Spring 4-17-2013

TEST-RETEST RELIABILITY FOR VOLUNTARY AND EVOKED MEASURES OF PEAK TORQUE, ELECTROMECHANICAL DELAY, AND RATE OF TORQUE DEVELOPMENT IN OLDER MEN.

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DEVELOPMENT IN OLDER MEN

by

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A THESIS

Presented to the Faculty of

The Graduate College at the University of Nebraska

In Partial Fulfillment of Requirements

For the Degree of Master of Science

Major: Nutrition and Health Sciences

Under the Supervision of Professor Joel T. Cramer

Lincoln, Nebraska

May, 2013

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The purpose of this study was to examine the test-retest reliability for peak torque (PT), rates of torque development (RTD), and electromechanical delay (EMD) calculated during voluntary and evoked muscle actions in men ages 65 and older. Fifteen older men (mean ± standard deviation (SD) age = 72.3 ± 7.3 years) completed 3 evoked and 3 voluntary isometric muscle actions of the leg extensors during two visits separated by 48 to 72 h. PT and EMD were calculated during voluntary and evoked muscle actions. RTD was quantified as the peak RTD, overall RTD, RTD in time intervals of 0-30 (RTD30), 0-50 (RTD50), 0-100 (RTD100), and 0-200 ms (RTD200) from the onset of torque, and RTD in 10 ms epochs during the first 250 ms after the onset of torque or to peak torque for voluntary and evoked muscle actions. Intraclass correlation coefficients (ICCs), standard errors of measurement (SEMs), and coefficients of variation (CV) were used to quantify the test-retest reliability. Voluntary and evoked PT demonstrated good reliability, whereas EMD can be considered unreliable. The ICCs for voluntary PRTD, RTD30, RTD50, RTD100, RTD200, and overall RTD ranged from 0.598-0.799, while for evoked PRTD, RTD30, RTD50, RTD100, and overall RTD, ICCs ranged from 0.943-0.984. Voluntary RTDs in 10 ms epochs had ICCs ranging from 0.179-0.939, while evoked RTD in 10 ms epochs demonstrated ICCs ranging from 0.693-0.975. Except for

PRTD and RTD in 10 ms epochs after 50 ms, CVs were higher for voluntary (11-41%) than evoked (7-24%) measures. Systematic decreases occurred from trial one to trial two for several voluntary measures of RTD, while there was only one for the evoked measures of RTD. **CONCLUSIONS:** There is dissociation in the reliability of voluntary and evoked PT, and RTD, such that the evoked measurements display greater reliability in older men. Voluntary RTDs were most suspect, consistently demonstrating lower ICCs and greater SEMs than evoked RTD. However, if choosing to measure voluntary RTD in older men, the most reliable measurements may be RTD in the first 10 ms, 80-110 ms, or overall RTD. Finally, EMD may be unreliable in older men.

ACKNOWLEDGEMENTS

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CHAPTER I

INTRODUCTION

Sarcopenia is defined as the age-related loss of skeletal muscle mass (7) and

function (39) and is associated with physical disability and functional impairment (34).

Estimates on the prevalence of sarcopenia report rates ranging from 5-13% in adults ages

60-70 years old and from 11-50% in adults 80 years and older (20,60). Using

conservative estimates, sarcopenia currently affects 50 million people and will affect 200

million within the next 40 years (18). Clinically, sarcopenia is defined as a combination

of low grip strength or gait speed and relative skeletal muscle mass ≥ 2 standard

deviations below a reference sample (20). When comparing genders, sarcopenia develops

at a faster rate in men than in women across the age span (21,24,33); therefore, men and

women are often studied separately regarding sarcopenic muscle function. Moreover,

there is a dissociation between the loss of skeletal muscle mass and the loss of muscle

strength with sarcopenia (60). Metter et al. (45) reported age-related decreases in strength

independent of changes in muscle mass for adults from 18 years to 93 years of age and

suggested that "muscle quality" be used as a relative index (strength $\div$ muscle mass) by

which to monitor changes with aging and sarcopenia. Identifying reliable measures of

skeletal muscle mass, strength, function, and muscle quality will be important to

understand the complex physiological changes that occur in skeletal muscle with age.

Consistent with sarcopenia is the elevated risk of falls in the elderly. Falls occur

in 30% of adults aged 65 years and older (26) and in 50% of adults aged 80 years and

older every year (58). Falling-related injuries are the sixth leading cause of death among

the elderly (57). In fact, 50% of elderly adults who are hospitalized due to a fall will have

a one-year survival rate (49). Therefore, exploring reliable measurements of muscle function that not only characterize sarcopenia, but also provide insight regarding the ability to avoid falls is of paramount importance. The recovery of balance following a destabilizing perturbation requires a rapid and forceful response (63). Andersen and Aagaard (4) previously defined the rate of torque development (RTD) as the "ability to rapidly develop muscle force" (pg. 47). Thus, RTD may be an important variable to monitor for reducing the risk of falls in the elderly (10,32,48,56). The electromechanical delay (EMD) is the time lag between the onset of electrical activity in a muscle and the onset of a measureable torque response (18,61,67) that is influenced by the series elastic component (SEC; 18). The SEC may change with age (36). Consequently, the EMD may be sensitive to age-related changes in muscle quality or stiffness that effect reaction time and RTD. However, RTD (2,10,37,48,56) and EMD (65) have only recently been studied in the elderly. Therefore, measuring these variables reliably, in addition to skeletal muscle mass and strength, may help to clarify the age-related changes in muscle function to better explain sarcopenia.

Christ et al. (19) stated that "…fear of injury may serve as an inhibitory mechanism in older, sedentary adults" (pg 503). This statement implied that central nervous system inhibition may influence measures of muscle function during voluntary muscle actions in the elderly. Variables such as muscle force production, RTD, and EMD can be measured during evoked muscle actions by stimulating the peripheral motor nerve that innervates the muscle or muscle group being studied. In theory, evoked muscle actions would not be influenced by motivation or central inhibition. Ishida et al. (31) suggested that the central component of muscle activation could be removed when using

evoked muscle actions. Therefore, a direct comparison of the reliability of evoked versus voluntary muscle actions may be helpful to examine the efficacy of these measures of muscle function in the elderly.

Given the recent focus of exercise- and nutrition-based interventions to reduce the negative impacts of sarcopenia (16,30,47), it is important to understand the reliability of variables used to quantify muscle function in the elderly. For example, Baier et al. (6) examined the effects of once-daily supplementation with either hydroxy-β-methylbutyrate, L-arginine, and L-lysine over a one-year period on protein turnover, body composition, isokinetic leg extensor and flexor strength, hand-grip strength, and functionality in elderly men and women. This study indicated that this blend of amino acids increased whole body protein turnover and lean body mass in the elderly, however, it did not result in increased strength or functional performance. Reliability of voluntary peak torque (PT) and evoked twitch properties has been examined in the dorsi- and plantar-flexors of elderly men and women (64) and in the leg extensors of elderly women (17). Buckthorpe et al. (14) recently reported reliability for evoked and voluntary RTD and PT in young, healthy adults. However, to our knowledge, no previous studies have established test-retest reliability of PT, RTD, or the EMD in the leg extensors of elderly men. Therefore, the purpose of this study will be to examine test-retest reliability for PT, RTD, and EMD calculated during voluntary and evoked muscle actions in elderly men.

CHAPTER II

REVIEW OF LITERATURE

2.1 Historical Perspective of Evoked and Voluntary Contractions

2.1.1. Asmussen and Heeboll-Nielsen (5)

The purpose of this investigation was to determine the changes in muscular strength that occur during aging using voluntary isometric contractions. Isometric muscle strength was measured in 25 muscle groups in 360 men and 250 women, ages 15 to 60. Maximal isometric force was measured via strain gauge dynamometers. The measured values were then grouped and averaged according to the age of the subjects. The over-all change in isometric strength was determined by expressing the measured values as a percentage of strength in the same muscle group of 20 to 22 year old men (i.e. $\left(\frac{Strength\ in\ 55-60\ yr\ old\ male}{Strength\ in\ 20-22\ yr\ old\ male}\right)*100$). The results showed that isometric strength increases in men until the age of 30 and then begins to decline. By age 60, isometric strength is 90% that of 20-22 year olds. In women, isometric strength fails to increase appreciably after the age of 20 and is about 65% of aged matched men. After age 40, women's strength decreases more rapidly than men's, such that by age 55, women's strength is only 54% that of aged matched men. There is also a difference in the rate of decline in strength of the upper and lower limbs. Maximum lower limb strength is reached later in life than upper limb strength, but declines more rapidly than in the upper limbs.

2.1.2. Merton (44)

The purpose of this study was to compare voluntary tension with the tension elicited from electrically elicited motor volleys to determine the ability of a maximal

tetanic stimulus to maximally activate the contractile mechanism, voluntary activation, and the contribution of the central nervous system to fatigue during a sustained contraction.

Maximal stimuli were applied to the ulnar nerve at the wrist in order to cause contraction of the adductor pollicis, which is the only ulnar-nerve supplied muscle acting on the thumb. Therefore, the force produced by the electrical stimuli and by the voluntary adduction could be compared. A special splinting device was used to stabilize the hand at the wrist joint. The amplified action potentials from surface-electromyography and the mechanical force were recorded and then photographed on cathode-ray tubes.

The results of the first experiment in this study indicated that a 50 Hz tetanic stimulus was capable of maximally activating the contractile mechanism. The second experiment demonstrated that during a maximal voluntary effort, maximal activation of the adductor pollicis occurred. The third experiment showed that, during fatiguing contractions, the superimposed stimuli did not result in an increase in force, which demonstrates that the fatigue was largely, if not completely, due to peripheral factors. The authors speculated that failure of the contractile processes may be due to ischemia. In addition to the above results, this article demonstrates how electrical stimuli can be used to study neuromuscular function.

2.1.3. Bigland-Ritchie, Jones, Hosking, and Edwards (12)

The purpose of this study was to determine the cause of fatigue during a sustained, 60-second maximal voluntary contraction of the quadriceps femoris muscle in nine healthy adults (ages 25-50 years). Force and EMG were recorded from the subjects while they were seated on an adjustable chair fitted with a strain gauge. Electrical stimuli

were delivered to the vastus lateralis (VL) transcutaneously via the femoral nerve or percutaneously on the muscle belly with surface pad electrodes. Subjects then performed sustained, 60-second maximal voluntary contractions (MVC), during which the force fell by an average of 30%. The central and peripheral contributions to fatigue were tested in one subject by stimulating the femoral nerve throughout the sustained MVC. If central fatigue were present, the MVC force would theoretically decline more rapidly than would the tetanic force produced by the electrical stimuli. During the first 30s, the voluntary and stimulated contractions declined equally. However, after 45s, the voluntary force was less than the force produced by the electrical tetani. This demonstrated that during the first 30 s, fatigue was due to failure at or distal to the myoneural junction but after 45 s central drive contributed to fatigue. The same protocol was then repeated in the remaining subjects using percutaneous stimulation of the muscle belly. In five of these subjects, central fatigue accounted for 10 to 30% of the force loss after 60 s. In the other four, there was little evidence of central fatigue. This study demonstrated the simultaneous use of evoked and voluntary muscle actions in order to determine the mechanisms of fatigue.

2.2 Common Measures of Neuromuscular Function

2.2.1 Zhou, Lawson, Morrison, and Fairweather (67)

The purpose of this study was to investigate the differences in EMD of the leg extensor muscles during isometric contractions evoked by reflex, voluntary, and electrical stimulation. Twenty-one healthy young women (n=5) and men (n=16) (mean±SD age = 22.7±6.5 years, height = 175.9±7.3 cm, and weight = 68.7±10.6 kg) volunteered for this study. Electromechanical delay was measured in the vastus lateralis (VL) and rectus femoris (RF) while subjects were seated in a chair with a knee joint angle of 90° and a

hip joint angle of 120°. Isometric force was measured via a load cell that was fixed to the subject's leg just above the ankle. The EMD was calculated as the difference between the point in time at which EMG activity began and the onset of torque development. EMD was calculated at 30%, 60%, and 90% of maximal voluntary contraction (MVC); tendon reflex at 60°, 75°, and 90° angles, as well as electrically evoked muscle actions at intensities of 150 V, 120 V, and 90 V. Total reaction time, peak contraction force, peak rate of force development (RFD), the time to peak force, and muscle fiber conduction velocity were also assessed.

The results of this study demonstrated that EMD was longest ($p<0.05$) at 30%. MVC. Further, EMD was significantly longer ($p<0.05$) during the voluntary conditions compared to the reflex or electrically evoked conditions. EMD was significantly shorter ($p<0.05$) during 150V electrically evoked muscle actions than in all other conditions. Peak forces of the electrically evoked muscle actions were 5.8%, 10.1%, and 14.6% of MVC at 90 V, 120 V, and 150 V, respectively. Peak rate of force development was significantly higher ($p<0.05$) in the voluntary condition than in TR or ES. The time to peak force was significantly longer ($p<0.05$) in the voluntary condition than in TR or ES. Furthermore, the time to peak force in ES was significantly lower ($p<0.05$) than the other conditions. The EMD was significantly correlated ($p<0.05$) to the peak force of the voluntary, ES, and TR contractions and to the peak RFD of MVC. The authors speculated that the relationship between evoked peak force and EMD may be related to the contractile properties of the muscle.

2.2.2. Bilodeau, Houck, Cuddeford, Sharma, and Riley (13)

The purpose of this study was to determine if a greater association between the frequency content of EMG and rate of torque development (RTD) existed during either voluntary or evoked contractions of the forearm flexors. The author's hypothesized that a stronger association between the frequency content of EMG and the RTD would be found in evoked muscle actions, due to the elimination of confounding factors during voluntary conditions. Twenty-three healthy adults (mean ± SD age = 28.4 ± 5.5, height = 1.70 m ± 0.10, weight = 65.5 ± 12.8) volunteered to participate in this study. Condition 1 consisted of ballistic muscle actions at four randomly assigned target torques at 20, 40, 60, and 100% of maximal voluntary contraction (MVC). During condition 2, m-waves and twitch torques were evoked from the biceps brachii and brachioradialis while at rest as well as during an isometric contraction at 15% MVC. The mean power frequency (MPF), median frequency (MF), and rate of torque development (RTD) were then calculated for both voluntary and evoked conditions. The RTD was calculated from three different torque sectors: 10-40%, 40-70%, and 10-70% MVC.

The results of condition 1 indicated that RTD increased progressively as the target torque level increased. The MPF and MF of the brachioradialis and the MPF of the biceps brachii also increased as target torque level increased. There were significant correlations ($p < 0.05$) between MPF, MF, and RTD at target torques of 20% and 40% MVC in the biceps brachii. In the brachioradialis, significant correlations ($p < 0.05$) were observed at 40% and 60% of MVC. The results of condition 2 revealed significant ($p < 0.05$) negative correlations between RTD and m-wave MPF ($r = -0.64$), with RTD calculated at 40-70% MVC for the biceps brachii short head while subjects contracted at 15% MVC. There were also significant negative correlations for the brachioradialis both at rest ($r = -0.49$ to -

0.57) and while subjects contracted at 15% MVC (r= -0.55 to -0.58) for all three calculations of RTD (10-40%, 40-70%, and 10-70% MVC).

These results suggest that factors other than muscle fiber composition influence the MPF and the RTD. The author's hypothesized that the relative contribution of these factors varies between conditions. The results of this study suggest that the factors that influence RTD and the frequency content of EMG vary dependent upon the contraction type.

2.3 Previous Reliability Studies

2.3.1. Winegard, Hicks, and Vandervoort (64)

The purpose of this study was to examine the reproducibility of isometric twitch properties and voluntary strength in elderly subjects. Ten subjects (five male and five female) ages 73 to 97 years were tested on two days separated by one week. All of the subjects were able to walk independently and were also involved in light physical activities. Measurements were recorded while the subjects sat in an upright chair with their leg flexed at 90°. A footplate apparatus was used to record isometric twitch properties and voluntary strength of the dorsiflexor and plantar flexor muscles. All measurements of the plantar flexors and dorsiflexors were performed with the ankle at 30° and 10° of flexion, respectively. Electrical stimuli were delivered to the common peroneal nerve in order to elicit twitches in the dorsiflexors and to the tibial nerve to elicit contractions in the plantarflexors. The stimuli were delivered via a constant current stimulator in single 50μs pulses. The stimulation voltage was progressively increased until a plateau in twitch torque was seen. This voltage was then used to elicit maximal twitches. Compound muscle action potentials (M-waves) were recorded via EMG

electrodes placed on the tibialis anterior and the gastrocnemius. The subjects performed maximal voluntary contractions (MVC) during both plantar- and dorsiflexion while a stimulus was applied in order to determine the level of voluntary activation. The MVC attempts were performed until either an interpolated twitch was no longer present or the torque output reached a plateau. Following this, the subjects performed a 5 second MVC followed 3 seconds later by an evoked twitch in order to determine postactivation potentiation.

The ICCs of the resting evoked plantar- and dorsiflexor measurements ranged from 0.80 to 0.97. The method errors $((\sqrt{MS}$ error/mean score) x 100%) ranged from 5.17 to 12.30%. The ICCs and method errors for voluntary peak torque of the plantar- and dorsiflexors were .97 and .98 and -8.95 and 5.96%. This study showed that isometric twitch properties and voluntary peak torque measurements in the elderly demonstrate acceptable reliability.

2.3.2. Cannon, Kay, Tarpenning, and Marino (17)

The purpose of this study was to determine the effect of resistance training on evoked twitch properties in young and old women and to evaluate the reproducibility of evoked twitch measurements.

Nine young (mean ± SD; age 25.0 ± 4.0 yrs, height 167.7 ± 7.6 cm, mass 71.4 ± 10.1 kg, and BMI 25.9 ± 4.5 kg/m^2) and ten elderly (67.1 ± 6.6 yrs, 166.0 ± 6.0 cm, 69.5 ± 12.7 kg, and BMI 27.1 ± 4.2 kg/m^2), moderately active women volunteered to participate in this study. The data obtained from the first and third weeks of testing were used to determine the reproducibility of the measurements. Data from the third week was used to examine age-related differences. Finally, a 10-week resistance-training program

was performed from week three to week thirteen. Data were obtained during the resistance training program at weeks 0, 3, 6, and 10.

Evoked twitch properties and MVC of the right leg extensors were assessed on a Kin-Com isokinetic dynamometer with subjects seated upright with the hip flexed at 75° and the knee flexed at 60°. The variables measured from the evoked muscle actions included: peak twitch torque, time to peak torque, half-relaxation time, contraction duration, rate of torque development, and rate of relaxation. This study also determined the reproducibility of evoked twitch properties by using the Pearson's r, intraclass correlation coefficient (ICC), and the technical error of the measurement (TEM).

The results of this study demonstrated significant differences ($p < 0.05$) between young and old women concerning peak torque, rate of torque development, and rate of relaxation and that the variables measured in this study could be repeated.

2.3.3. Buckthorpe, Hannah, Pain, Folland (14)

The purpose of this study was to determine the between-session reliability of voluntary and involuntary leg extensor measurements of explosive force production and agonist EMG during the initial phases of explosive contractions and at maximal force. Thirteen physically active, healthy men (mean age $\pm$ SD = 22 $\pm$ 3 yrs; height = 178 $\pm$ 4.0 cm; body mass = 70.6 $\pm$ 9.2 kg) visited the laboratory on four separate occasions. The subjects were seated with the hip and knee joint angles set at 100° and 85°, respectively. Surface EMG was recorded from the rectus femoris, vastus lateralis, and vastus medialis. Subjects completed four, three-second isometric maximal voluntary contractions (MVC) and 10 explosive voluntary contractions. From the explosive contractions, force was measured at 50, 100, and 150 ms from the onset of contraction; impulse and rate of force

development (RFD) was measured as peak slope (pRFD) and in windows of 0-50, 50-100, and 100-150 ms after the onset of contraction. RMS EMG was measured from 0-50, 50-100, and 100-150 ms after the initiation of EMG activity.

Involuntary contractions were produced with supra-maximal twitches and with supra-maximal octets. The Mmax P-P and total Mmax area obtained for each muscle during these twitches was used for normalization of the voluntary EMG. The twitch force-time curve was also analyzed for peak force (TPF), force at 50 ms (TF50), pRFD in a 2ms time window (pRFD), impulse from 0-50 ms (TI50), time to peak force (TPF), and half relaxation time (HRT) for both single twitch and octect muscle actions. Inter-class correlation coefficients (ICC) and coefficient of variations (CV) were calculated for each variable.

The maximal voluntary force showed excellent reliability across sessions (ICC=0.95). Absolute EMG amplitudes during maximal and submaximal contractions were consistent (ICC=0.89-0.91). The ICCs for the force, RFD, and impulse at each of time windows (i.e. 0-50, 50-100, and 100-150ms) during voluntary explosive contractions ranged from 0.62 to 0.91. The CVs for these four variables during the 50-100 and 100-150ms windows ranged from 5.1-10.5%. The force responses to the octet stimulations had ICC values ranging from 0.71-0.82 and CV values ranging from 5.4-7.3%. The CV values for force, force at 50ms, and impulse from 0-50ms were similar for twitch and octet stimulation (p≥0.41). Twitch TPT and HRT displayed excellent ICC values (0.89 and 0.86, respectively) and very low CV values (3.6 and 4.9%, respectively). Mmax P-P and Mmax area fluctuated significantly across sessions (p=0.025 and p=0.033,

respectively) and demonstrated poor CV values (14.1 and 13.7%, respectively). However, the ICCs (0.95 and 0.93) were high for both measures.

This study demonstrated that measures of voluntary explosive force production are inconsistent during the first 50ms of force production, but become more consistent from 100ms onward. Furthermore, good reliability (CV<10.0%, ICC>.70) was shown for maximal voluntary force and force responses to octet and twitch stimulation.

2.4 Ageing

2.4.1. Young, Stokes, and Crowe (66)

The purpose of this study was to compare the cross sectional area (CSA) in the quadriceps femoris muscles as well as isometric quadriceps strength of men in their twenties compared to men in their seventies. Twelve older men (mean age=75 yrs, weight=73kg) and twelve younger men (age=25 yrs, weight=74kg) volunteered to participate in this study. All of the elderly subjects were moderately active. Six of the young subjects participated in recreational sport and the other six participated in moderate physical activity. Isometric leg extensor strength was measured with the subjects seated in an adjustable, straight-backed chair with the leg flexed to 90 degrees. The isometric maximal voluntary strength was defined as the peak force maintained for at least 1 s of contraction. The highest recorded force of at least three maximal efforts was taken as the MVC. Quadriceps CSA was measured via bilateral transverse ultrasound scans at the mid-thigh. Subjects lay supine with their thigh supported at a 5-10 degree angle, the knee straightened, and the quadriceps relaxed. Four transverse scans were completed with the CSA taken to be the mean of the four values.

The results of this study demonstrate that elderly men have markedly lower quadriceps strength (39%) and a decreased MVC/CSA ratio compared to young men. The author's hypothesized that this was due to a difference in voluntary activation and/or the fiber type make-up of the muscles. There is also an association between MVC and CSA in older men that does not appear in younger men. The authors concluded that it is important to emphasize the use of age-matched normal data when measuring strength.

2.4.2. Hakkinen, K., Pastinen, U-M., Karsikas, R., and Linnamo, V. (25)

The purpose of this study was to examine the effects of age on voluntary isometric force in unilateral and bilateral conditions and to examine the effects of age on evoked force production compared to the force produced by combined voluntary and evoked muscle actions. Eleven young men (mean age ± SD; 29.0 ± 3.1 yrs), 12 middle-aged men (49.6 ± 4.1 yrs), and 10 elderly men (67.2 ± 3.9 yrs) volunteered for this study. All subjects were considered healthy and habitually active, however, none had a background in strength training or competitive sport.

Subjects were seated on a dynamometer and performed three to four maximal bilateral isometric contractions followed by two to three maximal unilateral isometric contractions of each leg. Subjects were instructed to contract and relax as fast as possible during each of these contractions. Peak force, force-time, and relaxation-time characteristics were recorded from each of these contractions. Electromyographic (EMG) information was recorded from the vastus lateralis (VL), vastus medialis (VM), and rectus femoris (RF). Electrostimulation was applied to the thigh at the motor point of the RF muscle using a 2 s, square pulse with a pulse rate of 50Hz. The first evoked condition included applying three separate maximal stimuli for both the right and left leg while the

subjects remained at rest. In the second evoked condition, subjects performed MVC's while the supramaximal stimuli were applied.

The results of this study showed no IEMG or force evidence of a bilateral deficit for the leg extensors in any of the age groups (p>0.05). However, according to the absolute force-time curve, the ability for explosive force production diminishes with age (p<0.05). Furthermore, there were differences in the relative force-time curves such that the bilateral force produced in the same short period of time relative to the maximal force was higher in young men (p<0.01). The relative neuromuscular activation was lower in the elderly than in the young adults during this same short period of time. These results indicate that the ability to rapidly recruit motor units decreases with age and affects the ability of elderly individuals to display explosive strength properties. Finally, evoked force was significantly lower in the elderly than in the young adults, while there was no difference between the middle-aged and elderly subjects, which may indicate that there is a peripheral component to the loss of strength observed with age.

2.4.3. Hurley, Rees, and Newham (29)

The purpose of this study was to compare strength, activation, proprioceptive acuity, postural stability, and functional activity of the quadriceps femoris muscles in young, middle-aged, and old adults. Twenty young (mean age = 23 yrs), 10 middle aged (mean age = 56 yrs), and 15 elderly (mean age = 72 years) subjects volunteered for this study. Quadriceps strength was measured by a strain gauge with the subjects seated and their hips and knees at 90 degrees of flexion. Subjects performed three maximal voluntary isometric contractions (MVC) of the quadriceps. Voluntary activation was estimated via twitch interpolation. To measure joint position sense (JPS), each subject

was seated with an electro-goniometer fixed to his or her leg. Subjects were asked to estimate their knee joint angle at 10 randomly assigned joint positions. The angle displayed on the goniometer was then compared to the estimated angle that the subject provided. Postural sway was measured while subjects stood on a force plate with three different stances: (1) bipedal with eyes closed, (2) bipedal with eyes open, and (3) monopedal with eyes open. Functional performance was measured via a timed up and go test, a timed walk, a timed stair ascent, a timed stair descent, and a calculated total time for all of the tests performed.

The results of this study demonstrated that quadriceps strength was significantly lower in the older compared to the younger adults ($p < 0.001$). Further, quadriceps strength was negatively correlated with age ($r = -0.511$, $p < 0.001$). There was no difference in quadriceps activation between the young, middle-aged, and old subject groups ($p > 0.05$), or relationship between age and quadriceps activation ($p = 0.345$). JPS was lower in the elderly than in the young ($p < 0.001$) subjects and increasing age was associated with a decreased JPS ($r = 0.603$, $p < 0.001$). In sway tests where subjects closed their eyes, the elderly and middle-aged groups were less stable ($p < 0.002$). Elderly and middle-aged subjects were unable to maintain the monopedal stance for 15 s and at 7 s the elderly were significantly ($p < 0.005$) less stable then the young and middle aged. The elderly subjects were significantly slower than the young and the middle-aged subjects in all of the individual functional performance tests ($p < 0.001$) and the aggregate time ($p < 0.001$). Furthermore, the aggregate functional performance time increased as subjects' age increased ($r = 0.636$, $p < 0.001$), JPS decreased ($r = -0.535$, $p < 0.001$), and as quadriceps strength decreased ($r = -0.37$, $p < 0.02$).

This study suggests that voluntary activation, and therefore central drive, is not the cause of thigh muscular weakness associated with age. The authors hypothesized that the decrease in JPS was due to decreased muscle spindle sensitivity. The combination of decreased strength and proprioceptive abilities appears to have led to an increase in postural sway in the elderly subjects.

2.4.4. Bento, Pereira, Ugrinowitsch, Rodacki (10)

The purpose of this study was to determine the relationship between rate of torque development and peak torque in the lower limbs of elderly individuals with and without a history of falling. A secondary aim was to determine if these measures were related to the number of falls. Thirty-one women aged 60 years and older were split into three groups based on the number of falls they had experienced in the last 12 months. Group one (mean age ± SD age = 67.6 ± 7.5 yrs) had no history of falls, group two (66.0 ± 4.9 yrs) had experienced one fall, and group three (67.8 ± 8.8 yrs) experienced two or more falls. Subjects performed maximal isometric thigh abduction and adduction, leg flexion and extension, and dorsiflexion and plantar-flexion. Peak torque and rate of torque development were determined from the torque-time curves of each muscle action. Peak torque was measured as the highest torque obtained after the onset of contraction. Rate of torque development was measured as the slope of the curve from 20% to 80% of peak torque. The results of this study demonstrate that the rate of torque development in the leg flexor muscles of non-fallers was significantly greater than the rate of torque development observed in fallers. There was also a significant (p<0.05) relationship between peak torque in the leg flexors and the number of falls. However, there was no significant difference in peak torque of the leg flexors in non-fallers and fallers. Finally,

rate of torque development of the leg extensors was higher in non-fallers than in fallers, although not statistically significant. The authors concluded that rate of torque development was a fall-related determinant among the elderly while peak torque was not.

CHAPTER III

METHODS

<u>Subjects</u>

Fifteen older men between the ages of 65-88 years (mean ± standard deviation

(SD) age = 72.3 ± 7.3 years; height = 178.2 ± 6.2 cm; mass = 81.0 ± 13.3 kg) volunteered

for this study. Prior to testing, all subjects signed an informed consent, completed a

health history questionnaire, and received physician's clearance to participate in this

study. All participants had a body mass index below 30 $kg \cdot m^{-2}$ and did not have any

current or ongoing musculoskeletal injuries or neuromuscular diseases that involved the

hip, knee, or ankle joints. Of the 15 participants, 14 reported engaging in 1-11 $h \bullet wk^{-1}$ of

aerobic exercise and 9 reported 1–4 $h \bullet wk^{-1}$ of resistance exercise. This study was

approved by the University of Nebraska-Lincoln Institutional Review Board for Human

Subjects.

<u>Research Design</u>

This was a repeated measures reliability study that required each subject to visit

the laboratory on three separate occasions. Each laboratory visit was separated by 48-72

hours and occurred at the same time of day (±2 hours). During the first study visit,

subjects signed an informed consent and completed a health history questionnaire before

being familiarized with the testing procedures. During visits two and three, subjects

completed the following tests in order: (a) three electrically evoked isometric muscle

actions of the leg extensors and (b) three 6-s maximal voluntary isometric contractions

(MVIC) of the leg extensors.

Isometric Torque

Subjects were seated on a calibrated isokinetic dynamometer (Biodex System 3, Biodex Medical Systems, Inc., Shirley, NY, USA) with restraining straps securing their trunk, pelvis, and contralateral thigh. The axis of rotation of the dynamometer head was aligned with the lateral epicondyle of the right femur, and the right leg was tested for all subjects. The seat was tilted back so that there was a 120° between the thigh and the trunk to expose the femoral triangle for location of the femoral nerve trunk and delivery of the electrical stimuli. The leg was flexed to 90° between the leg and the horizontal plane for all muscle actions. In order to remove any slack resulting in a delay of the transmission of torque from the leg to the dynamometer's potentiometer, the investigator placed a minimal baseline pressure on the lever arm prior to the initiation of the isometric muscle actions.

Isometric force (N) was recorded with a calibrated load cell (Omegadyne, model LC402, range 0-500 lbs; Stamford, CT, USA) that was fixed between the lever arm and the leg pad. Lever arm length (m) was measured and recorded prior to each experimental session. Force and lever arm length were then used to calculate torque using the equation: Torque (Nm) = Force (N) x Lever Arm Length (m).

Electrically Evoked Isometric Muscle Actions

Transcutaneous electrical stimuli were delivered via bipolar surface electrodes placed over the femoral nerve in the lateral most corner of the femoral triangle. The electrical stimuli were delivered using a high-voltage (maximal voltage = 400 V), constant-current stimulator (Digitimer DS7AH, Herthfordshire, UK). Optimal stimulation electrode placements were determined by delivering single low-amperage exploratory

stimuli (20-40 mA) using a hand-held stimulation probe (Digitimer Bipolar Felt Pad Electrodes, Herthfordshire, UK). Electrode location was selected based on visual inspections of the twitch torque and the compound muscle action potential (M-Wave) amplitudes that were displayed on an external computer screen after each exploratory stimulus. Once the location was determined and marked, maximal stimulus intensity was determined by increasing the amperage in 20 mA increments until a plateau in peak-to-peak M-wave (M_{p-p}) amplitude and twitch torque were observed after three consecutive increments. One hundred and twenty percent of the stimulus used to elicit M_{p-p} was used to evoke the femoral nerve trunk with a single 200 μs square wave impulse to ensure a supramaximal stimulus. Three supramaximal stimuli were then administered to record peak twitch torque from the leg extensors with 30 seconds of rest between each stimulus.

Maximal Voluntary Isometric Muscle Actions

Subjects completed four, 4-s isometric warm-up leg extension muscle actions at 25%, 50%, 75%, and 100% of their perceived effort with 30 s of rest between each muscle action. Following two minutes of rest after the warmup, subjects completed three, 6-s MVICs of the leg extensors with two minutes of rest between each attempt. For each attempt, subjects were instructed to contract as "hard and fast" as possible when the investigator said "go!". Loud, verbal encouragement was provided during each MVIC.

Electromyography

Pre-gelled bipolar surface electrodes (Ag/AgCl, Quinton Quick Prep, Quinton Instruments Co., Bothell, WA, USA) were placed on the vastus lateralis muscle of the right thigh with an inter-electrode distance of 40 mm. The center of the bipolar electrode pair was placed at 66% of the distance between the anterior superior iliac spine (ASIS)

and the lateral superior border of the patella (27). The longitudinal axis of the bipolar

electrode pair was parallel to the angle of pennation of the vastus lateralis fibers

(approximately 20°) (15,22,38). A single pre-gelled surface electrode (Ag/AgCl, Quinton

Quick Prep, Quinton Instruments Co., Bothell, WA, USA) was placed on the tibial

tuberosity to serve as the reference electrode. In order to reduce inter-electrode

impedance and increase the signal-to-noise ratio (8,54), local areas of the skin were

shaved, abraded, and cleaned with isopropyl alcohol prior to the placement of the

electrodes. Interelectrode impedance was measured using a digital multimeter (National

Medical Sales, Mission Viejo, CA) to keep impedance below 2,000 Ω (8).

Signal Processing

      The torque and EMG signals were sampled simultaneously at 2 kHz with a

Biopac data acquisition system (MP150WSW, Biopac Systems, Inc., Santa Barbara, CA,

USA). The signals were recorded and stored on a personal computer and processed off-

line with custom written software (Labview 11.0, National Instruments, Austin, TX,

USA). The EMG signals were digitally filtered (zero-phase shift 4th-order Butterworth

filter) with a band-pass of 10-999 Hz. The torque signal was low-pass filtered with a 15

Hz cutoff (zero-phase shift 4th-order Butterworth filter). All subsequent analyses were

completed on the filtered signals.

      The dependent variables included peak torque (PT), rate of torque development

(RTD), and the electromechanical delay (EMD). Voluntary peak torque (PT_V) was

calculated as the highest consecutive 500 ms average torque value (Nm) obtained during

the MVIC. The evoked peak twitch torque (PT_E) was defined as the highest torque value

(Nm) obtained after the onset of the evoked twitch.

Rate of torque development (RTD) was quantified using four different methods for voluntary and evoked muscle actions: (a) Voluntary ($PRTD_V$) and evoked ($PRTD_E$) peak rate of torque development were calculated as the peak of the first derivative of the torque signal ($Nm \cdot s^{-1}$) occurring between the onset of torque and peak torque, (b) RTD was measured from the first derivative of the torque signal as an average of 10 ms epochs over the first 250 ms (i.e. 0-10, 10-20, 20-30…240-250 ms) for voluntary muscle actions, and in 10 ms epochs up to PT_E for evoked muscle actions, (c) RTD was measured as the slopes of the torque-time curve in time intervals of 0-30 ($RTD30_v$), 0-50 ($RTD50_v$), 0-100 ($RTD100_v$), and 0-200 ($RTD200_v$) ms from the onset of torque for voluntary muscle actions (3) and as the slopes of the torque-time curve in time intervals of 0-30 ($RTD30_E$), 0-50 ($RTD50_E$), and 0-100 ($RTD100_E$) for evoked muscle actions. Unlike the voluntary muscle actions, the slope from 0-200 ms was not calculated for the evoked muscle actions because PT_E occurred at approximately 100 ms, (d) Overall RTD was measured as the slope of the torque signal from the onset of torque to peak torque ($Nm \cdot s^{-1}$) for voluntary and evoked muscle actions.

Voluntary electromechanical delay (EMD_V) was defined as the time lag (ms) between the onset of the voluntary EMG amplitude and the onset of the torque response. Evoked electromechanical delay (EMD_E) was defined as the time lag (ms) between the onset of the M-wave and the onset of the torque response. The onsets of torque and EMG amplitude were manually identified as the point where the torque or EMG signal crossed three standard deviation units above the respective signal baselines.

Statistical Analyses

  The average across the three voluntary or evoked attempts for each subject during both trials was used for statistical analyses. Means, standard deviations, and 95% confidence intervals using the studentized t-distribution were reported for each dependent variable (Table 1).

  Test-retest reliability was quantified by calculating the intraclass correlation coefficient (ICC) for relative consistency among trials using Model "2,k" from Shrout and Fleiss (52):

$$ICC_{2,k} = \frac{MSs - MSe}{MSs + \left(\frac{k(MSt - MSe)}{n}\right)}$$

  Where MS_S was the mean square for subjects, MS_e was the mean square error, MS_t was the mean square total, k was the number of trials (k=2 for voluntary and evoked), and n represented the sample size. In addition, the 95% confidence interval for the $ICC_{2,k}$ was calculated according to the procedure described by Shrout and Fleiss (52) and McGraw and Wong (43), and the 95% confidence interval was used to test the null hypotheses that each ICC was equal to zero according to the recommendation of Vincent and Weir (59).

  The standard error of the measurement (SEM) was reported as a measure of absolute consistency (62). The SEM was calculated using the following equation (28, 53):

$$SEM = \sqrt{MSe}$$

  The coefficient of variation (CV) was calculated as a normalized measure of the SEM using the following equation (28):

$$CV = \frac{SEM}{Grand\ Mean} \times 100$$

A one-way repeated measures analyses of variance (ANOVA) was used to compare the means between trials one and two for systematic variability, and the p-values for this comparison are reported in Tables 1 and 2. In addition, the mean square values used to calculate the $ICC_{2,k}$, SEM, and CV were derived from the ANOVA tables.

The calculations for ICC, SEM, and CV were performed using a custom-written spreadsheet (Microsoft Excel for Mac 2011, Microsoft Corporation, Redmond, WA) based on the article by Weir (62). All other data analyses were performed using SPSS v. 14.0 (SPSS Inc., Chicago, IL.). A type I error rate of $\leq 5\%$ was considered statistically significant for all analyses.

CHAPTER IV

ANALYSIS OF DATA

<u>RESULTS</u>

Table 1 shows the means, standard deviations, and 95% confidence intervals for voluntary and evoked PT, EMD, and RTD for trials one and two. Table 2 shows the means, standard deviations, and 95% confidence intervals for voluntary and evoked RTD during the 10 ms epochs for trials one and two. The reliability for PT, EMD, and RTD, and RTD during the 10 ms epochs are displayed in Tables 3 and 4, respectively. There were systematic decreases in $PRTD_V$ (p=0.01) and $RTD200_V$ (p=0.034), in RTD calculated in 10 ms epochs for voluntary muscle actions during 140-150 ms (p=0.03), 150-160 ms (p=0.005), 160-170 ms (p=0.003), and 170-180 ms (p=0.004), and for evoked muscle actions during 80-90 ms (p=0.035) from trial one to two (Tables 3 and 4).

Figures 1 and 2 display the ICCs ± 95% confidence intervals for each dependent variable. The ICCs for $RTD50_E$, EMD_E, and voluntary RTD in 10 ms epochs from 30-60 ms and from 120-180 ms exhibited 95% confidence intervals that included zero, which indicated that those ICCs were not different from zero (p>0.05). All other ICCs were greater than zero (p≤0.05).

DISCUSSION

In the present investigation, the ICCs for PT, EMD, and RTD during voluntary and evoked muscle actions ranged from 0.596 to 0.887 and from 0.625 to 0.984, respectively. For PT_V and PT_E, the ICCs were 0.887 and 0.974, respectively. In contrast, the ICCs for EMD_V and EMD_E were 0.596 and 0.625, respectively. The ICC for $PRTD_V$ was 0.799 and the ICC for $PRTD_E$ was 0.984. The ICCs for $RTD30_V$, $RTD50_V$, $RTD100_V$, $RTD200_V$, and overall RTD_V ranged from 0.598-0.793, while for $RTD30_E$, $RTD50_E$, $RTD100_E$, and overall RTD_E, ICCs ranged from 0.943-0.980. Voluntary RTDs calculated in 10 ms epochs had ICCs ranging from 0.179-0.939, while evoked RTD in 10 ms epochs demonstrated ICCs ranging from 0.693-0.975 (Figure 2). Except for PRTD and RTD in 10 ms epochs after 50 ms, CVs were higher for voluntary (11-41%) than evoked (7-24%) measures. Systematic decreases occurred from trial one to trial two for several voluntary measures of RTD ($PRTD_V$, $RTD200_V$, and for voluntary RTD in 10 ms epochs from 140-180 ms), while there was only one systematic decrease for the evoked measures of RTD (the evoked RTD 10 ms epoch from 80-90 ms). Therefore, in the present study, qualitative comparisons of ICCs, SEMs, and CVs between voluntary and evoked measures of PT, EMD, and RTD indicated that, for these elderly men, voluntary and evoked PT were comparably reliable, EMD was comparably unreliable, and RTD was more reliable during evoked than voluntary muscle actions. These findings supported those of Jenkins et al. (35) for the reliability comparisons of voluntary and evoked PT and EMD, but did not support the comparable reliability between voluntary and evoked RTD in young men.

Winegard et al. (64) reported reliability coefficients (0.94-0.98) for voluntary and evoked PT during dorsiflexion and plantar-flexion in older men and women (ages 73-97 yrs) that were similar to the ICCs for PT_V and PT_E in the current investigation (0.89 and 0.97). Cannon et al. (17) reported greater reliability coefficients for voluntary (0.92-0.94) than evoked (0.84) PT, and ICCs of 0.80-0.81 for evoked overall RTD during isometric leg extension in both young and old women, which implied that reliability was similar for voluntary and evoked muscle actions regardless of age. Buckthorpe et al. (14) demonstrated that the reliability of PT and PRTD were greater during voluntary (0.95 and 0.90) than evoked (0.83 and 0.80) muscle actions and that the ICCs for voluntary RTD calculated in time intervals of 0-50 ms and 0-100 ms were 0.80 and 0.90. In contrast, the present study showed better reliability for evoked (0.974 and 0.984 with no systematic error) than voluntary (0.887 and 0.799 with systematic error) PT and PRTD, and lower reliability for $RTD50_V$ and $RTD100_V$ (0.598 and 0.742) compared to Buckthorpe et al. (14). The reliability reported by Jenkins et al. (35) in young men, in combination with reliability for older men in the present study, suggested that voluntary and evoked PT and EMD were similar for young and older men. However, Jenkins et al. (35) reported that voluntary and evoked PRTD was similarly reliable in young men, which was not consistent with better reliability of evoked RTD than voluntary RTD in the present investigation. When examined collectively, these data suggested that voluntary RTD may be more reliable in young than old men, which may reflect an age-related decrease in the ability to consistently, voluntarily produce force rapidly.

Christ et al. (19) previously raised concern with the accuracy of estimates of muscle function during maximal voluntary efforts requiring elderly individuals to

contract as hard and fast as possible. Voluntary ICCs and CVs for RTD30, RTD50, RTD100, RTD200, and overall RTD (0.598-0.793 and 9.8-37.9%) demonstrated lower relative and absolute reliability than evoked (0.943-0.980 and 6.8-11.5%). Apart from 0-10 ms and 80-110 ms, voluntary RTDs in 10 ms epochs were unreliable; indeed, 11 of the 25 ICCs were no different from zero (Figure 2). Previous studies have highlighted the importance of instructing subjects to contract as fast as possible in order to obtain the greatest rate of force development (9,50,51). However, it has also been recommended that subjects gradually build up force during an isometric muscle action in order to minimize the pain and/or discomfort (23). While subjects were instructed to contract as "…fast as possible," it is possible that the differences in reliability between voluntary and evoked RTD variables observed in the present investigation were a result of fear of injury, apprehension, or discomfort related to explosive isometric muscle actions. Therefore, voluntary RTD variables recorded from older men should be interpreted with caution. However, RTD calculated in the earliest time phase (0-10 ms), during 80-110 ms after the onset of torque, or overall RTD were the voluntary RTD variables in the present study that yielded the highest ICCs and lowest CVs and may be appropriate for future studies. It is possible that additional familiarization sessions (i.e., greater than the one familiarization session used in the present study) for older adults are necessary to provide better reliability for voluntary RTD measures.

The relative reliability of EMD_V and EMD_E were low in the present study (ICCs of 0.596 and 0.625, respectively). Jenkins et al. (35) suggested that the low ICCs associated with EMD may be a result of low between-subjects variability. Weir (62) explained that "the relative nature of the ICC is reflected in the fact that the magnitude of

an ICC depends on the between-subjects variability" (pg. 232). Specifically, the ICC will be low if the sample is homogenous, even if trial-to-trial variability is small (62). In the present study, the mean square between subjects (MS_S) expressed as a percentage of the grand mean was 452% for EMD_V and 166% for EMD_E. In comparison, MS_S was 1078% and 919% for PT_V and PT_E. These data indicated that between subjects variability was lower for EMD than PT. In addition, the CVs for EMD_V and EMD_E were lower than those previously reported in college-aged men (35). The 95% confidence interval for the EMD_E ICC indicated that EMD_E had no relative reliability. Therefore, despite the lower between-subjects variability that may have influenced the lower ICCs for EMD, EMD_E should still be considered unreliable.

Interpreting relative and absolute test-retest reliability has traditionally been qualitative and subjective. For example, Weir (62) stated that, "…the ICC for a test is context specific…" (p. 232). Streiner and Norman (54) noted that, "There is literally no such thing as the reliability of a test, unqualified; the coefficient has meaning only when applied to specific populations" (p. 112). In addition, Cannon et al. (17) stated, "Because there is no preferred method to evaluate measurement reliability and no single statistical approach is universally recommended, assessing measurement reproducibility is somewhat problematic" (p. 632). In the present study, 95% confidence intervals were calculated about the ICCs, which provided a mechanism to test the null hypothesis that each ICC was equal to zero. This technique was described by Vincent and Weir (59) as an alternative to the traditional null hypothesis statistical test. Therefore, a unique aspect of the present study was applying this method of hypothesis testing to evaluate the ICC.

Future studies should consider this evaluation of reliability to avoid the challenge of interpreting reliability.

Conclusions

        This was the first study, to our knowledge, to quantify the test-retest reliability of voluntary and evoked measurements of RTD in 10 ms epochs, and time intervals of 0-30, 0-50, 0-100, and 0-200 ms. Furthermore, we are aware of no previous studies that have statistically evaluated ICCs with 95% confidence intervals. The results of the present study, in conjunction with a previous study (35), indicated that voluntary and evoked measurements of PT are comparably reliable in both young and old men. Voluntary and evoked EMD, however, exhibited lower ICCs than PT, which may be due to low between-subjects variability, but when evaluated with 95% confidence intervals, EMD was unreliable in the present study. Finally, except for RTD in 10 ms epochs after the initial 50 ms, evoked RTD demonstrated high reliability in older men. Voluntary RTD was only reliable when calculated in 10 ms epochs during the first 10 ms, 80-110 ms, and calculated as the overall RTD – all other voluntary RTD measures were unreliable in the present study. It is possible that additional familiarization sessions are needed to improve the reliability of voluntary RTD and/or EMD measures in older men. Alternatively, it is possible that older men may alter the rate at which they voluntarily produce torque as a protective mechanism or fear of injury (19), which may have caused the low reliability for voluntary RTD.

CHAPTER V

SUMMARY

Statement of Purpose

The purpose of the present study was to examine test-retest reliability for PT,

RTD, and EMD calculated during voluntary and evoked muscle actions in elderly men.

Procedures for Collection of Data

Fifteen older men between the ages of 65-88 years (mean ± standard deviation

(SD) age = 72.3 ± 7.3 years; height = 178.2 ± 6.2 cm; mass = 81.0 ± 13.3 kg) volunteered

to complete 3 supramaximal, electrically evoked muscle actions and 3 6-s MVICs of the

leg extensors during two trials separated by 48-72 hrs. PT, EMD, and RTD were

calculated during each of the muscle actions, averaged across mode during each trial, and

then used to calculate the reliability for the two experimental sessions.

Analysis

Means, standard deviations, and 95% confidence intervals using the studentized t-

distribution were calculated for each dependent variable. A one-way repeated measures

analyses of variance (ANOVA) was used to compare the means between trials one and

two for systematic variability. In addition, the mean square values used to calculate the

ICC (2,k), SEM, and CV were derived from the ANOVA tables. Test-retest reliability

was quantified by calculating the intraclass correlation coefficient (ICC), the standard

error of the measurement (SEM), and the coefficient of variation (CV).

Findings

Voluntary and evoked PT demonstrated good reliability (ICCs = 0.887-0.974;

CVs = 8.7%), whereas EMD may be considered unreliable (ICCs = 0.596-0.625; CVs =

5.4-17.6%). The ICCs for voluntary PRTD, RTD30, RTD50, RTD100, RTD200, and

overall RTD ranged from 0.598-0.799, while for evoked PRTD, RTD30, RTD50,

RTD100, and overall RTD, ICCs ranged from 0.943-0.984. Voluntary RTDs in 10 ms

epochs had ICCs ranging from 0.179-0.939, while evoked RTD in 10 ms epochs

demonstrated ICCs ranging from 0.693-0.975. Except for PRTD and RTD in 10 ms

epochs after 50 ms, CVs were higher for voluntary (11-41%) than evoked (7-24%)

measures. Systematic decreases occurred from trial one to trial two for several voluntary

measures of RTD, while there was only one for the evoked measures of RTD.

Conclusions

This was the first study, to our knowledge, to quantify the test-retest reliability of

voluntary and evoked measurements of RTD in 10 ms epochs, and time intervals of 0-30,

0-50, 0-100, and 0-200 ms. Furthermore, we are aware of no previous studies that have

statistically evaluated ICCs with 95% confidence intervals. The results of the present

study, in conjunction with a previous study (35), indicated that voluntary and evoked

measurements of PT may be comparably reliable in both young and old men. Voluntary

and evoked EMD, however, exhibited lower ICCs than PT, which may be due to low

between-subjects variability, but when evaluated with 95% confidence intervals, EMD

was unreliable in the present study. Finally, except for RTD in 10 ms epochs after the

initial 50 ms, evoked RTD demonstrated high reliability in older men. Voluntary RTD

was only reliable when calculated in 10 ms epochs during the first 10 ms, 80-110 ms, and

calculated as the overall RTD – all other voluntary RTD measures were unreliable in the

present study. It is possible that additional familiarization sessions are needed to improve

the reliability of voluntary RTD and/or EMD measures in older men. Alternatively, it is

possible that older men may alter the rate at which they voluntarily produce torque as a

protective mechanism or fear of injury (19), which may have caused the low reliability

for voluntary RTD.

TABLE 1. The means, standard deviations, and 95% confidence intervals for voluntary and evoked PT, RTD, and EMD.

	Variable (Units)	Trial One		Trial Two		*P*-value
		Mean (±SD)	95% CI	Mean (±SD)	95% CI	
Voluntary	PT_V (Nm)	124.9 (±26.9)	±14.9	117.3 (±26.4)	±14.6	0.067
	EMD_V VL (ms)	50.1 (±11.9)	±6.6	43.9 (±11.8)	±6.5	0.060
	$PRTD_V$ (Nm·s^{-1})	936.2 (±233.5)	±129.3	824.7 (±228.8)	±126.7	0.010*
	$RTD30_V$ (Nm·s^{-1})	270.5 (±134.0)	±134.0	265.2 (±169.9)	±94.1	0.888
	$RTD50_V$ (Nm·s^{-1})	419.9 (±176.4)	±97.7	394.6 (±211.1)	±116.9	0.653
	$RTD100_V$ (Nm·s^{-1})	574.9 (±180.5)	±99.9	534.8 (±195.4)	±108.2	0.380
	$RTD200_V$ (Nm·s^{-1})	469.8 (±89.3)	±49.4	428.5 (±101.4)	±56.2	0.034*
	Overall RTD_V (Nm·s^{-1})	419.3 (±70.0)	±38.8	390.3 (±81.6)	±45.2	0.070
Evoked	PT_E (Nm)	33.6 (±12.9)	±7.1	32.8 (±12.1)	±6.7	0.437
	EMD_E VL (ms)	24.3 (±6.2)	±3.43	25.8 (±4.3)	±2.4	0.302
	$PRTD_E$ (Nm·s^{-1})	668.4 (±202.8)	±112.3	654.5 (±203.9)	±112.9	0.299
	$RTD30_E$ (Nm·s^{-1})	314.9 (±164.3)	±91.0	323.3 (±154.4)	±85.5	0.541
	$RTD50_E$ (Nm·s^{-1})	429.6 (±175.2)	±97.0	432.6 (±175.4)	±97.1	0.826
	$RTD100_E$ (Nm·s^{-1})	369.5 (±114.4)	±63.4	363.9 (±111.1)	±61.5	0.545
	Overall RTD_E (Nm·s^{-1})	366.5 (±86.7)	±48.0	349.5 (±80.7)	±44.7	0.113

P-value = type I error rate for the one-way repeated measures ANOVA across trials one and two.
(*) Signifies that trial one was significantly greater (p<0.05) than trial two.

TABLE 2. The means, standard deviations, and 95% confidence intervals for voluntary and evoked RTD in 10 ms epochs.

	Rate of Torque Development Calculated in Nm·s⁻¹	Trial One Mean (±SD)	95% CI	Trial Two Mean (±SD)	95% CI	*P*-value
	RTD 0-10	137.4 (±86.8)	±48.1	137.2 (±105.3)	±58.3	0.995
	RTD 10-20	258.5 (±133.9)	±74.2	255.4 (±174.0)	±96.4	0.931
	RTD 20-30	415.6 (±187.5)	±103.8	402.9 (±242.6)	±134.4	0.838
	RTD 30-40	578.6 (±236.8)	±131.1	539.6 (±292.5)	±162.0	0.646
	RTD 40-50	709.4 (±268.2)	±148.5	637.8 (±296.1)	±164.0	0.427
	RTD 50-60	784.8 (±275.5)	±152.6	691.8 (±267.8)	±148.3	0.230
	RTD 60-70	801.9 (±265.4)	±147.0	716.2 (±241.1)	±133.5	0.137
	RTD 70-80	769.8 (±243.9)	±135.1	707.6 (±223.7)	±123.9	0.129
	RTD 80-90	697.8 (±212.2)	±117.5	666.7 (±202.4)	±112.1	0.295
	RTD 90-100	596.2 (±178.3)	±98.8	593.0 (±180.9)	±100.2	0.894
	RTD 100-110	484.6 (±157.2)	±87.0	499.4 (±147.5)	±81.7	0.595
Voluntary	RTD 110-120	388.6 (±155.3)	±86.0	400.7 (±108.0)	±59.8	0.735
	RTD 120-130	329.3 (±160.0)	±88.6	318.1 (±84.3)	±46.7	0.781
	RTD 130-140	313.5 (±151.3)	±83.8	267.1 (±87.3)	±48.3	0.236
	RTD 140-150	330.4 (±127.0)	±70.34	250.0 (±97.3)	±53.9	0.030*
	RTD 150-160	355.8 (±101.9)	±56.4	251.8 (±77.7)	±43.0	0.005*
	RTD 160-170	379.6 (±90.1)	±49.9	274.2 (±69.6)	±38.6	0.003*
	RTD 170-180	381.4 (±82.8)	±45.9	301.2 (±66.4)	±36.8	0.004*
	RTD 180-190	357.7 (±74.7)	±41.3	316.9 (±77.5)	±42.9	0.051
	RTD 190-200	318.2 (±65.2)	±36.1	315.5 (±88.0)	±48.8	0.790
	RTD 200-210	278.3 (±68.8)	±38.1	297.7 (±89.9)	±49.8	0.265
	RTD 210-220	237.9 (±81.8)	±45.3	267.6 (±87.5)	±48.5	0.063
	RTD 220-230	207.0 (±87.1)	±48.2	233.8 (±87.4)	±48.4	0.093
	RTD 230-240	186.1 (±103.1)	±57.1	204.3 (±90.1)	±50.3	0.352
	RTD 240-250	178.0 (±111.0)	±61.5	185.6 (±92.4)	±51.2	0.735
	RTD 0-10	155.7 (±124.8)	±69.1	165.0 (±102.6)	±56.8	0.451
	RTD 10-20	311.5 (±169.1)	±93.7	321.8 (±157.7)	±87.3	0.548
Evoked	RTD 20-30	477.5 (±214.2)	±118.6	483.1 (±212.1)	±117.5	0.769
	RTD 30-40	594.4 (±232.3)	±128.6	588.7 (±238.1)	±131.9	0.794
	RTD 40-50	608.6 (±203.6)	±112.7	604.5 (±203.5)	±112.7	0.851
	RTD 50-60	525.0 (±142.7)	±79.0	517.0 (±142.2)	±78.8	0.711
	RTD 60-70	407.5 (±99.5)	±55.1	386.6 (±91.1)	±50.4	0.326
	RTD 70-80	268.3 (±101.7)	±56.3	259.4 (±62.4)	±34.5	0.688
	RTD 80-90	206.0 (±91.2)	±49.9	185.3 (±68.2)	±37.8	0.035*
	RTD 90-100	140.7 (±96.1)	±53.2	127.4 (±85.0)	±47.1	0.536

P-value = type I error rate for the one-way repeated measures ANOVA across trials one and two.
(*) Signifies that trial one was significantly greater (p<0.05) than trial two.

TABLE 3. Absolute and normalized reliability for PT, EMD, and RTD.

	Voluntary			Evoked		
	$ICC_{2,k}$	SEM	CV	$ICC_{2,k}$	SEM	CV
PT (Nm)	0.887	10.5	8.7%	0.974	2.87	8.7%
EMD (ms)	0.596	8.3	17.6%	0.625	3.93	5.4%
PRTD (Nm·s^{-1})	0.799	102.9	11.7%	0.984	35.45	15.8%
RTD30 (Nm·s^{-1})	0.746	101.4	37.9%	0.975	36.59	11.5%
RTD50 (Nm·s^{-1})	0.598	150.8	37.0%	0.980	37.3	8.7%
RTD100 (Nm·s^{-1})	0.742	121.3	21.9%	0.977	25.03	6.8%
RTD200 (Nm·s^{-1})	0.786	48.2	10.7%			
Overall RTD (Nm·s^{-1})	0.793	39.7	9.8%	0.943	27.91	8.1%

$ICC_{2,k}$ = Intraclass correlation coefficient; model 2,k (Shrout and Fleiss, 1979)

SEM = Standard error of the measurement

CV = Coefficient of variation; calculated as a normalized measure of SEM

TABLE 4. Absolute and normalized reliability for RTD calculated in 10 ms epochs.

	Voluntary			Evoked		
	$ICC_{2,k}$	SEM	CV	$ICC_{2,k}$	SEM	CV
RTD 0-10 (Nm·s⁻¹)	0.878	47.6	34.6%	0.959	32.8	29.2%
RTD 10-20 (Nm·s⁻¹)	0.776	98.1	38.2%	0.962	45.9	28.6%
RTD 20-30 (Nm·s⁻¹)	0.614	166.6	40.7%	0.975	50.4	24.1%
RTD 30-40 (Nm·s⁻¹)	0.454	227.1	40.6%	0.972	58.9	25.5%
RTD 40-50 (Nm·s⁻¹)	0.449	239.8	35.6%	0.962	59.0	29.5%
RTD 50-60 (Nm·s⁻¹)	0.594	203.1	27.5%	0.919	58.2	41.6%
RTD 60-70 (Nm·s⁻¹)	0.761	148.7	19.6%	0.789	56.3	59.7%
RTD 70-80 (Nm·s⁻¹)	0.866	105.5	14.3%	0.693	59.6	71.8%
RTD 80-90 (Nm·s⁻¹)	0.922	78.1	11.5%	0.925	24.3	30.7%
RTD 90-100 (Nm·s⁻¹)	0.939	64.9	10.9%	0.762	57.7	64.5%
RTD 100-110 (Nm·s⁻¹)	0.875	74.6	15.2%			
RTD 110-120 (Nm·s⁻¹)	0.679	96.3	24.4%			
RTD 120-130 (Nm·s⁻¹)	0.480	107.9	33.3%			
RTD 130-140 (Nm·s⁻¹)	0.460	102.4	35.3%			
RTD 140-150 (Nm·s⁻¹)	0.399	91.0	31.4%			
RTD 150-160 (Nm·s⁻¹)	0.263	81.0	26.1%			
RTD 160-170 (Nm·s⁻¹)	0.179	74.2	22.4%			
RTD 170-180 (Nm·s⁻¹)	0.346	59.6	17.4%			
RTD 180-190 (Nm·s⁻¹)	0.644	50.0	14.8%			
RTD 190-200 (Nm·s⁻¹)	0.782	48.6	15.2%			
RTD 200-210 (Nm·s⁻¹)	0.796	45.9	57.9%			
RTD 210-220 (Nm·s⁻¹)	0.828	40.4	47.8%			
RTD 220-230 (Nm·s⁻¹)	0.847	40.6	46.8%			
RTD 230-240 (Nm·s⁻¹)	0.837	51.7	53.9%			
RTD 240-250 (Nm·s⁻¹)	0.814	59.6	59.4%			

$ICC_{2,k}$ = Intraclass correlation coefficient; model 2,k (Shrout and Fleiss, 1979)

SEM = Standard error of the measurement

CV = Coefficient of variation; calculated as a normalized measure of SEM

FIGURE 1. Intraclass correlation coefficients for voluntary and evoked PT, EMD, and RTD. The error bars represent the ±95% confidence intervals associated with the intraclass correlation coefficient for each dependent variable.
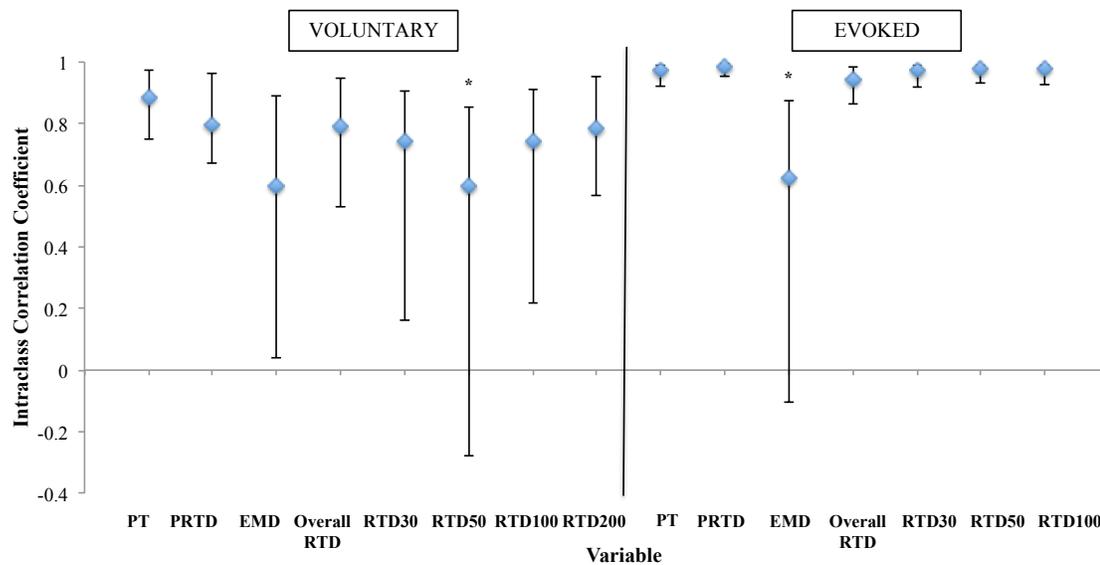
[*] 95% confidence interval indicates that the intraclass correlation coefficient is no greater than zero.

FIGURE 2. Intraclass correlation coefficients for voluntary (solid line) and evoked (dashed line) RTD calculated in 10 ms epochs. The error bars represent the ±95% confidence intervals associated with the intraclass correlation coefficient for each dependent variable.
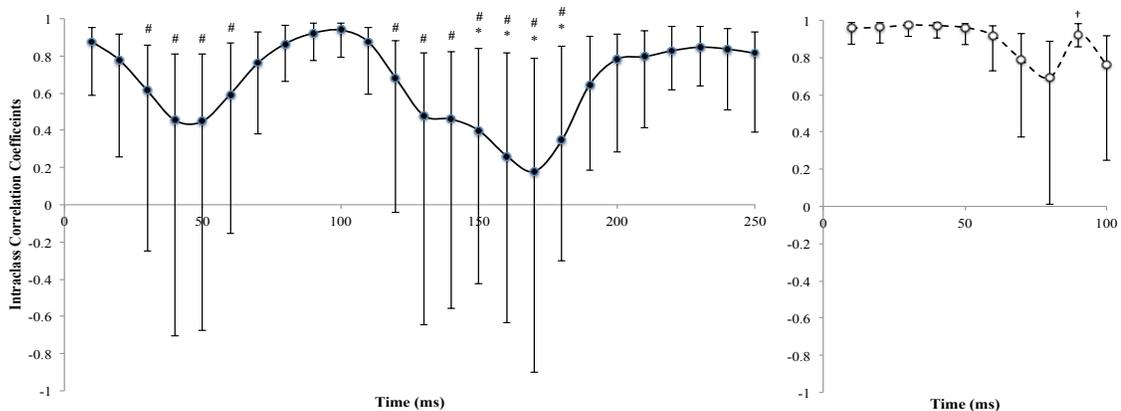
†Systematic variability (trial one > trial two; p<0.05) for evoked RTD
*Systematic variability (trial one > trial two p<0.05) for voluntary RTD
#95% confidence interval indicates that the intraclass correlation coefficient is no greater than zero.

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APENDIX A

Glossary

PT peak torque

EMD electromechanical delay

RTD rate of torque development

ICC interclass correlation coefficient

SEM standard error of the measurement

CV coefficient of variation

Nm   newton meters

Nm·s^{-1} newton meters per second

ms milliseconds

APPENDIX B

UNIVERSITY OF Nebraska Lincoln

Human Performance Laboratory
Center for Youth Fitness and Sports Research
Department of Nutrition and Health Sciences
110 Ruth Leverton Hall
University of Nebraska-Lincoln
Lincoln, NE 68583-0806

Director: Joel T Cramer, Ph.D.

Statement of Informed Consent

Title of Research Study

Test-retest reliability of voluntary and evoked muscle actions to study neuromuscular function in the elderly

Invitation to Participate
You are invited to participate in this research study. The following is provided in order to help you make an informed decision whether or not to participate. If you have any questions, please do not hesitate to ask.

Basis for Subject Selection
You were selected as a potential volunteer because you are between the ages of 19 and 29 You were selected as a potential volunteer because you are aged 65 years or older and in good health. If you wish to participate you must fill out a health history questionnaire. You will also fill out a nutritional status survey and risk of falls assessment form. You will be prevented from participating in this research study if there are indications from the health history questionnaire that you may have health risks. Such indications include symptoms suggestive of chest pain, breathing difficulties, irregular heart beat, kidney or liver problems, high blood pressure or cholesterol, and/or abnormal electrocardiogram (EKG). Muscle or skeletal disorders including previous or current ankle, knee, and/or hip injuries may also preclude you from participation in this study. A pacemaker or metal implant in either hip may also preclude you from participation in this study. You are also being asked to provide consent for the investigators to send a Medical Clearance form to your attending physician for physician's clearance. By signing this document you are also consenting to allow the investigators to request medical clearance from your physician. If you have no muscle/skeletal disorders or disease that will prevent you from engaging in physical activity and your doctor has provided consent, you will be asked to perform the physical tests described below. Overall, there are numerous health-related issues that may preclude you from participation in this study and inclusion will be determined on a subject-by-subject basis.

Purpose of the Study
The purpose of this research study is to examine the reliability of measures of leg muscle strength, hand-grip strength, and balance. This study will also assess your nutritional

status and risk of falls through the use of two short surveys. These measurements have significant implications in the elderly and have been associated with risk of falls and overall functional status. They are also used as outcome measures in clinical settings. You are being asked to participate because we need a sufficient number of subjects to calculate the reliability statistics.

Explanation of Procedures

- You will be asked to visit the Exercise Physiology Laboratory located in Ruth Leverton Hall (Room 211) on the UN-L East campus on three separate days, separated by 48 – 72 hours. Visit 1 will consist of deciding if you want to participate in the current study, reading the informed consent, filling out and completing a health history questionnaire, and completing a nutritional status assessment and risk of falls assessment surveys. This is the only time you will have to complete these documents. The information you provide on the health history questionnaire may disqualify you as a participant. You will then complete the following procedures on visits 2 and 3.

- After "final" eligibility is determined, visits 2 and 3 will be scheduled and will include the following assessments:

  o Thigh skinfold thickness and thigh circumference.

  o Hand-grip strength will be measured 3 times with a common handgrip dynamometer with 30 seconds rest between trials.

  o The "Functional Reach Test," where the you will stand next to a wall with your arm held out in front of you. You will then reach as far as possible without taking a step. This is a measure of balance. The farther you can reach, the better your balance (which is associated with a lower risk of falls).

  o Sensor's will be placed on the skin of the thigh. In order for the readings from these sensors to be accurate, the areas on the skin must be shaved, dead skin rubbed off, and the area cleansed with rubbing alcohol. If you feel it is uncomfortable for the investigator to shave your thigh, you may request to shave it on your own. These sensors will record muscle activity during the leg extension exercises described below.

  o A 5-min warm-up on a treadmill, walking at 3.0 miles per hour.

  o After the warm-up, you will be seated on a strength-measuring device called an "isokinetic dynamometer," which is commonly used in physical therapy clinics. Straps will be placed across your chest, hips, thigh, and ankle to avoid extraneous movements during the strength tests. A second warm-up will be completed by practicing the leg extension exercises at

25%, 50%, 75%, and 100% of your best effort. You will then be asked to perform leg extension exercises as hard and fast as possible 3 times to measure strength where the machine will not move and 6 times for strength where the machine will allow movement of the leg. One minute of rest will be allowed among these trials. This machine will not add weight to your leg, rather it only tests the strength of your effort.

o   Electrical stimulation will be used to make your thigh muscles contract. About 60-80 stimulated contractions - with about 10 seconds rest between each - will be performed during lab visits 2 and 3. The exact number of contractions is based on your individual response to the electrical stimuli. A small electrical current will be used at first, then the current will be increases in a stepwise fashion to determine the minimal current necessary for a maximal twitch contraction. The machine will measure your strength during these stimulated contractions the same way it is measured during the contractions from your own efforts. After the optimal electrical current is determined, 9 electrically-stimulated leg extensions will be performed with 10 seconds rest between each where the machine will not move, and 18 electrically-stimulated leg extensions will be performed with 10 seconds rests between each where the machine will be allowed to move. The electrical stimulations will be applied to the femoral nerve at the top of the thigh. The electrical stimulation will be delivered using a single stimulus, a doublet stimulus, and a triplet stimulus. The differences between these stimuli are the frequency at which they are delivered, but you will not be able to tell the difference, other than the stimulus "intensity." The sensation of the electric stimulation is often described as a hard "flick" to the skin or a stern tendon tap. Electrical stimulation is also something that is used in physical therapy and rehab clinics. Furthermore, the Digitimer DS7AH (Herthfordshire,UK) that we will be using is FDA approved for use on humans (this is not a study on the equipment, rather the reliability of the properties of skeletal muscle as measured by evoked muscle actions).

Total Time Commitment

The total time commitment for the 3 visits in this study will be approximately 3 to 5 hours with each visit lasting approximately 1 to 1.5 hours. Visits 1 and 2 will be separated by 24-48 hours and visits 2 and 3 will be separated by a minimum of 48 hours and visits 2 and 3 must be completed within 72 hours from the start of visit 2. The visits will be scheduled as follows; visit 1: Screening, Informed Consent, Health History Questionnaire, and assessment surveys (1.0 hours), visit 2: exercise protocol (1.5 hours), visit 3: exercise protocol (1.5 hours).

Potential Risks and Discomforts
The following are the potential risks and discomforts you may experience during this study:

- Electrode Preparation and Use – The use of electrodes and the preparation of the skin for their application may lead to the remote possibility of complications such as a rash or infection.

- You may experience a slight discomfort (like a stern finger flick) from the muscle stimulation. You may experience minor skin irritation and redness from the shaving, rubbing, and alcohol cleansing. Finally, you may experience very minor muscle soreness from the leg contractions.
- There are no known risks associated with this project that are greater than those ordinarily encountered in rehabilitative settings.

- Heavy exercise can cause high or low blood pressure, fainting, irregular heart rhythm, chest pain, and very rarely, heart attack, stroke or cardiac arrest. The need for hospital admission is reported in less than six of every 10,000 exercise tests. Cardiac arrest is reported in less than one of every 10,000 exercise tests.

Protection Against Risks
To minimize any potential risks and/or discomforts, you will be given instructions for special stretches, which may aid in the elimination of any muscle soreness as a result of the tests. In addition, you will be asked repeatedly during the tests how you feel in relation to your ability to continue the test. Throughout all the tests, you will be monitored by laboratory personnel trained in Cardiopulmonary Pulmonary Resuscitation (CPR) and use of an Automated External Defibrillator (AED). In addition, you will be asked repeatedly if you feel you can continue the tests.

Potential Benefits to Subjects
You will be helping to advance the understanding of testing procedures used to commonly measure strength in the exercise physiology field. You may also gain an understanding of these testing results and procedures for your own benefit. Finally, a report will be provided to you that includes your heart rate, blood pressure, body mass index (BMI), handgrip and leg extensor strength, risk of falls status, and nutritional status. You may give this report to your doctor to provide a more comprehensive snapshot of your health. However, this report is not to be used for diagnosis or treatment.

Subject Compensation
You will receive a $50 stipend for completing the study. You will be paid at the completion of visit 2 and 3 and completion of the first visit will not result in compensation. The final two visits are worth $25 each. You will be paid in cash.

In Case of Emergency Contact Procedures
If you are injured while you are in Ruth Leverton hall during your participation in the study, inform one of the investigators who will contact a local health care provider. You may (and should) always contact any of the investigators listed at the end of this consent form if you have any questions.

Medical Care in Case of Injury
In the unlikely event that you should suffer an injury as a direct consequence of the research procedures described above, the acute medical care required to treat the injury

will be provided by the local community health care providers or your personal health care provided. The cost of such medical care will be the responsibility of the subject.

Assurance of Confidentiality
Any information obtained from this study that could identify you will be kept strictly confidential. The information may be published in scientific journals or presented at scientific meetings, but your identity will be kept strictly confidential. All data collected as a result of your participation will be kept in a locked cabinet in the office of the primary investigator (Room 211 Ruth Leverton Hall). Your data will receive an identifying number and only the investigators will be able to identify you from your data. Your data will be compiled and only group data will be used for dissemination without identifying your name. For the purposes of future reference, your data will be stored for a minimum of 15 years.

Rights of Research Subjects

You may ask any questions concerning this research and have those questions answered before agreeing to participate in or during the study. Or you may call the investigator, Nathaniel Jenkins, at any time, (267) 987-9208. You may also contact Dr. Joel Cramer at his office phone, (402) 472-7533. Please contact the investigator:

- if you want to voice concerns or complaints about the research

- in the event of a research related injury.

Please contact the University of Nebraska-Lincoln Institutional Review Board at (402) 472-6965 for the following reasons:

- you wish to talk to someone other than the research staff to obtain answers to questions about your rights as a research participant

- to voice concerns or complaints about the research

- to provide input concerning the research process

- in the event the study staff could not be reached.

Voluntary Participation Withdrawal
You are free to decide not to participate in this study, or to withdraw at any time without adversely affecting your relationship with the investigators or the University of Nebraska. Your decision will not result in any loss of benefits to which you are otherwise entitled.

You are voluntarily making a decision whether or not to participate in this research study. Your signature certifies that the content and meaning of the information on this consent form have been fully explained to you and that you have decided to participate having read and understood the information presented. Your signature also certifies that you have had all your questions answered to your satisfaction. If you think of any questions

during this study, please contact the investigators. You will be given a copy of this consent form to keep.

_____   _____
Signature of Research Participant   Date

_____
Printed name of Research Participant

My signature as witness certifies that the subject signed this consent form in my presence as his/her voluntary act and deed.

_____   _____
Signature of Investigator   Date

Investigators:

    Nathaniel Jenkins   work phone   (402) 472-2690
                                        home phone   (267) 987-9208

    Joel Cramer   work phone   (402) 472-7533
                                          home phone   (402) 405-4345

PRE-EXERCISE TESTING HEALTH STATUS QUESTIONNAIRE

Subject Number   _____   Date

_____

Work Phone   _____   Home Phone_____

_____

Birthday (mm/dd/yy)____/_____/_____

Person to contact in case of emergency _____Emergency Contact
Phone_____

Personal Physician   _____   Physician's Phone_____

Gender_____   Age _____(yrs)   Have you gained or lost weight over the past year?
Yes / No

                           If yes, how much? _____

Do you currently have a pacemaker? (YES/NO) _____
Do you have metal in your hip (hip replacement)? (YES/NO) _____

A.   **JOINT-MUSCLE STATUS** (✓Check areas where you currently have problems)

Joint Areas	Muscle Areas
( ) Wrists	( ) Arms
( ) Elbows	( ) Shoulders
( ) Shoulders	( ) Chest
( ) Upper Spine & Neck	( ) Upper Back & Neck
( ) Lower Spine	( ) Abdominal Regions
( ) Hips	( ) Lower Back
( ) Knees	( ) Buttocks
( ) Ankles	( ) Thighs
( ) Feet	( ) Lower Leg
( ) Other_____	( ) Feet
	( ) Other_____

B.   **HEALTH STATUS** (✓Check if you previously had or currently have any of the
             following conditions)

( ) High Blood Pressure	( ) Acute Infection
( ) Heart Disease or Dysfunction Abnormality	( ) Diabetes or Blood Sugar Level
( ) Peripheral Circulatory Disorder	( ) Anemia
( ) Lung Disease or Dysfunction	( ) Hernias
( ) Arthritis or Gout	( ) Thyroid Dysfunction
( ) Edema	( ) Pancreas Dysfunction
( ) Epilepsy	( ) Liver Dysfunction
( ) Multiply Sclerosis	( ) Kidney Dysfunction

( ) High Blood Cholesterol or   ( ) Phenylketonuria (PKU)
      Triglyceride Levels   ( ) Allergic Reactions to Medication
( ) Loss of Consciousness   please
      describe_____
( ) Others That You Feel We Should Know   ( ) Allergic Reactions to Any Other
      substance About_____   please
      describe_____
( ) Pregnant

C.   PHYSICAL EXAMINATION HISTORY

Approximate date of your last physical
examination_____

Physical problems noted at that
time_____

Has a physician ever made any recommendations relative to limiting your level of
physical exertion?   _____YES   _____NO
If YES, what limitations were
recommended?_____

_____

_____

Have you ever had an abnormal resting electrocardiogram (ECG)?
_____YES_____NO

D.   CURRENT MEDICATION USAGE (List the drug name and the condition being managed)

MEDICATION	CONDITION
_____	
	_____
_____	
	_____
_____	
	_____

E.   PHYSICAL PERCEPTIONS (Indicate any unusual sensations or perceptions. ✓Check if you have recently experienced any of the following during or soon after *physical activity* (PA); or during *sedentary periods* (SED))

PA	SED		PA	SED	
( )	( )	Chest Pain	( )	( )	Nausea
( )	( )	Heart Palpitations "fast irregular heart beats"	( )	( )	Light Headedness

( )　( ) Unusually Rapid Breathing　　　　　( )　( ) Loss of
Consciousness
( )　( ) Overheating　　　　　　　　　　　( )　( ) Loss of Balance
( )　( ) Muscle Cramping　　　　　　　　　( )　( ) Loss of
Coordination
( )　( ) Muscle Pain　　　　　　　　　　　( )　( ) Extreme
Weakness
( )　( ) Joint Pain　　　　　　　　　　　　( )　( )
Numbness
( )　( ) Mental Confusion
( )　( ) Other_____　( )　( ) Pacemaker

F.　**FAMILY HISTORY** (✓Check if any of your blood relatives . . . parents, brothers, sisters, aunts, uncles, and/or grandparents . . . have or had any of the following)

( ) Heart Disease
( ) Heart Attacks or Strokes (prior to age 50)
( ) Elevated Blood Cholesterol or Triglyceride Levels
( ) High Blood Pressure
( ) Diabetes
( ) Sudden Death (other than accidental)

G.　**CURRENT HABITS** (✓Check any of the following if they are characteristic of you current habits)

( ) Smoking. If so, how many per day? _____
( ) Regularly does manual garden or yard work
( ) Regularly goes for long walks　Hours per week?_____
( ) Frequently rides a bicycle　　　　Hours per week?_____
( ) Frequently runs/jogs for exercise　Hours per week?_____
( ) Regularly participates in a weight training exercise program Hours per week?_____
( ) Engages in a sports program more than once per week. If so, what does the program consist of?

_____

E.　**FALL HISTORY** (✓Check the statement which best describes the number of falls you have experienced in the past year)

( ) No falls in the past 12 months
( ) One fall in the past 12 months
( ) Two falls in the past 12 months
( ) Three or more falls in the past 12 months

If you experienced a fall, were there any resulting injuries (Yes/No)? _____
If Yes, was hospitalization required (Yes/No)? _____

Department of Nutrition and Health Science - University of Nebraska-Lincoln

Test-retest reliability of voluntary and evoked muscle actions to study neuromuscular function in the elderly.

To the Attending Physician of: _____

This individual has indicated that he wishes to participate in a research study investigating the reliability of voluntary and evoked muscle actions to study neuromuscular function in elderly men. This project has been approved by the Institutional Review Board at the University of Nebraska-Lincoln.

Description of the Study

The purpose of this research study is to examine the reliability of voluntary and electrically-stimulated leg muscle strength, hand-grip strength, and balance measures in older men. These measures are often used as outcome variables in studies of muscle function in the elderly (1,2) and in clinical trials (3). However, the reliability of these measures are not often reported, especially in the elderly. Furthermore, it is the goal of our lab to establish test-retest reliability of our common measurements for use in future studies and clinical trials.

This study will consist of three visits to the laboratory, separated by 48-72 hours. During visit one, participants will complete a "Mini Nutritional Assessment" and a survey assessing their risk of falls, along with the procedures outlined below. During each subsequent visit, the procedures outlined below will be performed. Prior to the beginning of the assessments, electromyography (EMG) and mechanomyography (MMG) sensors will be placed on the skins surface of the vastus lateralis muscle and on the tibial tuberosity, which will be used to assess neuromuscular function. Our lab has previously performed and published these procedures and no one to date has reported any deleterious side-effects.

Body Composition Assessment:

- A skin fold and circumference measurement of the thigh will be taken.

Balance Assessment

- Subjects will perform the "Functional Reach Test," where the subject will stand next to a wall with their arm held out in front of them. They will then reach as far as possible without taking a step. This is a measure of balance.

Strength Assessments:

- Hand-grip strength will be measured 3 times with a common handgrip

dynamometer with 30 seconds rest between trials.

- Sensor's will be placed on the skin of the thigh. In order for the readings from these sensors to be accurate, the areas on the skin must be shaved, dead skin rubbed off, and the area cleansed with rubbing alcohol (see attached picture). These sensors will record muscle activity during the leg extension exercises described below.

- A 5-min warm-up on a treadmill, walking at 3.0 miles per hour.

- After the warm-up, subjects will be seated on a strength-measuring device called an "isokinetic dynamometer," which is commonly used in physical therapy clinics. Straps will be placed across their chest, hips, thigh, and ankle to avoid extraneous movements during the strength tests. A second warm-up will be completed by practicing the leg extension exercises at 25%, 50%, 75%, and 100% of their best effort. Subjects will then be asked to perform leg extension exercises as hard and fast as possible 3 times for "static" strength where the machine will not move, but strength will be recorded, and 6 times for "dynamic" strength where the machine will allow movement of the leg throughout the range of motion. One minute of rest will be allowed among these trials. This machine will not add weight to their leg, rather it only tests the strength of their effort.

- Electrical stimulation will be used to make the subject's thigh muscles contract. About 60-80 stimulated contractions - with about 10 seconds rest between each - will be performed during lab visits 2 and 3. The exact number of contractions is based on each individual's response to the electrical stimuli. A small electrical current will be used at first, then the current will be increases in a stepwise fashion to determine the minimal current necessary for a maximal twitch contraction. The machine will measure their strength during these stimulated contractions the same way it is measured during the contractions from the subject's own efforts. After the optimal electrical current is determined, 9 "static" electrically-stimulated leg extensions will be performed with 10 seconds rest between each (machine will not move), and 18 "dynamic" electrically-stimulated leg extensions will be performed with 10 seconds rests between each (machine will be allowed to move). The electrical stimulations will be applied to the femoral nerve at the top of the thigh. The electrical stimulation will be delivered using a single stimulus, a doublet stimulus, and a triplet stimulus. The differences between these stimuli are the frequency at which they are delivered, but the subject will not be able to tell the difference, other than the stimulus "intensity." The sensation of the electric stimulation is often described as a hard "flick" to the skin or a stern tendon tap. Electrical stimulation is also something that is used in physical therapy and rehab clinics. Furthermore, the Digitimer DS7AH (Herthfordshire,UK) that we will be using is FDA approved for use on humans (this is not a study on the equipment, rather the reliability of the properties of skeletal muscle as measured by evoked muscle actions)..

Please advise the investigators regarding any physical limitations and/or contraindications that this patient might have from engaging in this exercise study.

Participants will not be allowed to participate (exclusion criteria) in this study if they:

1.) have any orthopedic problems (e.g., previous surgery, joint replacements, etc.) or previously diagnosed neuromuscular disease that will prevent them from participating in the strength or flexibility assessment session or;
2.) have any absolute or relative contraindication for exercise testing as outlined by the American College of Sports Medicine (provided below):

Absolute Contraindications to Exercise Testing (check all that applies)
- ❑ A recent significant change in the resting ECG suggesting significant ischemia, recent MI or other acute cardiac event
- ❑ Unstable angina
- ❑ Uncontrolled cardiac dysrhythmias causing symptoms or hemodynamic compromise
- ❑ Symptomatic severe aortic stenosis
- ❑ Uncontrolled symptomatic heart failure
- ❑ Acute pulmonary embolus or pulmonary infarction
- ❑ Acute myocarditis or pericarditis
- ❑ Suspected or known dissecting aneurysm
- ❑ Acute systemic infection, accompanied by fever, body aches, or swollen lymph glands

Relative Contraindications to Exercise Testing (check all that applies)
- ❑ Left main coronary stenosis
- ❑ Moderate stenotic valvular heart disease
- ❑ Electrolyte abnormalities (e.g. hypokalemia, hypomagnesemia)
- ❑ Severe arterial hypertension (i.e. SBP>200 and/or DBP >110) at rest
- ❑ Tachydysrhythmia or bradydysrhythmia
- ❑ Hypertrophic cardiomyopathy and other forms of outflow tract obstruction
- ❑ Neuromuscular, musculoskeletal, or rheumatoid disorders that are exacerbated by exercise
- ❑ High-degree atrioventricular block
- ❑ Ventricular aneurysm
- ❑ Uncontrolled metabolic disease (e.g., diabetes, thyrotoxicosis, or myxedema)
- ❑ Chronic infectious disease (e.g., mononucleosis, hepatitis, or AIDS)
- ❑ Mental or physical impairment leading to inability to exercise adequately

Pertaining to the above mentioned patient, I advise the following:

☐ To my knowledge, there is no reason why this patient should not be allowed to participate in this study.

☐ I recommend that this patient be allowed to participate in the study with the following restrictions:_____
_____

_____
_____

☐ I recommend that this patient should **not** be allowed to participate in the study for the following reasons:_____
_____

_____
_____

Physician's Name (Printed) _____

Date_____

Physician's Signature _____

If you have any questions about this form, please contact: Nathaniel D.M. Jenkins, Graduate Assistant, at **Phone: 267-987-9208, Email: nathaniel.jenkins@unl.edu**