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AGE AND GENDER DIFFERENCES IN HIP EXTENSION AND FLEXION TORQUE STEADINESS

by

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AGE AND GENDER DIFFERENCES IN HIP EXTENSION AND FLEXION TORQUE STEADINESS

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PHYSICAL EDUCATION

Abstract

Purpose of this study was to compare age and gender differences in hip extension (HE) and flexion (HF) relative (5, 25, and 50% of maximal voluntary contraction [MVC]) and absolute (25 Nm) torque steadiness measured as standard deviation (SD) and coefficient of variation (CV) of torque fluctuations, and torque accuracy (TA). MVC and steadiness were assessed for 20 young (24.0 ± 2.2 yrs) and 11 older (65.4 ± 4.5 yrs) men and women. MVC was lower for HF, but HE had greater torque fluctuations. For HE, CV of 5% MVC was greater for older compared to young adults and women compared to men ($p < 0.05$). For both HE and HF older were less accurate (higher TA) than young adults at 25 Nm. Results indicate age-related decline in torque steadiness especially at lower relative target torque levels in the HE. There were no age or gender differences for the HF.

Key Words: maximal voluntary contraction, strength, elderly

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Introduction

Aging is commonly associated with sarcopenia (i.e., muscle atrophy) characterized as a decline in muscle strength and performance (Buchner & de Lateur, 1991, Faulkner et al., 2007). Such reduction in muscular function may account for age related decrements in postural stability and functional tasks like walking and stair climbing. Torque steadiness for knee extension has been previously reported as being one of the independent predictors for functional performance in older women (Seynnes et al., 2005). Steadiness of submaximal isometric contractions is a measure of muscle torque control assessed by measuring the standard deviation (SD) or coefficient of variation (CV) of torque fluctuations about some target torque level (Enoka et al., 2003). Another way to quantify steadiness is torque accuracy (TA), which is the difference between target constant torque level and actual mean torque of the data (Seynnes et al., 2005; Hortobagyi et al., 2001). There have been only a few lower extremity muscle groups studied examining torque steadiness. Previous investigations have examined torque steadiness of the first dorsal interosseus (Burnet et al., 2000, Laidlaw et al., 2000), elbow flexors (Tracy et al., 2002, Lavander & Nosaka, 2007), knee extensors (Carville et al, 2007, Manini et al., 2005, Welsh et al., 2007), and ankle plantar and dorsiflexor muscles (Tracy, 2007, Patten & Kamen, 2000, Shinohara et al., 2003). Hip muscle function is crucial for many types of activities of daily living and may be important for postural stability and dynamic balance. The literature describes two prominent strategies for maintaining postural stability: ankle and hip strategy (Nashner, 1977, O`Sullivan 2001, Horak & Nashner, 1986). The ankle strategy explained by Nashner equalizes small changes in the center of mass (COM) position and slow body sway motions while hip strategy is characterized by adapting changes in the COM positioning and faster body sway motions (Nashner, 1977). This strategy involves early activation of the hip musculature followed by activation of distal limb muscles. Stepping movements utilize the hip strategy (O`Sullivan, 2001). Therefore, torque control in hip musculature would appear important for maintaining dynamic postural stability for everyday functional tasks. Examination of torque steadiness in the hip musculature could provide valuable information about the capabilities of older compared to young adults. Despite its potential importance, to our knowledge, no studies have investigated torque steadiness in the hip joint.

Torque fluctuation amplitude is affected by the muscle contraction type, muscle contraction intensity, the physical activity level of the individual, and the muscle group performing the task (Enoka et al., 2003, Tracy 2007). In previous studies the amplitude of the fluctuations has been found to differ between young and older adults (Burnett et al., 2000, Enoka et al., 1999, Tracy, 2007), however, this is not a consistent finding (Carville et al, 2007, Lavander & Nosaka, 2007, Manini et al., 2005, Tracy, 2007). When there is a difference in the amplitude of the torque fluctuations between young and old adults, it is greatest at low forces (Enoka et al., 2003, Tracy 2007), with age difference affecting torque fluctuations at target levels smaller than 10% of MVC (Tracy 2007) for the first dorsal interosseus (Laidlaw 2000, Tracy 2005), knee extensors (Tracy& Enoka 2002), and ankle plantar and dorsiflexors (Tracy, 2007).

The intensity of muscle contraction and the muscle group performing a task have been associated with torque fluctuation amplitude (Enoka et al., 2003). In a recent study

Tracy (2007) reported that women, as compared to men, have 25% lower MVC for ankle dorsiflerxors and 24% lower MVC for plantarflexors. Tracy (2007) also reported greater torque fluctuations in ankle dorsiflexor than plantarflexor muscle contractions. Decreases in torque fluctuations have been shown to occur with strength training (Manini et al., 2006). Since torque capacity of the hip extension (HE) is typically greater than hip flexion (HF) (Oatis, 2004), torque steadiness between HE and HF may be different during isometric contractions. The majority of previous investigations combined genders in reporting data; we are interested to investigating gender differences between young and older men and women to better understand gender and age impact on torque steadiness during HE and HF.

Major movements at the hip joints involve the activation and coordination of multiple HE (gluteus maximus and all hamstrings except biceps femoris short head) and HF (iliopsoas, tensor fascia latae, rectus femoris, sartorius, and adductors) muscles as compared to joints that have previously been investigated. Multiple muscle activation of these movements may result in higher level of torque fluctuations as compared to joint movements previously investigated that employed fewer activated muscles. Most previous studies have compared torque steadiness in terms of relative strength (percent of MVC). We are interested in investigating age and gender related differences in steadiness during both relative and absolute loads of isometric HE and HF contractions.

The purpose of this study is to compare torque steadiness in terms of relative (5, 25, and 50% MVC), and absolute strength (25 Nm) of the HE and HF in young and older men and women. Based on previous research the first hypothesis is that older adults exhibit greater torque fluctuations (less steady) during constant voluntary isometric contractions while attempting to control submaximal absolute and relative torque of HE and HF muscles. Second, we predict lack of significant gender differences for contractions at the same relative strength, but expect females to be less steady at the absolute strength of 25 Nm. Thirdly, we hypothesize that HE muscles will exhibit less age and gender related torque fluctuations than HF.

Literature Review

Aging is commonly associated with sarcopenia (i.e., muscle atrophy) characterized as a decline in muscle strength and performance (Buchner & de Lateur, 1991; Lin & Woollacott, 2005; Faulkner et al., 2007). Neuromuscular abilities have also been reported to decrease with aging (Whipple et al., 1993). Such reduction in muscular function may account for age related decrements in postural stability and functional tasks like walking, stair climbing, and standing, and increased risk of falling. Most of these daily activities require not only muscular strength and neuromuscular control, but also visual-motor control. One method to estimate control of motor task performance is to measure torque steadiness during voluntary isometric contractions (Laidlaw et al., 2000). Torque steadiness for knee extension has been previously reported as being one of the independent predictors for functional performance in older women (Seynnes et al., 2005). Steadiness of submaximal isometric contractions is a measure of muscle torque control assessed by measuring the fluctuations (standard deviations or coefficient of variation) while an individual is attempting to exert constant torque to match a particular torque target level. Hip muscle function, however, is crucial for many types of activities of daily living and may be important for postural stability and dynamic balance. Therefore, torque control in hip musculature would appear important for maintaining dynamic postural stability for everyday functional tasks. Since none of the previous studies on torque steadiness have examined hip musculature, assessment of torque steadiness in the hip musculature would provide valuable information about the capabilities of older compared to young adults. This review of literature could provide an overview of the previous research on torque steadiness. A brief section on methodology of research will cover different musculature and joint movements that have been assessed for torque steadiness in previous studies. This review will also summarize age and gender differences and discuss possible explanations of controversy in previous research.

Measure of Torque Steadiness

Torque exerted during isometric contractions is not constant but rather fluctuates about an average value (Enoka, 1997; Enoka et al., 2003; Tracy, 2007; Welsh et al., 2007). The variability of these torque fluctuations can be expressed in absolute terms as a standard deviation (SD) of torque fluctuations about the line of best fit through the data or in relative terms as coefficient of variation (CV) ([SD/mean torque] X 100) of the torque fluctuations about the actual mean torque (Burnett et al., 2000; Galanski et al., 1993; Laidlaw et al., 1999; Manini et al., 2005; Enoka et al., 2003; Tracy et al., 2002; Schiffman et, al., 2002; Slifkin et al., 1999). Another way to quantify fluctuation variability is as torque accuracy (TA), which is a difference between target constant torque level and actual mean torque of the data (Seynnes et al., 2005; Hortobagyi et al., 2001). To assess a desired target torque level, researchers use either relative strength (a certain percentage of subject's maximal voluntary contraction) for a particular muscle group (Carville et al., 2005; Carville et al, 2007; Christou & Carlton, 2001; Tracy, 2007; Tracy & Enoka, 2002) or compare torque steadiness in terms of absolute strength (Hortobagyi et al., 2001; Christou et al., 2002).

Relationships to Functional Tasks

Few studies have addressed the direct relationship between submaximal torque steadiness and functional performance tasks and they employed only torque steadiness for knee extension to predict steadiness correlation to functional performance tasks. Manini et al. (2005) examined functionally limited older adults (22 women and 2 men, 74.6 ± 7.6 yrs) who displayed difficulty performing everyday functional tasks. Criteria for functional limitations were not clearly defined. In response to resistance and functional training, no changes were found in torque fluctuations during submaximal isometric contractions for knee extensors. Seynnes et al. (2005) tested 19 older women (77.9 ± 1.2 yrs) and reported isometric torque steadiness to be a significant independent predictor of chair-rise time and stair climbing, accounting for 63% and 34 % of the variance in these variables, respectively. Walking endurance (6 min walk test) was not directly related to torque steadiness, however, it was related to muscle strength, and increases in strength with exercise training have previously been reported to increase both absolute (Hortobagyi et al., 2001) and relative torque steadiness (Keen et al., 1994; Laidlaw et al., 1999; Patten, 2000).

Musculature and Joint Movements

Torque steadiness has been previously assessed for different upper and lower body musculature and joint movements: the first dorsal interosseus (Burnet et al., 2000; Enoka et al., 1999; Semmler et al., 2000), elbow flexors (Tracy et al., 2002; Graves et al., 2000; Lavander and Nosaka, 2006, 2007), knee extensors (Carville et al., 2005; Carville et al, 2007; Christou et al., 2002; Manini et al., 2005; Tracy & Enoka, 2000; Welsh et al., 2007), and ankle plantar and dorsiflexor muscles (Tracy, 2007; Patten & Kamen, 2000; Shinohara et al., 2003).

Early studies mainly examined torque steadiness during submaximal voluntary contractions for the first dorsal interosseus or small finger muscle (Burnet et al., 2000; Enoka et al., 1999; Galanski et al., 1993; Laidlaw et al., 1999; Laidlaw et al., 2000; Keen et al., 1994; Semmler et al., 2000; Spiegel et al., 1996), and a few studies have examined finger grip torque steadiness (Kinoshita & Francis; 1996, Lowe, 2001). Tracy et al. (2002), found no significant correlation between knee extensor muscle and first dorsal interosseus muscle torque steadiness CV between ten young (22 ± 3 yrs) and 10 old (72 ± 4 yrs) healthy, sedentary men. Thus, there is no direct implication from studies examining upper extremities that muscular strength, neuromuscular control, and visual-motor control are involved in more complex lower extremity muscles responsible for postural stability and functional performance.

Even though previous studies have found significant positive correlations in the CV of torque of elbow flexor muscles and knee extensor muscles (r = 0.5 - 0.7) at the 5, 30, and 50% of maximal voluntary contraction (MVC), age and gender differences are not a consistent finding of elbow flexor and knee extensor torque CV. For example, elbow flexor muscles have been previously studied by Graves et al. (2000) and Lavander and Nosaka (2007). Authors reported no significant age (Graves et al., 2000; Lavander & Nosaka, 2007, 2006) or gender (Lavander & Nosaka, 2007) differences in CV of torque between young and older adults. These findings conflicted with the study by Tracy and Enoka (2000) examining torque steadiness of knee extensor muscles who reported both age differences in torque CV at 2, 5, and 10% MVC (SD = 2.375 vs. 3.330; 2.195 vs.

2.695, and 2.120 vs. 2.415), respectively, and higher CV by older man than older woman at 2, 5, and 10% MVC (SD = 3.035 vs. 2.670, 2.545 vs. 2.345, and 2.305 vs. 2.230), respectively. Results from other studies on knee extensor muscle torque steadiness during submaximal isometric contractions were not consistent either (Carville et al., 2005; Carville et al, 2007; Christou et al., 2002; Christou & Carlton, 2001; Hortobagyi et al., 2001; Manini et al., 2005; Schiffman et, al., 2002; Schiffman & Luchies, 2001; Seynnes et al., 2005; Shinohara et al., 2003; Tracy & Enoka, 2000; Welsh et al., 2007). Tracy & Enoka (2002) and Tracy et al. (2002) reported a significant age effect during submaximal target level matching tasks, while others found no age related reduction in torque steadiness (Carville et al., 2005; Carville et al, 2007; Christou et al., 2002; Christou & Carlton, 2001; Hortobagyi et al., 2001; Manini et al., 2005; Schiffman and Luchies, 2001). Because there is little or no correlation between upper and lower extremity torque steadiness and lower extremity torque steadiness results are inconsistent in previous research, it would seem that task-specific torque steadiness should be assessed for the hip musculature, which is directly involved in postural stability and balance.

A recent study on torque steadiness by Tracy (2007) examined torque CV for ankle plantar and dorsiflexor muscles. Interestingly, results varied between the two muscle groups around the same joint. During plantarflexion older adults had greater torque fluctuations than young adults at 2.5 and 5% MVC; 2.64 vs 1.71% CV and 1.78 vs. 1.24% CV, respectively. Coefficient of variation at 10, 50, and 80% target levels was similar between the two age groups. During dorsiflexion, no significant differences in CV were found across target levels for young compared to older adults. Coefficient of variations for dorsiflexors at lower target torque levels (2.5, 5, and 10% MVC) were significantly greater than for plantarflexors, 58, 58, and 44% greater CV respectively. Contradictory findings for ankle have been previously reported by Patten and Kamen (2000) who reported no significant age differences in torque steadiness during ankle dorsiflexion. Shinohara et al. (2003) also studied plantarflexion torque steadiness before and after twenty days of bed rest and reported 88% increase in torque variability due to immobility, however, only young males were examined in this study. To our knowledge, no previous studies have investigated torque steadiness in either hip extension (HE) or hip flexion (HF). Since each of these movements have different contributions to common functional tasks, it seems important to inspect age and gender differences in torque steadiness for both HE and HF. A better control over torque steadiness during hip contractions may relate to balance in older populations. In this case, improvement in performance requiring submaximal torque regulation as part of an exercise prescription might translate into improved lower extremity muscular strength and improve postural stability.

Age Differences

The majority of previous studies examined age differences in torque fluctuations during voluntary submaximal isometric contractions. Even though the working hypothesis is that older adults exhibit greater torque fluctuations, findings were not consistent among the different researchers. Some investigators reported a significant age effect during submaximal target level matching tasks (Burnett et al., 2000; Enoka et al., 1999; Galanski et al., 1993; Laidlaw et al., 2000; Laidlaw et al., 1999; Kinoshita and Francis, 1996; Semmler et al., 2000; Tracy, 2007; Tracy & Enoka, 2002; Tracy et al., 2002). while others reported no age related reduction in torque steadiness (Carville et al., 2005; Carville et al, 2007; Christou et al., 2002; Christou & Carlton, 2001; Enoka et al., 1999; Graves et al., 2000; Hortobagyi et al., 2001; Lavander & Nosaka, 2007, 2006; Lowe, 2001; Manini et al., 2005; Schiffman et, al., 2002; Schiffman & Luchies, 2001; Spiegel et al., 1996). When there is a difference in the amplitude of the torque fluctuations between young and old adults, it tends to be greatest at low forces (Burnett et al., 2000; Galanski et al., 1993; Kinoshita & Francis, 1996; Laidlaw et al., 2000; Semmler et al., 2000; Tracy 2007; Tracy & Enoka, 2002), with older subjects having greater torque fluctuations at target levels smaller than 10% MVC. Tracy and Enoka (2002), reported that SD for knee flexors was significantly less for the young adults at 5, 10, and 50% MVC (SD = 0.588 vs. 0.428; 1.075 vs. 0.788, and 7.458 vs. 4.494), but similar between both young and older individuals at 2% MVC (SD = 0.269 vs. 0.234). In relative terms (CV) older subjects demonstrated significantly greater fluctuations at 2, 5, and 10% MVC (SD = 2.375 vs. 3.330; 2.195 vs. 2.695, and 2.120 vs. 2.415). Burnett et al. (2000) reported torque fluctuations for first dorsal interosseus being greater for older adults at 2.5, 5, and 50% MVC. Galanski et al. (1993) reported a 67% greater CV for first dorsal interosseus torque exerted at 5% MVC and 35% greater CV for torque at 50% MVC in older compared to young subjects. Laidlaw et al. (2000) also examined torque steadiness at 2.5, 5, and 10% MVC for first dorsal interosseus muscle in older vs. young adults and reported greater CV in older adults: 132, 158, and 123%, respectively. Semmler et al. (2000) also found that older adults demonstrate greater SD of torque steadiness (15.5 ± 12.1 Nm) compared to young subjects (7.3 ± 5.7 Nm), particularly at lower target levels (2.5% and 5% MVC) during first dorsal interosseus muscle isometric contractions. Kinoshita and Francis (1996), who examined finger grip torque steadiness while subject held free weight (3N) for 8 s with two different surface textures silk and sandpaper, also reported increased torque variability with age across three age groups 18 - 32 yrs (3.15 ± 0.48 N), 69 - 79 yrs (5.89 ± 1.38 N), and 81 - 93 yrs (6.83 ± 2.06 N) for sandpaper surface and 18 - 32 yrs (6.28 ± 1.50 N), 69 - 79 yrs (8.10 ± 2.00 N), and 81 - 93 yrs (9.51 ± 1.81 N) for silk surface. The oldest age group (81 - 93 yrs) tended to be less steady than 69 - 79 yrs group. Finally, Tracy (2007) found that during plantarflexion, older adults demonstrated greater torque fluctuations that young adults at 2.5 and 5 % MVC; 2.64 vs 1.71% CV and 1.78 vs. 1.24 % CV, respectively. Coefficient of variation at 10, 50, and 80% target levels was similar between two age groups. Authors who did not find significant age differences in torque steadiness primarily examined target torque levels ≥ 10% MVC (Manini et al., 2005, (10, 25, and 50% MVC), Carville et al., 2005 (10, 25, 50, and 100% MVC), Carville et al, 2007,(10, 25, and 50% MVC), Christou and Carlton, 2001, (5-90% MVC), Graves et al., 2000, (5, 10, 20, 35, 50, and 65% MVC), Hortobagyi et al., 2001, (25 Nm), Lavander and Nosaka, 2007, (30, 50, and 80% MVC), Lavander and Nosaka, 2006, (30, 50, and 80% MVC), Schiffman et al., 2002, (20 and 60% MVC), Schiffman and Luchies, 2001, (20 and 60% MVC), respectively. Hip muscle function is crucial for many types of activities of daily living, yet existing studies investigating torque steadiness for lower extremities are limited to assessing steadiness at the knee and ankle. Thus, it is necessary to examine age differences in HE and HF torque steadiness.

Gender Differences

Few studies have accounted for gender differences in submaximal torque steadiness. Tracy and Enoka (2002), reported greater increase in CV for knee extensors at low forces by men than women at 2, 5, and 10% MVC (SD= 3.035 vs. 2.670, 2.545 vs. 2.345, and 2.305 vs. 2.230), whereas, Lavander and Nosaka (2007), reported no age or gender effects during elbow flexor isometric contractions. Since the majority of previous investigations used combined research from both sexes, further research with the separation of males and females within young and older age group may provide better understanding of the torque steadiness abilities, especially at lower target torque levels, where more differences in torque steadiness have been shown previously.

Explanations of Controversial Reports in Previous Research

The possible explanations why findings from these studies differed could be methodological differences in research protocols and subject characteristics. Analysis of torque steadiness has been previously determined over different sections of a muscle contraction during torque-matching test (torque development, constant torque level generation, and/or torque reduction phases). For instance, Tracey and Enoka (2002) reported significantly greater torque variability during isometric knee flexor contractions for older vs. young subjects for both SD at 5, 10, and 50% MVC (SD = 0.588 vs. 0.428; 1.075 vs. 0.788, and 7.458 vs. 4.494) and CV of torque fluctuations at 2, 5, and 10% MVC (SD = 3.330 vs. 2.375; 2.695 vs. 2.195, and 2.415 vs. 2.120). In contrast Hortobagyi et al. (2001), who also examined knee extensor muscle torque steadiness in older (72 ± 4.7 yrs, n =30) and young (21.1 ± 1.2 yrs, n =10) men and women, reported no age differences in torque steadiness. However, Hortobagyi et al., used the entire 5 s of data of a target torque level matching task including torque development to target and the torque reduction phase of the task. Spiegel et al. (1996), who studied age differences in isometric steadiness for first dorsal interosseus muscle between ten young and 12 older subjects, used a similar protocol (included torque development to and steady portion of target torque level) and reported no significant age or gender differences, whereas, Tracy and Enoka (2002), used only the constant torque level middle 8 s of a 10-12 s contraction. Schiffman and Luchies (2001) also examined torque steadiness between twenty young and 19 older adults during isometric contraction of knee extensors at 20 and 60% MVC. No significant age effect was reported, however, they observed torque steadiness using 6.1 Nm range around the target level instead of matching a constant target level. This bandwidth (± 6.10 Nm) was 3.7% MVC for young and 5.9% MVC for older adults at 20% MVC target level; therefore, subjects were actually matching slightly different target levels.

In addition, methodological differences in statistical analysis could also explain some of the divergence in previous research. For instance, Schiffman et al. (2002) examined torque steadiness with or without visual feedback in 20 young (25.8 ± 2.7 yrs) and 20 older (71.8 ± 2.0 yrs) males. Significant differences for age, torque, feedback, and age x torque, and feedback x torque were reported, however, after correction for Type I error with Holm`s sequential Bonferroni method the main effect of visual feedback on variability was not significant. Tracy (2007) used planned comparisons for statistical analysis to examine age effect on torque steadiness without Bonferroni corrections for family-wise error rates and did find a significant age effect.

Differences in subject characteristics could also account for the differences in results among torque steadiness studies. First, since increase in muscle strength due to exercise training has been previously reported to increase torque steadiness (Hortobagy et al., 2001; Keen et al., 1994; Laidlaw et al., 1999; Patten, 2000), differences in subject physical activity levels could account for differences in age related findings when examining torque steadiness. Christou and Carlton (2001) found no differences in CV of the knee extensor torque steadiness at torque levels 5 - 90% MVC between twenty-four young and 24 older subjects. All subjects were healthy, physically active and much stronger individuals than subjects in the study by Tracy and Enoka (2002), who did report greater CV for older subjects compared to young at 2, 5, and 10% MVC (SD = 2.375 vs. 3.330; 2.195 vs. 2.695, and 2.120 vs. 2.415). Therefore, physical activity level and muscle strength could have a possible contribution to torque steadiness and may explain differences in CV at lower torque levels between the two studies.

Another subject characteristic that could account for the difference in results among torque steadiness studies is their age range. Kinoshita and Francis (1996) examined age related differences in finger grip torque steadiness and reported increased torque variability with age across age groups 18 - 32 yrs (3.15 ± 0.48 N), 69- 79 yrs (5.89 ± 1.38 N), and 81 - 93 yrs (6.83 ± 2.06 N) for sandpaper surface and 18- 32 yrs (6.28 ± 1.50 N), 69 - 79 yrs (8.10 ± 2.00 N), and 81 - 93 yr (9.51 ± 1.81 N) silk surface. The oldest age group (81 - 93 yrs) tended to be less steady than 69- 79 yrs group. These findings indicate that just a slight increase in age can influence individual's ability to control torque during submaximal isometric contractions. Therefore, greater mean age separation could account for differences in torque steadiness between young and older individuals. Lowe (2001) examined grip torque steadiness between nine young (39.4 ± 11.8 yrs) and 9 older (73.9 ± 4.9 yrs) subjects and found no statistically significant age effect. Interestingly, Lowe grouped subjects in 2 groups young (<65 yrs, range 23 - 62 yrs) and older (>65 yrs, range 66 - 82 yrs). Similar age ranges were used by Carville et al. (2007) who studied torque steadiness differences between young (18 - 40 yrs) and older (age > 70 yrs) adults for knee extensors during isometric contractions. The average subject age in studies by Lowe (2001) and Carville et al. (2007), was 34 yrs for young and > 70 yrs for older subjects, respectively. No significant difference that indicated increased steadiness with aging was found between the groups. However, studies in which the age separation is larger, averaging 19 - 30 for young (mean = 24.1 yrs) and 63-81 years for older (mean = 72.5 yrs), did find significant age effects on torque steadiness during submaximal contractions (Tracy and Enoka 2002; Laidlaw et al., 1999; Semmler et al., 2000; Tracy, 2007). Therefore, dissimilarity in age separation might have contributed to the differences in the results.

Conclusion

Reduction in muscular function may account for age related decrements in postural stability and functional tasks like walking, stair climbing, and chair stand, and increased risk of falling. Most of these daily activities require not only muscular strengths and neuromuscular control, but also visual-motor control. One of the methods to estimate ability to control motor task performance is to measure torque steadiness during voluntary isometric contractions. The variability of these torque fluctuations can be expressed in absolute terms as a SD of torque fluctuations, CV of the torque fluctuations about the actual mean torque, or TA which is a difference between target constant torque level and actual mean torque of the data. Torque steadiness has been previously assessed for upper and lower body musculature around several joint movements: the first dorsal interosseus, elbow flexors, knee extensors, and ankle plantar and dorsiflexor muscles, however, no research has been done for hip musculature. Previous studies reported contradictory results for age and gender differences during submaximal target level matching tasks. Possible explanations of controversial reports from previous studies include methodological differences in research protocols and statistical analysis as well as differences in subject characteristics such as muscle strength, activity level, and age separation between young and older adults.

Methods

Subjects

Twenty young (10 males and 10 females) and 21 older healthy adult (11 males and 10 females) subjects were recruited from the Birmingham, Alabama area. Subject characteristics are presented in Table 1. Subjects with cardio-respiratory, metabolic, musculoskeletal, or neurological disorders, which would have interfered with procedures for this study or placed an individual at more than minimal risk during procedures of this study, were excluded from participation. All subjects were habitually active in exercise and/or sport activities (defined as participation of at least once per week for at least the year prior to study participation), but have not participated regularly (one or more sessions per week) in a lower body strength training program within the last year.

All subjects provided signed informed consent and all elderly subjects also provided signed physician's authorization forms prior to participation in this study. The Institutional Review Board of the University of Alabama at Birmingham approved the procedures used in this study.

Table 1

Subject Characteristics

	n	Age, yr	Body mass, kg	Height, cm	BMI (kg/m^2)	Body fat, %
Young subjects	20	24.0 ± 2.2	68.2 ± 11.5	171.2 ± 8.1	23.2 ± 2.1	16.7 ± 6.7†
Men	10	24.7 ± 3.0	75.9 ± 9.0¶	176.5 ± 9.0¶	24.3 ± 1.5	11.5 ± 4.7¶
Women	10	23.3 ± 0.7	60.5 ± 8.1	165.9 ± 5.5	21.9 ± 2.0	21.9 ± 3.5
Older subjects	21	65.4 ± 4.5	72.1 ± 8.2	168.9 ± 7.2	25.2 ± 1.9	25.6 ± 6.2
Men	11	67.3 ± 5.1	78.0 ± 5.4¶	175.0 ± 2.4¶	25.5 ± 2.0	20.9 ± 2.8¶
Women	10	63.7 ± 3.3	67.0 ± 6.8	164.0 ± 5.2	24.9 ± 1.9	30.4 ± 4.8

Values are group means ± SD. ¶Main gender effect, $p < 0.05$. †Main age effect, $p < 0.05$.

Experimental Design

Subjects reported to the Human Performance Laboratory, University of Alabama at Birmingham, for a familiarization and a testing session separated by two to seven days. During the familiarization session subjects were introduced and practiced performing HF and HE MVC and steadiness testing for all target torque levels. For the testing session body composition was estimated from the sum of three skinfold measurements using gender- and age-specific equations (Jackson et al., 1978; Jackson et al., 1980). Subjects performed warm-ups, MVC followed by torque steadiness tests for HF and HE. Subjects refrained from caffeine and alcohol consumption for at least 12 hours and exercise for 24 hours prior to the experiment.

Testing Set-up

Subjects were tested to perform dominant side only HF and HE on a Biodex Multi- Joint System 3 Pro Dynamometer (Biodex Medical Systems, Inc., Shirley, NY) in the functional position of standing. Both hip and knee angles were at 0º (both extended) with the axis of rotation on the dynamometer aligned with the greater trochanter of the dominant leg and the non-dominant (non-test) leg supported over a 1 cm high non-slip support. The thigh cuff was positioned and attached with its lower border approximately 2.5 cm above the superior border of the patella. Subjects stood erect with arms out laterally to each side and held on with both hands to secure supports to stabilize body position in an upright posture throughout the testing.

Isometric Maximal Voluntary Contractions and Torque Steadiness

Prior to testing, subjects performed a warm-up on a cycle ergometer at 50 rpm at a self-selected work load between 25-50 watts for five minutes. Assessments were performed on the dominant leg, first assessing HF performance then HE. Subjects were given a three minute rest break between HF and HE testing. For HF a series of warm-up isometric contractions were performed at 25, 50, and 75% of self-estimated maximal torque followed by four maximal effort HF contractions. Each trial lasted 5 seconds, with 60 seconds rest between trials to allow full recovery (Sale, 1991). If the MVC of the fourth trial was 5% or greater than the highest MVC of any of the previous trials, another trial was performed. The highest MVC in any of the trials was used as the criterion score and it was also used to calculate relative target torque levels.

Torque steadiness was assessed by asking subjects to attempt to match a horizontal target line for 15 seconds that was displayed on a 19-inch computer monitor 1.5 meters in front of the subject. Subjects performed voluntary isometric contractions to match constant torque target levels at 5, 25, and 50% MVC (torque relative to maximal strength) and at 25 Nm (absolute torque). The order of target levels was randomized as determined by a computer randomization program for each subject. Two trials separated with 35 seconds rest periods were performed at each target level with the mean of the trials used for analysis. After the completion of HF testing, same procedures were then performed for HE.

Muscle Performance Data Acquisition System

Isometric steadiness analysis measures were assessed utilizing the Biodex Dynamometer interfaced with a National Instruments (Austin, TX) data acquisition system, which included custom software written in LabVIEW (Laboratory Virtual Instrument Engineering Workbench, version 7.1) running on a Pentium 4 personal computer with a 16-channel data acquisition card. A direct connection to the analog signal access port on the dynamometer was utilized to sample at a 1000 Hz analog-to-digital conversion rate. As indicated by previous investigations, a high resolution of torque signals is required to accurately assess steadiness, especially at low load target levels where very small fluctuations in torque may occur (Tracy & Enoka, 2002). To address this, our system also utilized System 3 Research Tool Kit software (Biodex Medical Systems, Inc.) to greatly enhance resolution of torque measurements. Sensitivity of torque was adjusted for target settings to maximize the resolution of the system. The lowest torque targets (28 Nm and below) had a sensitivity setting of 0.1152 volts/Nm.

Data Analysis

Analysis for torque steadiness for each trial of submaximal contractions was determined over the middle 10 seconds of the 15-second test and was automatically calculated by the custom LabVIEW program using SD of torque fluctuations (SD of the torque about the line of best fit through the data), CV ([SD/mean torque] X 100) of the torque fluctuations about the actual mean torque, and TA (difference between target constant torque level and actual mean torque of the data).

Statistical Analysis

To compare torque fluctuations between HE and HF a 3 by 2 (torque level X muscle) analysis of variance (ANOVA) was run with relative torque level serving as a repeated measure. A factorial analysis of variance (ANOVA) was computed for 25 Nm and MVC with independent variables of muscle and level. To compare torque fluctuations at different torque levels within one muscle, ANOVA was run with torque level serving as a repeated measure and between-subjects factors of age and gender. A factorial analysis of variance (ANOVA) was computed for 25 Nm and MVC with independent variables of age groups and gender. Analysis of co-variance (ANCOVA) was calculated for MVC with fat free mass (FFM) serving as the co-variant. Follow-up Tukey’s post hoc tests were performed as appropriate. For all analyses the significance level was set at $\alpha = 0.05$.

Results

Results for HE and HF comparisons of MVC, torque steadiness and torque accuracy at relative (5, 25, and 50% MVC) and absolute (25 Nm) target torque levels are reported in Table 2. Results for HE and HF age and gender differences for MVC, torque steadiness and torque accuracy at relative (5, 25, and 50% MVC) and absolute (25 Nm) target torque levels are reported in Table 3 and Table 4.

Maximal Voluntary Contractions

Hip extensors had 5% greater MVC than HF ($p = 0.007$) (Table 2). During HE males (123.3 ± 27.7 Nm) (m ± SD) demonstrated 41% greater MVC torque output than females (87.2 ± 16.5 Nm) ($p < 0.001$), and young adults (119.42 ± 29.08 Nm) were 29% stronger that older (92.6 ± 22.7 Nm) ($p < 0.001$) (Table 3). When adjusted for FFM, young were 21.6% stronger than older adults ($p < 0.001$) (Table 3).

Similar results were found for the HF. During HF males (118.9 ± 30.9 Nm) were 49% stronger than females (80.1 ± 21.4 Nm) ($p < 0.001$), and young adults (116.24 ± 34.10) were 38% stronger that older adults (84.5 ± 23.3 Nm) ($p < 0.001$) (Table 4). When adjusted for FFM, young were 28% stronger than older adults ($p < 0.001$) (Table 4).

Table 2

Hip Extension and Flexion Comparisons of MVC, Torque Steadiness and Torque Accuracy at Relative and Absolute Target Torque Levels

	Hip Extension	Hip Flexion	*p*	
MVC (Nm)	105.7 ± 29.1	100.0 ± 33.0	Muscle	0.007
Standard Deviation (Nm)				
5% MVC ^{a}	0.42 ± 0.40	0.20 ± 0.07	Level	0.000
25% MVC ^{b}	0.76 ± 0.36	0.52 ± 0.29	Muscle	0.001
50% MVC ^{b}	1.64 ± 0.93	1.39 ± 0.76	L x M	0.847
25 Nm	0.72 ± 0.50	0.52 ± 0.18	Muscle	0.001
Coefficient of Variation (%)				
5% MVC ^{a}	9.99 ± 15.12¶	4.34 ± 1.87	Level	0.001
25% MVC ^{b}	3.00 ± 1.52	2.12 ± 0.95	Muscle	0.008
50% MVC ^{b}	3.25 ± 1.82	2.80 ± 1.07	L x M	0.033
25 Nm	2.90 ± 2.09	2.08 ± 0.73	Muscle	0.012
Torque Accuracy (Nm)				
5% MVC ^{a}	0.20 ± 0.22	0.12 ± 0.07	Level	0.000
25% MVC ^{a}	0.31 ± 0.21	0.22 ± 0.17	Muscle	0.676
50% MVC ^{b}	1.00 ± 0.74	1.08 ± 1.20	L x M	0.389
25 Nm	0.38 ± 0.30	0.32 ± 0.31	Muscle	0.190

Values are group means ± SD. MVC, maximum voluntary contraction; ¶Significantly different than all other target level means for HE and HF, $p < 0.05$. Target torque level means with different superscript letters are significantly different, $p < 0.05$.

Torque Steadiness

Standard Deviation

For both HE and HF, SD of exerted torque significantly increased as target torque increased ($p < 0.001$) (Table 2). Hip extension consistently had higher SD of torque than HF at 5, 25, and 50% MVC (110, 46, and 18%) and 25 Nm (38%) torque levels (Table 2).

Standard deviation of exerted relative torque during HE significantly increased with increase in target torque by 81% from 5 to 25% MVC, and by 116% from 25 to 50% MVC ($p < 0.001$) (Table 3).

During HF, older adults had 46% lower SD of relative torque than young adults at 50% MVC ($p = 0.016$) (Table 4).

Coefficient of Variation

Hip extension had higher CV of torque than HF at 5, 25, and 50% MVC (130, 42, and 16%) and 25 Nm (39%) torque levels ($p < 0.001$) (Table 2).

During HE CV of relative torque was 233% greater for 5% MVC compared to 25% MVC ($p< 0.001$) and 207% greater than 50% MVC ($p < 0.001$), but there was no significant difference in CV of relative torque between 25% MVC and 50% MVC ($p = 0.988$). For relative torque there was a significant interaction between age and level ($p = 0.019$) and gender and level ($p = 0.049$) (Table 3). Older adults demonstrated 189% greater CV of relative torque during HE at 5% MVC ($p = 0.023$) than young adults, but not at 25% MVC ($p = 1.000$) or 50% MVC ($p = 1.000$) (Table 3). Coefficient of variation of relative torque for females was 168% greater than males at 5% MVC ($p = 0.022$), but not at 25% MVC ($p = 0.999$) or 50% MVC ($p = 1.000$) during HE (Table 3).

During HF CV of relative torque was 105% greater at 5% MVC compared to 25% MVC ($p = 0.001$) and 55 % greater at 5% MVC than 50% MVC ($p > 0.001$), and CV of relative torque at 25 % MVC was 32% lower than 50% MVC ($p > 0.001$) (Table 4).

Torque Accuracy

For both HE and HF TA of exerted relative torque was lower (less accurate-higher TA values) at 50% MVC compared to 5% MVC ($p < 0.001$) and 25% MVC ($p < 0.001$). However, there was no significant difference between 25% MVC and 5% MVC was found ($p = 0.535$) (Table 2).

During HE, TA significantly declined with an increase in relative target torque ($p < 0.001$) (Table 3). Although all mean deviations from target torque (TA) were relatively small (1.08 Nm or less), exerted relative torque at 5% MVC had mean deviations that were 400% less compared to 50% MVC ($p > 0.001$), and at 25% MVC 223% less compared to 50% MVC ($p > 0.001$), but no significant differences were found at 25% MVC as compared to 5% MVC ($p = 0.369$). Older adults were 76% less accurate during HE at 25 Nm than young adults ($p = 0.022$) (Table 3).

During HF, TA significantly declined with an increase in target torque ($p < 0.001$) (Table 4). Exerted relative torque at 5% MVC had mean deviations that were 800% less compared to 50% MVC ($p < 0.001$) and at 25% MVC was 390% less compared to 50% MVC ($p < 0.001$). However, no significant difference was found between 25% MVC and

5% MVC (*p* = 0.766). Older adults were 126% less accurate during HF at 25 Nm than young adults (*p* = 0.010) (Table 4).

Table 3

Hip Extension Age and Gender Differences of MVC , Torque Steadiness and Torque Accuracy at Relative and Absolute Target Torque Levels

	Young		Old			
	Men	Women	Men	Women	*p*	
MVC (Nm)	141.3 ± 21.6	97.6 ± 16.0	106.9 ± 22.2	76.9 ± 8.7	Age	<0.001
					Gender	<0.001
					A x G	0.234
MVC adjusted	119.4 ± 11.26	112.3 ± 8.9	97.9 ± 7.3	92.6 ± 6.2	Age	0.001
					Gender	0.575
for FFM (Nm)					A x G	0.234
Standard Deviation (Nm)						
5% MVC ^{a}	0.24 ± 0.12	0.33 ± 0.14	0.40 ± 0.38	0.73 ± 0.58	Age	0.157
					Gender	0.661
25% MVC ^{b}	0.76 ± 0.28	1.03 ± 0.56	0.73 ± 0.13	0.56 ± 0.26	Level	<0.001
					A x G	0.216
50% MVC ^{c}	1.80 ± 0.88	2.14 ± 1.35	1.60 ± 0.66	1.1 ± 0.37	A x L	0.002
					G x L	0.374
					A x G x L	0.064
25 Nm	0.44 ± 0.14	0.94 ± 0.32	0.82 ± 0.81	0.68 ± 0.36	Age	0.676
					Gender	0.243
					A x G	0.041
Coefficient of Variation (%)						
5% MVC ^{a,*,†}	3.44 ± 1.75	6.88 ± 3.35	7.44 ± 7.66	22.32 ± 25.56	Age	0.065
					Gender	0.030
25% MVC ^{b}	2.16 ± 0.70	4.13 ± 2.22	2.84 ± 0.88	2.93 ± 1.44	Level	0.002
					A x G	0.438
50% MVC ^{b}	2.57 ± 1.10	4.25 ± 2.26	3.28 ± 2.19	2.92 ± 1.19	A x L	0.019
					G x L	0.049
					A x G x L	0.110
25 Nm	1.76 ± 0.55	3.76 ± 1.27	3.33 ± 3.40	2.72 ± 1.43	Age	0.678
					Gender	0.280
					A x G	0.045

Torque Accuracy (Nm)						
5% MVC ^{a}	0.13 ± 0.08	0.09 ± 0.04	0.26 ± 0.31	0.34 ± 0.27	Age	0.538
					Gender	0.906
25% MVC ^{a}	0.23 ± 0.22	0.18 ± 0.15	0.47 ± 0.29	0.42 ± 0.18	Level	<0.001
					A x G	0.382
50% MVC ^{b}	0.99 ± 0.5	1.30 ± 1.00	1.09 ± 0.89	0.74 ± 0.37	A x L	0.043
					G x L	0.850
					A x G x L	0.101
25 Nm	0.20 ± 0.90	0.35 ± 0.19	0.40 ± 0.40	0.57 ± 0.32	Age	0.022
					Gender	0.076
					A x G	0.932

Values are group means ± SD. MVC, maximum voluntary contraction. FFM, fat free mass; *Older > young, $p < 0.05$. †Women > men, $p < 0.05$. Target torque level means with different superscript letters are significantly different, $p < 0.05$. For standard deviation 25 Nm follow-up post hoc tests on the A x G interaction were not significant, $p > 0.05$. For coefficient of variation 25 Nm follow-up post hoc tests on the A x G interaction was not significant, $p > 0.05$. For torque accuracy across relative MVC torque levels follow-up post hoc tests on the A x G interaction were not significant, $p > 0.05$.

Table 4

Hip Flexion Age and Gender Differences of MVC, Torque Steadiness and Torque Accuracy at Relative and Absolute Target Torque Levels

	Young		Old			
	Men	Women	Men	Women	*p*	
MVC (Nm)	142.2 ± 22.9	90.4 ± 21.0	97.8 ± 20.3	60.8 ± 17.0	Age	<0.001
					Gender	<0.001
					A x G	0.070
MVC adjusted for FFM (Nm)	117.8 ± 12.5	106.8 ± 9.9	87.5 ± 8.1	87.3 ± 8.1	Age	<0.001
					Gender	0.655
					A x G	0.391

Standard Deviation						
5% MVC ^{a}	0.21 ± 0.09	0.21 ± 0.87	0.19 ± 0.44	0.19 ± 0.62	Age	0.009
					Gender	0.064
25% MVC ^{b}	0.73 ± 0.46	0.51 ± 0.23	0.45 ± 0.13	0.36 ± 0.11	Level	<0.001
					A x G	0.924
50% MVC ^{c,} ‡	1.85 ± 1.04	1.48 ± 0.75	1.30 ± 0.43	0.85 ± 0.32	A x L	0.012
					G x L	0.080
					A x G x L	0.683
25 Nm	0.47 ± 0.20	0.58 ± 0.17	0.49 ± 0.18	0.53 ± 0.18	Age	0.817
					Gender	0.212
					A x G	0.592
Coefficient of Variation (%)						
5% MVC ^{a}	3.04 ± 1.30	4.56 ± 2.09	4.18 ± 1.36	5.50 ± 1.86	Age	0.561
					Gender	0.080
25% MVC ^{b}	2.10 ± 1.37	2.16 ± 0.78	1.94 ± 0.63	2.18 ± 0.98	Level	<0.001
					A x G	0.626
50% MVC ^{c}	2.68 ± 1.44	3.29 ± 1.25	2.74 ± 0.63	2.43 ± 0.65	A x L	0.008
					G x L	0.010
					A x G x L	0.406
25 Nm	1.90 ± 0.77	2.30 ± 0.68	2.00 ± 0.72	2.16 ± 0.80	Age	0.897
					Gender	0.207
					A x G	0.639
Torque Accuracy (Nm)						
5% MVC ^{a}	0.11 ± 0.09	0.13 ± 0.05	0.09 ± 0.07	0.13 ± 0.07	Age	0.261
					Gender	0.542
25% MVC ^{a}	0.22 ± 0.16	0.16 ± 0.17	0.19 ± 0.16	0.30 ± 0.20	Level	<0.001
					A x G	0.163
50% MVC ^{b}	1.72 ± 1.70	0.94 ± 1.12	0.73 ± 0.67	0.91 ± 0.92	A x L	0.141
					G x L	0.369
					A x G x L	0.228
25 Nm	0.17 ± 0.12	0.22 ± 0.15	0.36 ± 0.26	0.52 ± 0.47	Age	0.010
					Gender	0.230
					A x G	0.558

Values are group means ± SD. MVC, maximum voluntary contraction. FFM, fat free mass; ‡Young >older, $p < 0.05$. Target torque level means with different subscript letters are significantly different, $p < 0.05$. For coefficient of variation across relative MVC torque levels follow-up post hoc tests on the A x L and G x L interactions were not significant, $p > 0.05$.

Discussion

The main findings of this study were that when compared to young adults and males, older adults and females have impaired normalized relative torque steadiness (CV) at lower target torques for HE but not HF. Amplitudes of HE torque fluctuations were consistently greater as compared to HF for both relative and absolute torque.

Torque steadiness differences between muscles

Based on previous research that increases in muscle strength with resistance exercise training lower torque fluctuations (Hamilton et al., 2004), we predicted that HE muscles would exhibit less torque fluctuations than hip flexors. Our prediction was contrary to our actual findings. Thus, age and gender related decrease in torque steadiness does not always affiliate with reduced muscle strength. The amplitude of HE torque fluctuations was consistently greater as compared to HF for both relative and absolute torque expressed as SD, CV, and TA. Our findings are consistent with findings from a recent study by Tracy (2007), who reported greater torque fluctuations in stronger plantarflexor muscles as compared to dorsiflexor muscles. Thus, it appears that torque steadiness may be affected depending upon the specific muscle being tested. A consideration for the different results in the different lower extremity muscle groups is that certain HE muscles (hamstrings and adductor magnus) have substantially greater moment arms when the hip is more flexed (Oatis, 2004). We tested HE with the hip positioned at 0º which place the hip extensor muscles in a shortened position. Previous research demonstrates that as the hip muscles go from lengthened to a shortened position muscle strength decreases (Oatis, 2004). Thus, disadvantage in functional positioning may account for greater torque fluctuations for HE as compared to HF.

Torque steadiness

The hip musculature plays an important role in many functional activities, and this is the first study to assess torque control or steadiness at the hip. Therefore, it would seem appropriate to compare our findings to other studies that have assessed lower extremity torque steadiness.

For both HE and HF, young and older males and females had greater torque fluctuations at very low target torque levels (5% MVC), when torque steadiness was expressed as CV (normalized for mean torque). In comparison, when torque steadiness was expressed as SD and TA, fluctuations increased with an increase in relative target torque. Tracy (2007) also reported greatest torque CV at very low target levels at 2.5% MVC that decreased with increase in target torque levels from 10-80% MVC; while SD increased as target torque progressed to higher levels. Thus, it appears that normalized relative torque fluctuations (CV), that are adjusted for actual mean torque, better reflect ones ability to control exerted torque during isometric contraction.

In terms of absolute torque (25 Nm) for both HE and HF, older adults had greater torque fluctuations when steadiness was expressed as TA, but not SD or CV. Our findings are consistent with Hortobagyi et al. (2001), who reported impaired knee extensor

TA relative to a 25 Nm target torque level in older adults and found no significant age differences in torque steadiness SD. Differences in magnitude of exerted torque (percent of MVC) between young and older adults while attempting to match absolute target torque level could account for age-related differences in TA.

It was hypothesized that older adults exhibit greater torque fluctuations during submaximal voluntary isometric contractions (less steady) in controlling submaximal torque levels in terms of relative strength and absolute strength generated during hip extensor and flexor muscle contractions. We found that only HE, and not HF, relative torque steadiness is impaired for older adults at very low target torque levels (5% MVC) when torque steadiness was expressed as CV, but no age or gender effect was found when relative torque steadiness was measured as either SD or TA. Similar to our findings, Tracy and Enoka (2002) reported greater torque fluctuations for older adults compared to younger adults in knee extension at low torques levels of 10% MVC and below, but not at higher torque levels. In another study, Tracy (2007) reported similar results to ours for ankle plantarflexion, with less torque variability in older adults than young adults at target torque levels of 5% MVC and lower; with no difference between age groups at higher target levels up to 80% MVC.

Our results also indicated women have greater CV of torque than men in HE at low load target levels, but no gender differences were observed for HF. Hip extension findings are in contrast with previous research reporting higher knee extension fluctuations (higher CVs) at low forces in men as compared with women (Tracy & Enoka, 2002).

For HF young adults had greater relative torque fluctuations at higher torque levels (50% MVC) when torque steadiness was expressed as SD, but no age or gender effect was found when relative torque steadiness was measured as either CV or TA. Our findings of no significant differences between young and older adults for HF torque steadiness are consistent with findings reported for dorsiflexion steadiness by Tracy (2007).

Based on our results and results of other investigations, the amount of torque fluctuation depends upon age, gender, muscle group, and intensity of contraction (torque level). Our results also showed that age and gender differences in torque steadiness do not affiliate with muscle strength in HF, as compared to HE. To determine if age and gender differences in HE and HF MVC occur irrespectively of body composition, MVC was adjusted for FFM as an estimate of muscle mass. After adjustment for FFM no gender differences were observed. Thus, it appears that males had higher HE and HF MVC due to greater FFM. Older adults, however, still demonstrated lower strength as compared to young adults even after adjusting MVC for FFM, potentially indicating an age-related decrease in muscle quality and/or neuromuscular function. Our findings are consistent with previous research indicating age associated reduction in muscle strength (Hunter et al., 2004).

Conclusions

In summary, these findings suggest age-related decline in torque steadiness especially at lower relative target torque levels in the hip extensors, but both young and older adults are fairly steady in the hip flexors. Results also indicate women as compared to men are less steady in hip extension at lower target torque levels, but not at higher torque levels. For hip flexion, torque steadiness is similar between men and women for all target torque levels.

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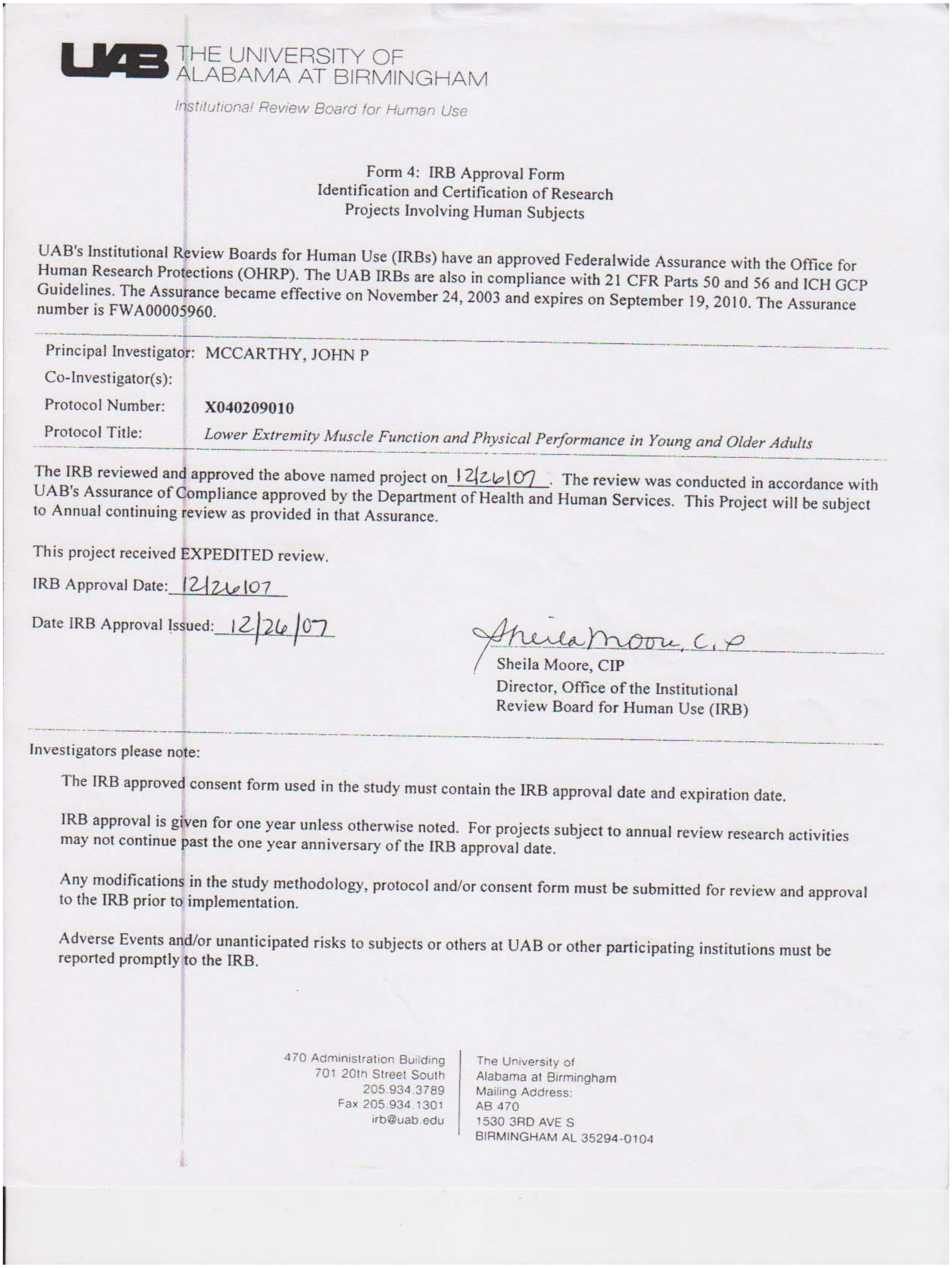
Appendix

Institutional Review Board Form



UAB THE UNIVERSITY OF
ALABAMA AT BIRMINGHAM

Institutional Review Board for Human Use

Form 4: IRB Approval Form
Identification and Certification of Research
Projects Involving Human Subjects

UAB's Institutional Review Boards for Human Use (IRBs) have an approved Federalwide Assurance with the Office for Human Research Protections (OHRP). The UAB IRBs are also in compliance with 21 CFR Parts 50 and 56 and ICH GCP Guidelines. The Assurance became effective on November 24, 2003 and expires on September 19, 2010. The Assurance number is FWA00005960.

Principal Investigator: MCCARTHY, JOHN P
Co-Investigator(s):
Protocol Number: **X040209010**
Protocol Title: *Lower Extremity Muscle Function and Physical Performance in Young and Older Adults*

The IRB reviewed and approved the above named project on 12/26/07. The review was conducted in accordance with UAB's Assurance of Compliance approved by the Department of Health and Human Services. This Project will be subject to Annual continuing review as provided in that Assurance.

This project received EXPEDITED review.

IRB Approval Date: 12/26/07

Date IRB Approval Issued: 12/26/07

Sheila Moore, C.I.P
Sheila Moore, CIP
Director, Office of the Institutional
Review Board for Human Use (IRB)

Investigators please note:

The IRB approved consent form used in the study must contain the IRB approval date and expiration date.

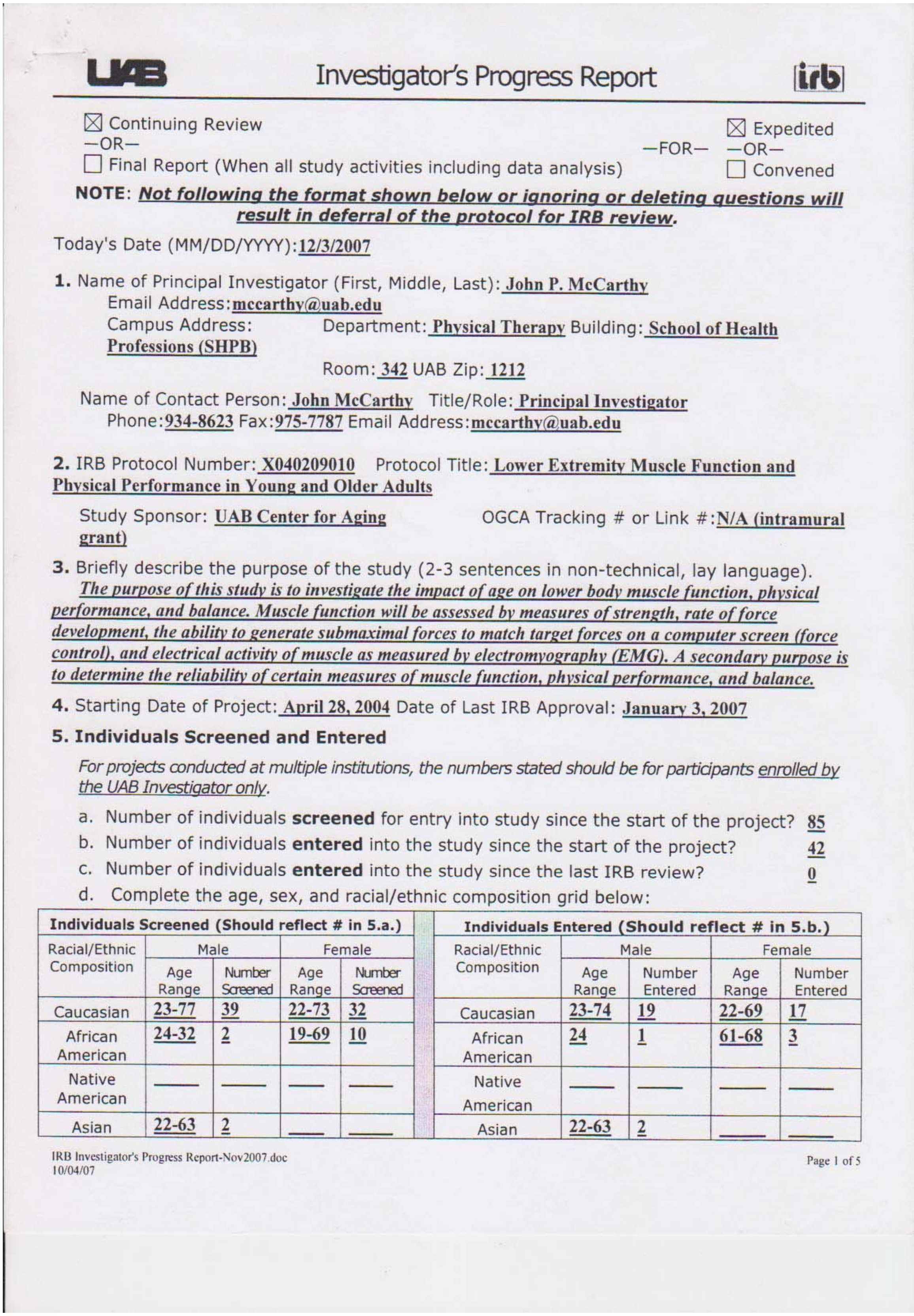
IRB approval is given for one year unless otherwise noted. For projects subject to annual review research activities may not continue past the one year anniversary of the IRB approval date.

Any modifications in the study methodology, protocol and/or consent form must be submitted for review and approval to the IRB prior to implementation.

Adverse Events and/or unanticipated risks to subjects or others at UAB or other participating institutions must be reported promptly to the IRB.

470 Administration Building
701 20th Street South
205.934.3789
Fax 205.934.1301
irb@uab.edu

The University of
Alabama at Birmingham
Mailing Address:
AB 470
1530 3RD AVE S
BIRMINGHAM AL 35294-0104



UAB

Investigator's Progress Report

irb

☒ Continuing Review
—OR—
☐ Final Report (When all study activities including data analysis)

—FOR—

☒ Expedited
—OR—
☐ Convened

NOTE: ***Not following the format shown below or ignoring or deleting questions will result in deferral of the protocol for IRB review.***

Today's Date (MM/DD/YYYY):12/3/2007

1. Name of Principal Investigator (First, Middle, Last): **John P. McCarthy**
Email Address:**mccarthy@uab.edu**
Campus Address: Department: **Physical Therapy** Building: **School of Health Professions (SHPB)**
Room: **342** UAB Zip: **1212**

Name of Contact Person: **John McCarthy** Title/Role: **Principal Investigator**
Phone:**934-8623** Fax:**975-7787** Email Address:**mccarthy@uab.edu**

2. IRB Protocol Number: **X040209010** Protocol Title: **Lower Extremity Muscle Function and Physical Performance in Young and Older Adults**

Study Sponsor: **UAB Center for Aging** OGCA Tracking # or Link #:**N/A (intramural grant)**

3. Briefly describe the purpose of the study (2-3 sentences in non-technical, lay language).
The purpose of this study is to investigate the impact of age on lower body muscle function, physical performance, and balance. Muscle function will be assessed by measures of strength, rate of force development, the ability to generate submaximal forces to match target forces on a computer screen (force control), and electrical activity of muscle as measured by electromyography (EMG). A secondary purpose is to determine the reliability of certain measures of muscle function, physical performance, and balance.

4. Starting Date of Project: **April 28, 2004** Date of Last IRB Approval: **January 3, 2007**

5. Individuals Screened and Entered

For projects conducted at multiple institutions, the numbers stated should be for participants enrolled by the UAB Investigator only.

a. Number of individuals **screened** for entry into study since the start of the project? **85**
b. Number of individuals **entered** into the study since the start of the project? **42**
c. Number of individuals **entered** into the study since the last IRB review? **0**
d. Complete the age, sex, and racial/ethnic composition grid below:

Individuals Screened (Should reflect # in 5.a.)				
Racial/Ethnic Composition	Male		Female	
	Age Range	Number Screened	Age Range	Number Screened
Caucasian	23-77	39	22-73	32
African American	24-32	2	19-69	10
Native American	—	—	—	—
Asian	22-63	2	—	—

Individuals Entered (Should reflect # in 5.b.)				
Racial/Ethnic Composition	Male		Female	
	Age Range	Number Entered	Age Range	Number Entered
Caucasian	23-74	19	22-69	17
African American	24	1	61-68	3
Native American	—	—	—	—
Asian	22-63	2	—	—

IRB Investigator's Progress Report-Nov2007.doc
10/04/07

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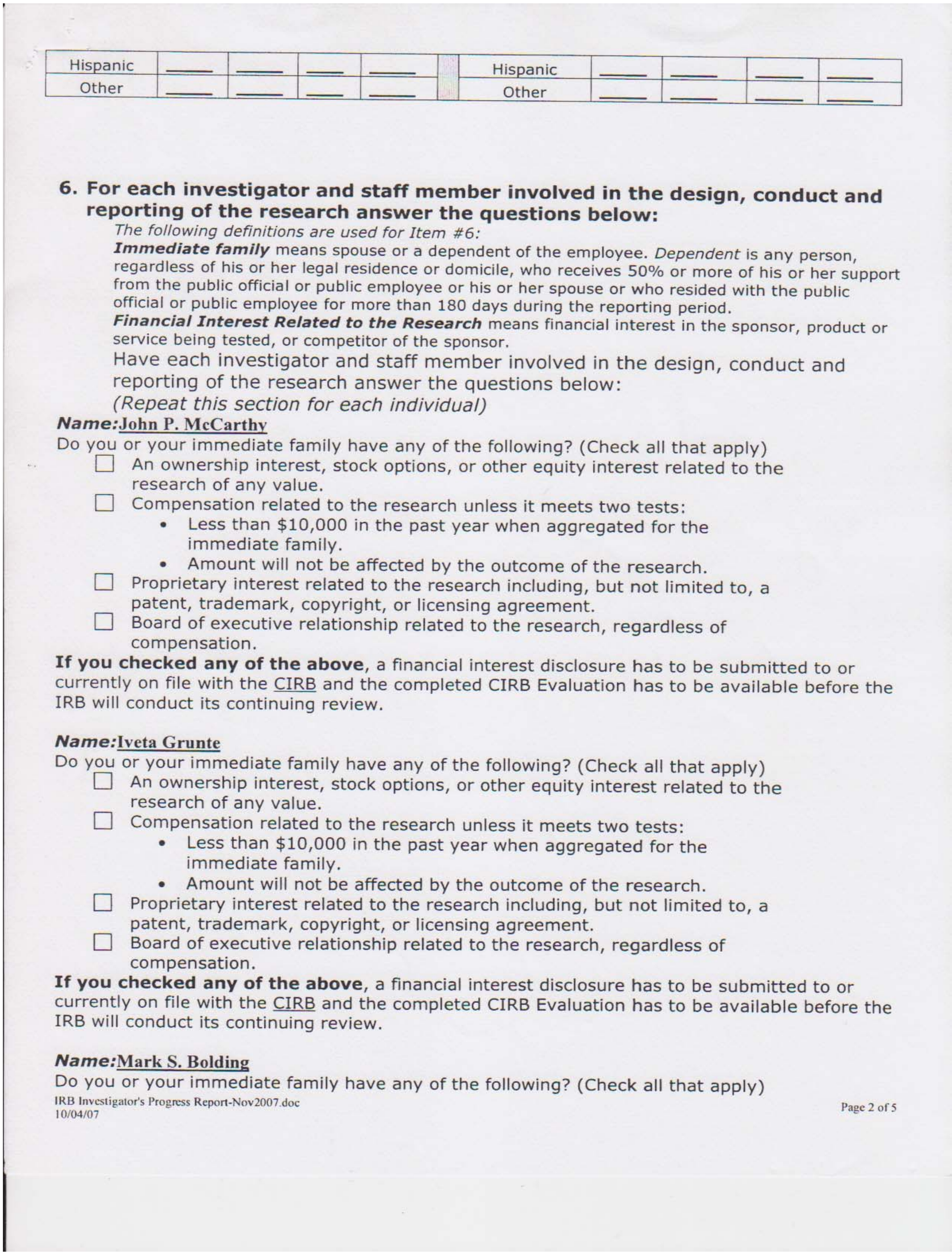

Hispanic	____	____	____	____		Hispanic	____	____	____	____
Other	____	____	____	____		Other	____	____	____	____

6. For each investigator and staff member involved in the design, conduct and reporting of the research answer the questions below:

The following definitions are used for Item #6:

Immediate family means spouse or a dependent of the employee. *Dependent* is any person, regardless of his or her legal residence or domicile, who receives 50% or more of his or her support from the public official or public employee or his or her spouse or who resided with the public official or public employee for more than 180 days during the reporting period.

Financial Interest Related to the Research means financial interest in the sponsor, product or service being tested, or competitor of the sponsor.

Have each investigator and staff member involved in the design, conduct and reporting of the research answer the questions below:

(Repeat this section for each individual)

Name: John P. McCarthy

Do you or your immediate family have any of the following? (Check all that apply)

☐ An ownership interest, stock options, or other equity interest related to the research of any value.

☐ Compensation related to the research unless it meets two tests:
  - Less than $10,000 in the past year when aggregated for the immediate family.
  - Amount will not be affected by the outcome of the research.

☐ Proprietary interest related to the research including, but not limited to, a patent, trademark, copyright, or licensing agreement.

☐ Board of executive relationship related to the research, regardless of compensation.

If you checked any of the above, a financial interest disclosure has to be submitted to or currently on file with the CIRB and the completed CIRB Evaluation has to be available before the IRB will conduct its continuing review.

Name: Iveta Grunte

Do you or your immediate family have any of the following? (Check all that apply)

☐ An ownership interest, stock options, or other equity interest related to the research of any value.

☐ Compensation related to the research unless it meets two tests:
  - Less than $10,000 in the past year when aggregated for the immediate family.
  - Amount will not be affected by the outcome of the research.

☐ Proprietary interest related to the research including, but not limited to, a patent, trademark, copyright, or licensing agreement.

☐ Board of executive relationship related to the research, regardless of compensation.

If you checked any of the above, a financial interest disclosure has to be submitted to or currently on file with the CIRB and the completed CIRB Evaluation has to be available before the IRB will conduct its continuing review.

Name: Mark S. Bolding

Do you or your immediate family have any of the following? (Check all that apply)