs). Four women were taking estrogen replacement medicine (mean duration = 22 ± 6 years), and four women were taking thyroid medication (mean duration = 25 ± 26 years). The mean number of chronic diseases for the group was 1.4 ± 0.9, and a mean number of 1.2 ± 1.2 prescription medicines were currently being taken. The most common chronic condition reported was osteoarthritis of the hip or knee joint (*n* = 19). The study was approved by the University of Western Ontario Review Board for Health Sciences Research Involving Human Subjects.

Torque Measurement Equipment

Dynamic CONC and ECC action torques were measured on a Kin-Com 500H isokinetic dynamometer with version 3.21 software (Kinetic Communicator, Chattecx, Chattanooga, TN). The Kin-Com ankle unit and universal stabilizer attachments were used with the subject seated in the standard positioning for ankle plantar and dorsiflexor muscle exercise (outlined in the operator's manual). The ankle plantar/dorsiflexion attachment was fitted onto the lever arm with the load cell at a constant 0.21 m distance for all subjects. A preload of 10 N · m, approximately 10% of the subject group's average maximal voluntary torque, was programmed into the protocol to decrease acceleration and deceleration phases in the ankle movement. The dynamometer head was fixed in the lowest height position with the universal stabilizer attachment in place under the leg to be tested.

Subjects performed exercise with their shoes on and wore the same shoes for all training and testing sessions. Extra padding to secure the foot into the ankle unit was thereby minimized, the foot was easily stabilized, and pressure from the strapping was modified to accommodate bunions and hammer toes. Lifting of the heel, especially during a plantar flexion movement, and sliding of the foot in the ankle unit was also diminished with a shod foot.

Subject Positioning

The subjects sat on the Kin-Com seat against a back support with their foot resting in the ankle unit. The seat was adjusted so that the knee was flexed to 90° with the ankle in neutral. The universal stabilizer was adjusted to support the

calf or thigh. Stabilizing belts were secured over the lap, thigh or shin (depending on the height of the subject), ankle, and forefoot to prevent extraneous movement. Foam padding was placed between the popliteal fossa and the universal attachment and between the foot and stabilizing belts at the ankle and forefoot to minimize discomfort during contractions. The rotational axis of the dynamometer was positioned to be coaxial with the ankle joint axis of plantar and dorsiflexion (fibular malleolus) during testing (19). The resistance pad was positioned directly under the heads of the metatarsals. During testing, subjects were asked to keep their arms folded across their chest.

Training Procedures

At the beginning of each training session, a warm-up consisted of sets of 6 repetitions (reps) of uninterrupted cycles of CONC dorsiflexion paired with CONC plantar flexion performed at each of 30°, 90°, and 180°/s velocities. These velocities were chosen based on previous literature and the capabilities of older adults. Another 6 reps were performed, as previously described, in reverse order with CONC plantar flexion followed by CONC dorsiflexion. The range of movement for training was individualized for subjects based on their pain-free active ankle joint range of movement and standardized for the remaining training sessions for that subject. The target ankle range of movement for training was 0° to 40° (or as near as possible) for individual subjects. This range of movement was in reference to the position of the ankle unit, with 0° or neutral ankle range of movement defined as the fifth metatarsal perpendicular to the midline of the leg, as measured by a goniometer, and 40° into ankle plantar flexion. The right leg for all subjects was chosen to be the experimental leg for the training program. A pre- and postexercise session were completed using the subjects' left leg as the control.

Two sets of 12 MVCs of the ankle dorsiflexor muscles were performed during each training session, at each of the three velocities—30°, 90°, and 180°/s for the right (trained) leg. The specific training protocol involved 6 cyclic (uninterrupted) CONC dorsiflexion/ECC dorsiflexion MVCs and 6 cyclic ECC dorsiflexion/CONC dorsiflexion MVCs. A 2-minute rest was given between the sets of 6 cycles at each velocity, and a 5-minute rest was given between CONC/ECC and ECC/CONC dorsiflexion contraction sequences. Training occurred three times per week over 2 weeks.

The subjects were instructed to “pull” for CONC and ECC dorsiflexion “as hard and as fast as possible,” but were not verbally encouraged for maximal output during the contractions. The investigator did, however, coach subjects for effective breathing during the maximal efforts to avoid increased intrathoracic pressures. Assurance from the subjects was sought periodically during rest periods to reinforce that they were performing MVCs at each velocity, throughout their full range of movement.

Isokinetic Peak Torque

The gravity correction factor (correcting for additional torque produced by the foot and leg segment mass) was determined at the beginning of each set of contractions by identifying the subject's leg-foot segment mass at a static

position near their end relaxed plantar flexion range of movement. The resultant gravity-corrected torques were used for analysis. To avoid inertial artefacts due to acceleration and deceleration periods of the movement, only torque data during the constant velocity portion of the range of motion were analyzed. The constant velocity periods were provided by filtering data by velocity in a statistical package (SigmaStat, SPSS, Inc, Chicago, IL). Constant velocity was limited to $30^\circ \pm 1^\circ/\text{s}$, $90^\circ \pm 1^\circ/\text{s}$, or $180^\circ \pm 1^\circ/\text{s}$ over the entire training range of movement. Only dorsiflexor torque achieved at the 30° , 90° , or $180^\circ/\text{s}$ set velocity was included in the analysis. The force data was transformed to torque using a lever arm length of 0.21 m for all subjects, based on the distance of the load cell from the axis of rotation on the dynamometer head. For each subject, the highest dorsiflexor CONC and ECC peak torques achieved at 30° , 90° , or $180^\circ/\text{s}$ were selected as the peak torques for each training session. Peak torque values for CONC dorsiflexion were taken from contraction sequences when CONC preceded ECC dorsiflexion, and ECC peak torque values were collected from contraction sequences when ECC preceded CONC dorsiflexion.

In addition to the comparison of peak torques, the torque-angle relationships were examined for CONC and ECC dorsiflexion actions on pretest versus post-test. Velocity-filtered torque for each set of 6 CONC or 6 ECC dorsiflexion contractions was plotted against ankle range of movement at pretest and post-test to produce the strength curves for each subject. The strength curves for all subjects ($N = 28$) were plotted on the same graph to compile a representative strength curve for the subject group. A CONC and ECC dorsiflexion strength curve was made for each movement speed.

The angle at which CONC dorsiflexor peak torque occurred was collected from the velocity-filtered force data (converted to torque) and used to calculate the rate of torque development for each of the training velocities for each subject. From the angle of peak torque, the time to reach peak torque could be calculated based on the angular velocity (30° , 90° , or $180^\circ/\text{s}$). The ankle range of motion to the angle of peak torque was determined by subtracting the angle of peak torque from the start position of the contraction (measured in degrees). Time to reach peak torque angle was determined by dividing the ankle range of movement for peak torque ($^\circ$) by the velocity of movement ($^\circ/\text{s}$). The average rate of torque development [i.e., peak torque ($\text{N} \cdot \text{m}$)/time (s)] was then calculated using the peak torque and time to reach this angle, as previously published (7).

Electromyography

Surface electromyographic (EMG) recordings were made from one agonist (tibialis anterior) and a representative antagonist (soleus) muscle. Agonist dorsiflexor (tibialis anterior) and antagonist plantar flexor (soleus) EMG was collected using 10 mm-diameter Beckman silver-silver chloride surface electrodes (Sensormedics Corp, Anaheim, CA) with a 16-channel, fiber-optic, biological amplifier (total gain 2000x, low-pass filter 1000 Hz, high-pass filter 10 Hz, common mode rejection ratio >70 dB at 100 Hz, sampling frequency 2500 Hz), custom-made system (Paul Guy Circuits Design, Waterloo, ON, Canada). EMG data were full-wave rectified and low-pass filtered at 3 Hz to produce a linear envelope

prior to analog/digital (A/D) conversion and storage by an IBM 386 compatible computer. A custom-designed software program (MEMG; C.Y. Yim Custom Software, Inc, Toronto, ON, Canada) sampled the digital EMG signal at 200 Hz/channel before EMG integration was completed.

Skin preparation, electrode placement, and recording procedures were standardized over the study period. Alcohol pads were used to clean the skin, followed by abrasion with a terry cloth towel and conducting gel until an erythema was produced. Two Beckman silver-silver chloride surface electrodes (Sensormedics Corp, Anaheim, CA), with an 8-mm diameter well, were positioned and fixed with collars overlapping and straddling the center of the muscle bulk of the tibialis anterior, approximately 5 cm superior to the muscle-tendon junction. The surface electrodes were placed during a maximal voluntary toe-raise contraction. Plantar flexor-recording electrodes were positioned during a heel raise over the soleus muscle, just lateral to the midline of the leg, and approximately 5 cm inferior to the bulk of the gastrocnemius. The ground electrode for the dorsiflexor channel was fixed over the head of the fibula. A ground electrode fixed over the lateral malleolus completed the plantar flexor channel circuit. The electrode positions were measured to minimize variability in electrode placement when retesting.

Mean EMG was calculated as the integral from the beginning to end of the CONC or ECC phase of dorsiflexor muscle contraction for the 3 most consistent, smoothest repetitions of the set (20). These 3 integrals were then averaged to produce the final mean EMG value for the training day measured in millivolt \cdot seconds ($\text{mV} \cdot \text{s}$). The potentiometer reading of lever arm angle (joint position) from the Kin-Com was processed concurrently with the linear envelope EMG data through the A/D board so that ankle joint angle position would be in "real time" beside the EMG data. By this connection, EMG specific to the CONC or ECC muscle action were analyzed.

Statistical Methods

The torque and the agonist tibialis anterior and antagonist soleus EMG data for the right (trained) leg were analyzed with a three-factor (time, velocity, contraction type) repeated measures analysis of variance (ANOVA; Unixstat 5.2). Post hoc analysis was performed for significant interactions using Tukey's test, which is a conservative method (21). The $p < .05$ level was used to establish statistical significance for post hoc comparisons. Critical values of the studentized range statistic, q , for Tukey's tests were determined from the Tukey table based on the total number of means in the comparison (r) and the df_e (21). Also, paired t tests on the right (trained) leg data were performed to compare rate of torque development over time at each velocity. The $p < .05$ level was used to establish statistical significance. Left leg (control) data for torque were analyzed with a three-factor (time, velocity, contraction type) repeated measures ANOVA.

RESULTS

Isokinetic Strength

Changes in the isokinetic peak torque were found during the 2 weeks of training (Figure 1). Overall, for the right

(trained) leg, the peak torque was higher post-test than pre-test [time main effect, $F(1,27) = 49.28, p < .01$] and higher for ECC than CONC contractions [type of contraction main effect, $F(1,27) = 328.18, p < .01$]. Higher velocities produced an overall lower peak torque than lower velocities [velocity main effect, $F(2,54) = 57.79, p < .01$], but this was almost entirely due to a reduction in peak torque in the CONC contractions with higher velocities, with little decline in torque levels observed for ECC contractions [velocity by type of contraction interaction, $F(2,54) = 85.78, p < .01$]. To further determine the significant differences between ECC and CONC torque production at each of the 30°, 90°, and 180°/s movement speeds, post hoc Tukey's tests were calculated. ECC dorsiflexion torque values were all consistently higher at each velocity, pre-, and post-test, compared with the torque values generated during CONC dorsiflexion contractions. Significant differences were found between CONC torque production at 30° versus 90°, 30° versus 180°, and 90° versus 180°/s movement speeds. However, for ECC torque, there were no torque production differences found across movement speeds. There was no significant change over time ($p = .38$) in the peak torque of the untrained left leg control at any movement speed for either CONC or ECC muscle actions (overall means were 26.8 ± 11.1 pretest, 25.9 ± 10.6 post-test).

Torque-Angle Relationship Curves for CONC and ECC Dorsiflexion Contractions

Pretest versus post-test strength (torque-angle) curves are plotted for CONC and ECC dorsiflexor muscle contractions at 30°/s (Figure 2), at 90°/s (Figure 3), and at 180°/s (Figure 4) for the right (trained) leg. For CONC and ECC dorsiflex-

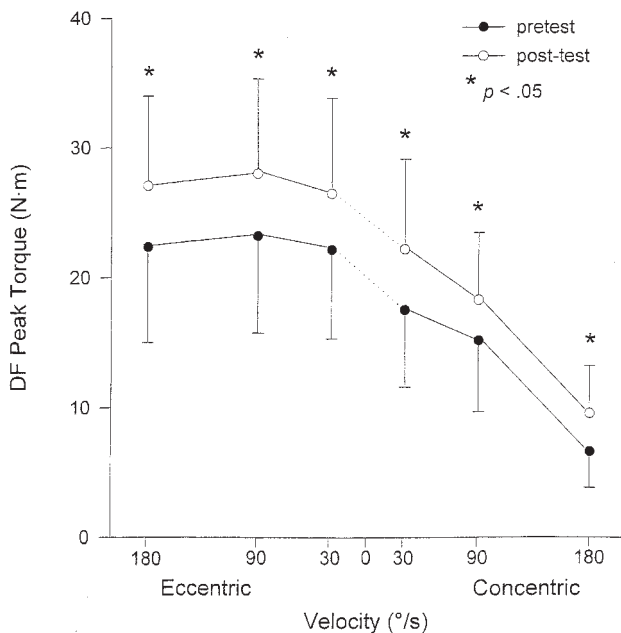


Figure 1. A force-velocity curve generated from concentric and eccentric maximal voluntary dorsiflexor contractions at 30°, 90°, and 180°/s. Pretest scores (filled circles) are plotted with post-test scores (open circles). Values are mean + 1 standard deviation. DF = dorsiflexion.

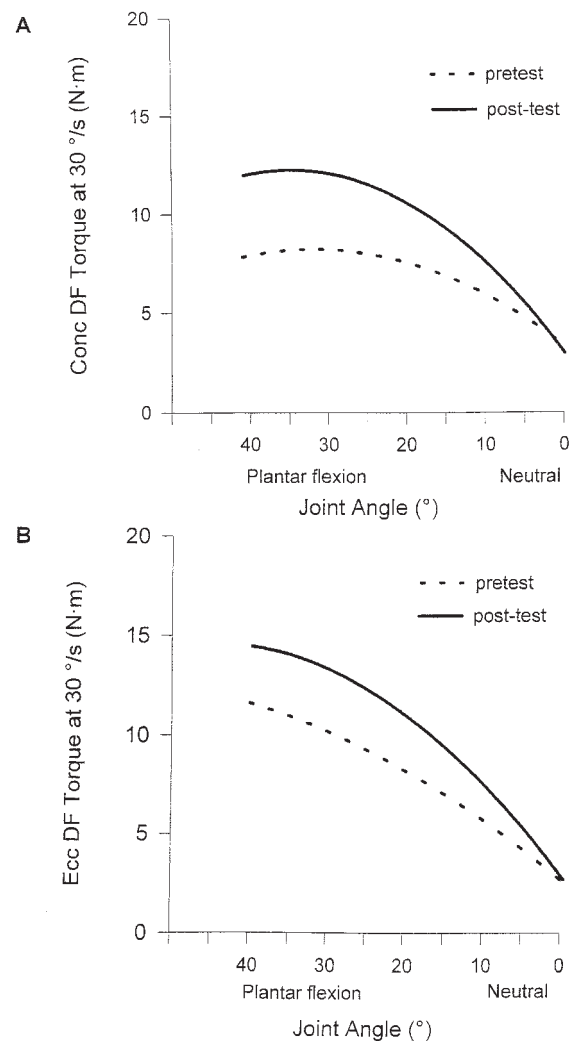


Figure 2. A strength curve (torque-angle) for voluntary torque production against joint angle at 30°/s for (A) concentric (Conc) and (B) eccentric (Ecc) dorsiflexion (DF). Pretest scores (dotted lines) are plotted with post-test scores (solid lines).

ion, a second-order polynomial regression was used to represent the overall curves of the compiled 28 subject curves. No statistically significant differences were found for angle of peak torque with training at any movement velocity. However, a tendency was observed for peak torque angles occurring earlier in the movement range on post-test.

Rate of Torque Development

Significant differences in the rate of torque development ($N \cdot m/s$) for CONC dorsiflexion were found over time for 30°, 90°, and 180°/s movement speeds (Table 2), with a greater rate of torque development following the training sessions for the right leg.

Dorsiflexor EMG

Increases in dorsiflexor surface EMG activity were found with 2 weeks of isokinetic exercise training for both CONC (Figure 5) and ECC (Figure 6) movements. Overall, for the

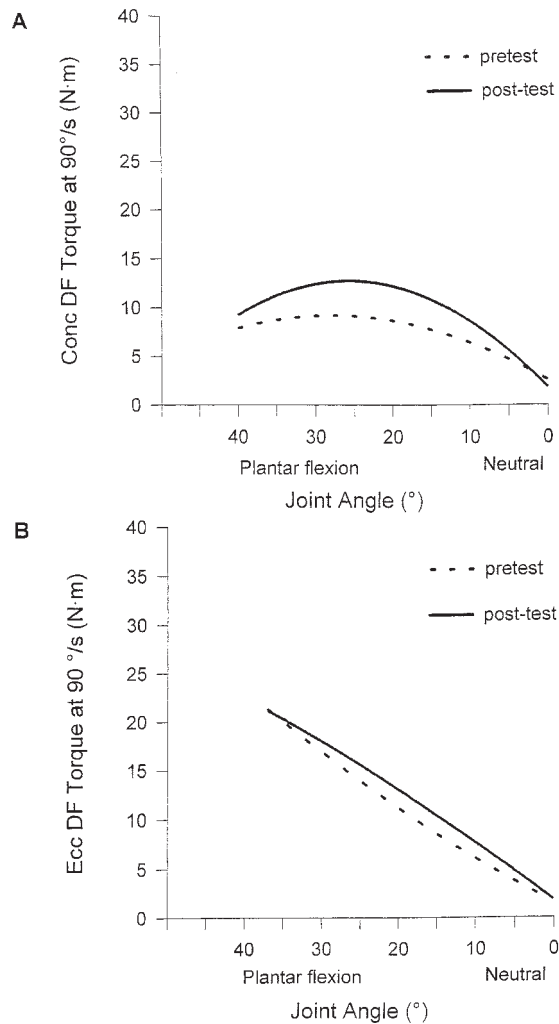


Figure 3. A strength curve (torque-angle) for voluntary torque production against joint angle at 90°/s for (A) concentric (Conc) and (B) eccentric (Ecc) dorsiflexion (DF). Pretest scores (dotted lines) are plotted with post-test scores (solid lines).

right (trained) leg, surface EMG activity was higher post-test than pretest [time main effect, $F(1,25) = 4.04, p < .05$] and appeared higher during CONC actions than ECC actions at 30°/s movement velocity [type of contraction by velocity interaction, $F(2,50) = 7.92, p < .01$]. Surface EMG activity for dorsiflexion was highest during the slowest velocity and was progressively lower with increasing movement velocity [velocity main effect, $F(2,50) = 55.73, p < .01$]. In addition, increased surface EMG activity on post-test was maintained in an order of highest to lowest EMG activity across increasing movement velocity—30°, 90°, and 180°/s for CONC and ECC contractions [time by velocity by type of contraction interaction, $F(2,50) = 3.73, p < .05$]. The higher dorsiflexor surface EMG activity for the 30°/s movement velocity between pretest and post-test than at any other velocity across time was most likely the condition-specific difference in the pattern of outcomes, which

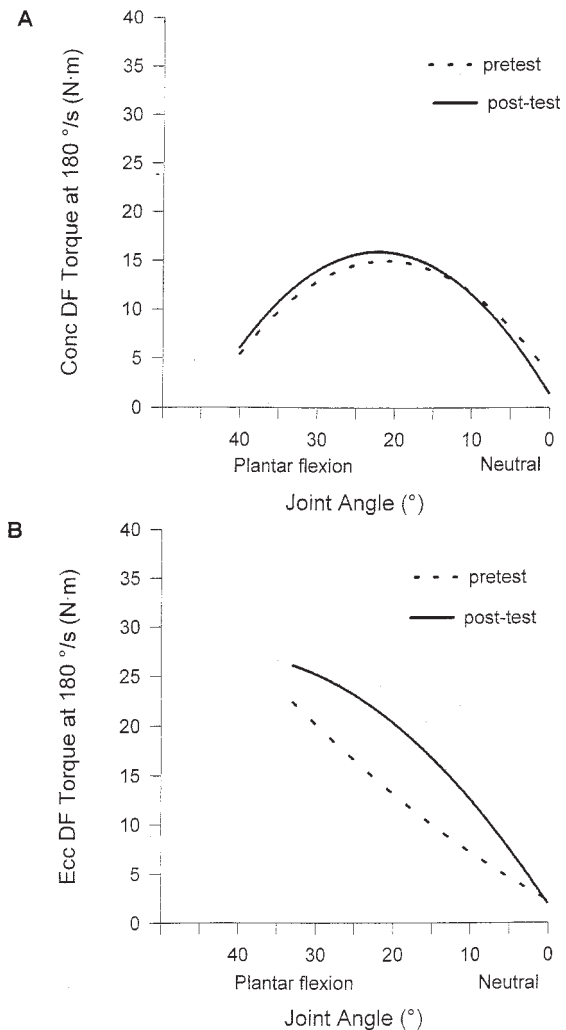


Figure 4. A strength curve (torque-angle) was plotted for voluntary torque production against joint angle at 180°/s for (A) concentric (Conc) and (B) eccentric (Ecc) dorsiflexion (DF). Pretest scores (dotted lines) are plotted with post-test scores (solid lines).

accounts for the three-way interaction. To further investigate these results, post hoc calculations were completed using Tukey's tests, which indicated that statistically significant increases in CONC and ECC dorsiflexor surface EMG at 30°, 90°, and 180°/s were evident after practice (Figures 5 and 6). No significant increases ($p = .70$) over time for dorsiflexor agonist EMG were found for the left control leg (465.4 ± 531.5 mV · s pretest, 426.8 ± 652.2 mV · s post-test).

Plantar Flexor Co-contraction EMG

Plantar flexor antagonist EMG from the soleus muscle, plotted as a co-contraction index (plantar flexor agonist activity \div plantar flexor antagonist activity), did not change markedly in the right (trained) leg with the practice at any velocity for either type of CONC or ECC muscle contraction ($p = .93$).

Table 2. Average Rate of Torque Development (RTD) From Resting to Peak Level (RTD = $N \cdot m/s$) Compared Over Time and Velocity of Concentric Dorsiflexion Muscle Actions

Velocity and Contraction	Pretest RTD ($\bar{x} \pm SD$) ($N \cdot m/s$)	Post-test RTD ($\bar{x} \pm SD$) ($N \cdot m/s$)	Percentage of Change
30°/s concentric	238.8 \pm 177.5	364.8 \pm 219.5*	52.8
90°/s concentric	67.6 \pm 31.6	80.9 \pm 26.9*	19.7
180°/s concentric	13.3 \pm 7.5	20.2 \pm 10.2*	51.9

Note: Values are mean \pm SD for each subject characteristic.

* $p < .05$ with adjusted alpha for multiple comparisons.

DISCUSSION

The primary findings obtained from this short-term training program of MVCs at various movement speeds demonstrated that torque production in untrained older adults was readily increased. Dorsiflexor peak torque values improved for both CONC and ECC dorsiflexor muscle actions across all three velocities. The short time frame for the increased response in torque production found suggests an improvement primarily in neural factors in these older adults similar to studies involving young subjects (22) and consistent with other studies using muscles crossing the knee or elbow joints (5,23,24). It should also be noted that these older adults (aged 70–85 years) showed decreased strength values at pretest compared with previously published data on young subjects (7,25).

Strength curves are important indicators of muscular capability to exert torque through range (26). The strength curves at 30° and 90°/s, for both CONC and ECC dorsiflex-

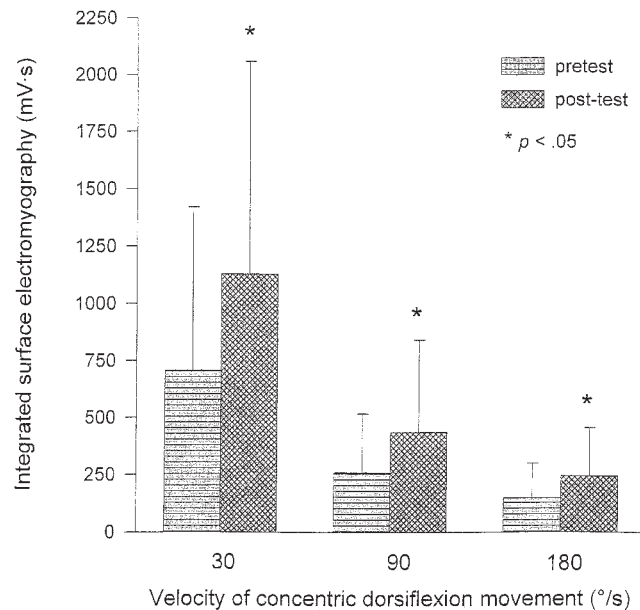


Figure 5. Surface electromyography (EMG), group means +1 standard deviation, plotted for concentric dorsiflexion at each of the tested movement velocities—30°, 90°, and 180°/s. EMG activity increased significantly from pretest to post-test at each movement velocity.

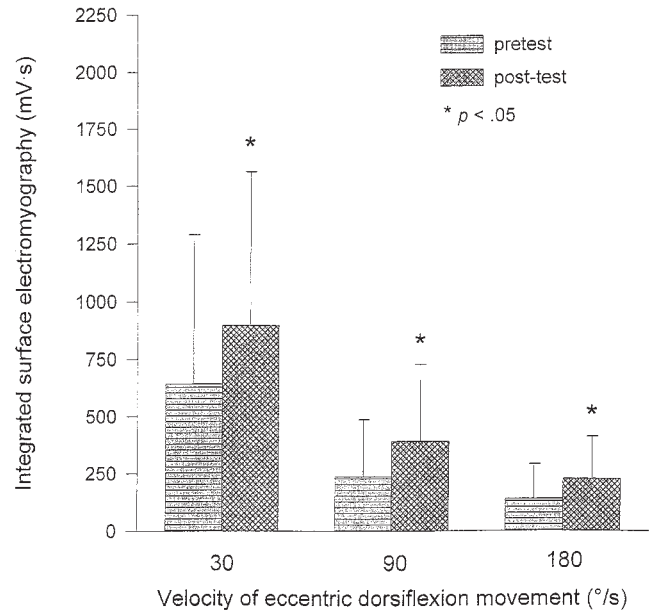


Figure 6. Surface electromyography (EMG), group means +1 standard deviation, plotted for eccentric dorsiflexion at each of the tested movement velocities—30°, 90°, and 180°/s. EMG activity increased significantly from pretest to post-test at each movement velocity.

ion, were shifted upward after the 2-week training period, representing increased torque production and some leftward displacement in the angle at which peak torque occurs at post-test. This leftward shift in peak torque angle, for CONC dorsiflexion more than ECC dorsiflexion, indicates the increased rate of torque development produced with training. Little change was found between pretest and post-test strength curves at 180°/s. These smallest changes at the highest movement velocity reflect the difficulty subjects had producing torque at this highest training/testing velocity and suggest that a greater amount of training is required to increase torque production in older adults at high movement velocities. Alternately, reduced torque production at high velocity suggests some loss of type II fibers and a reduced ability to perform fast contractions. However, it was encouraging to observe significant improvements in the rate of peak torque development for CONC dorsiflexion at 30°, 90°, and 180°/s. This increase in rate of peak torque development after several training sessions would appear to reflect an important improvement in the capacity of the nervous system to drive the muscle towards more rapid torque production.

This study presents an initial representation of CONC and ECC dorsiflexion torque-angle curves for older adults at velocities greater than 30°/s. The steep decline in torque production at increasing speeds during CONC dorsiflexion movements (Figure 1) demonstrates a rapid loss of capacity for fast, forceful shortening contractions at the ankle joint in older adults. The results definitely illustrate the compromised rate of torque development with increasing movement velocity (Table 2) and appear to be near the limits for

torque production at 180°/s for these older adults. Training effects from a short-term intensive training protocol suggest that neural factors can be retrained to improve peak torque production. However, improved torque at faster movement speeds requires a longer program or greater training volume to effect significant changes. In addition, ECC strength appears to be preserved with aging to a greater extent across movement velocities than CONC muscle work. The preserved level of ECC dorsiflexion strength in this group of older adults was also somewhat resistant to the short-term training program as greater effects were seen in CONC dorsiflexion torque-angle curves at 30° and 90°/s movement velocity.

Training-induced neural adaptations in this study were measured indirectly by analyzing changes that took place in EMG activity of the trained agonist dorsiflexor muscles during MVCs at various movement speeds. Increased agonist EMG represents an increase in net excitation of the motoneurons secondary to an increased excitatory input from a greater number of motoneurons that are active and/or an increased firing rate of already active motoneurons. Increased agonist activity, as measured by EMG, can result from increased excitatory input or be increased as a result of reduced inhibitory input, or both (22,27). Using the surface EMG method, it was not possible to determine whether the mechanism for increased EMG was increased firing rate or increased number of active motoneurons.

One theory for increasing firing rate in the agonist muscle and thereby increasing force production is the reflex inhibition mechanism (27). Reflex inhibition of the antagonist muscles during agonist activity is thought to reduce the opposition to agonist contraction, thereby increasing force production. However, the level of coactivation of the opposing plantar flexor muscle group remained unchanged over the training period and suggests that, in this group, a reduced level of co-contraction facilitating increased agonist torque production did not occur. In addition, dorsiflexion peak torque occurred in the lengthened position of the muscle, at which time the plantar flexor muscle group was quite shortened and less capable of producing antagonist force.

Another mechanism for the increase in muscle activation may result in part from possible adaptations in the recruitment pattern of the activated motor units (6,22). Previous work by Moritani and colleagues (28) found that after 2 weeks of biceps strength training at 30% MVC, EMG was significantly increased, and the mechanism proposed was synchronization of motor unit firing. Mean power frequency analysis reflected a shift toward lower frequency bands due possibly to better summation or synchronization of the underlying action potentials (29). Increased coordination of neural stimulation at the onset of a muscle contraction, to counteract the slower-contracting muscle of older adults (9,25), could be advantageous for increased force production.

Learning to recruit the larger fast-twitch motor units for these fast velocity MVCs has been hypothesized as an important advantage for rapid ballistic movements (22). There are still some fast-twitch fibers remaining in the muscle of older adults (12), and occasional high maximal motor unit firing rates, as found in young muscle, have been measured in aged muscles using the intramuscular recording tech-

niques (30–32). Thus, in the present study, one of the mechanisms for the increased torque could be due to learning to prime the neuromuscular system to more readily recruit additional motor units and/or discharge the already active motor units with higher frequency, perhaps with some neural pathways that also involve the segmental reflex loops (22,29).

In summary, rapid increases were observed in EMG, CONC and ECC peak torque, and the rate of torque development of the ankle dorsiflexor muscles across three velocities in older adults who performed several sessions of isokinetic strength training. These improvements in the short time frame investigated indicate that considerable training-induced adaptation takes place in the neuromuscular control system. This study concluded that training high velocity movements is feasible for older persons, and further study is warranted on the value of this approach, including dynamic/isotonic movements, for enhancing functional mobility and prevention of falls.

ACKNOWLEDGMENTS

We wish to acknowledge the support of the Natural Sciences and Engineering Research Council of Canada, and the support from a Gerontology Fellowship awarded by the Royal Canadian Legion in conjunction with the Physiotherapy Foundation of Canada.

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Received May 24, 1999

Accepted February 19, 2000

Decision Editor: Jay Roberts, PhD

Geron Corporation—Samuel Goldstein Distinguished Publication Award

The Geron Corporation—Samuel Goldstein Distinguished Publication Award lecture will be presented at 10:30 a.m. on Saturday, November 18, 2000, at the Annual Meeting of The Gerontological Society of America in Washington, DC. The lecture will be presented by Yusen Liu, a coauthor of the article selected by the Editorial Board of the *Journal of Gerontology: Biological Sciences* as the best article published in that journal starting April 1999 and ending March 2000.

The article chosen was:

Hutter D, Yo Y, Chen W, Liu P, Holbrook NJ, Roth GS, Liu Y. Age-related decline in ras/ERK mitogen-activated protein kinase cascade is linked to a reduced association between Shc and EGF receptor. *J Gerontol Biol Sci*. 2000;55A:B125–B134.

The award will be given again at the 2001 Annual Meeting for the best article published in the journal from April 2000 through March 2001.