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Assessing the Effect of YMCA Moving for Better Balance Program on Balance, Electromechanical Delay and Body Composition

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Abstract

The YMCA Moving for Better Balance Program is a 12-week, supervised, evidence-based falls prevention program that includes eight adapted Tai Chi forms to improve strength, balance, and coordination. **Purpose:** The purpose of this study was to examine the effects of the YMCA Moving for Better Balance program on electromechanical delay, proprioception, body composition, balance, and fear of falling. **Methods:** Eleven older adults (65.9±7.3 yrs.) completed this intervention. Electromechanical delay in the hip abductor muscles and proprioception were assessed with custom-made devices. Body composition was assessed using dual-energy x-ray absorptiometry (iDXA). The 4-stage balance test, 30-second chair test, and Brief-BESTest were used to assess balance and falls risk. Finally, the Activities Balance-Specific Confidence (ABC) Scale was used to assessed balance confidence and fear of falling. **Results:** Wilcoxon matched-pairs signed-rank test comparisons of pre- and post-intervention showed significant improvements on the 4-stage balance test (p=0.008), the 30-second chair test (p=0.002), the timed-up-and-go (p=0.002), and the Brief-BESTest (p=0.003). Participants also showed significant decreases in electromechanical delay of hip muscle contraction speed (p=0.028) and improvements in lower extremity proprioception (p=0.002). Participants showed improvements on the ABC Scale, but the changes did not reach statistical significance. There were no changes in leg lean mass or bone density. **Conclusions:** These data suggest that balance improved with the YMCA Moving for Better Balance program, and these changes were not due to muscular hypertrophy but rather sensorimotor changes, specifically faster hip abductor muscle contraction speed (i.e., decreased electromechanical delay) and hip proprioception improvements.

1. Introduction

Falls are the leading cause of fatal and nonfatal injuries amongst adults aged 65 and older, with injuries from falls constituting more than half of the yearly deaths from unintentional injuries[1-3]. In 2014 alone, about 29 million total falls occurred among older Americans, and seven million were injurious[4,5]. These falls and fall-related injuries resulted in an estimated $31 billion in annual Medicare costs[6]. Therefore, falls are a major health concern for the older adult population. Furthermore, as the number of Americans aged 65 and older is projected to increase 55% by 2030, the number of falls and related Medicare costs is expected to increase as well, unless preventative measures are taken[7].

There are many factors that influence an increased falls risk in older adults. As a person ages, posture control, body-orienting reflexes, muscle strength and tone, and height of stepping decline which limits the ability of an individual to avoid a fall[8]. Age-related changes in gait and balance, vision, hearing, memory and decreased activity, more severe chronic conditions, and the higher rates of medication use are also factors influencing an increased falls risk in older adults[9,10]. Thus, there is a strong need for interventions to counteract these risk factors and decrease falls risk in older adults. One type of intervention that has gained attention in reducing falls risk is Tai Chi[11-14]. Tai Chi is a form of martial arts that employs slow and rhythmic movements that emphasizes the participants' body awareness, postural alignment, and limb coordination. Wolf et al was one of the first studies to evaluate tai-chi and its effects related to falls in older adults. Wolf et al did not find significant changes in traditionally frail older adults as a result of a Tai Chi based falls prevention program but did conclude that Tai Chi may be useful in the robust older adult population and should be further evaluated[15]. In subsequent studies, when practiced regularly, Tai Chi has been shown to improve balance, decrease falls and falls-related injuries, decrease falls risk, and decrease the fear of falling[16-19]. In addition, Tai Chi does not require special equipment, which makes it easier to implement into the community.

The *Center for Disease Control Compendium of Effective Fall Interventions* (2015) includes a program called Tai Chi: Moving for Better Balance[20]. In a 26-week randomized control trial, Li and colleagues (2005) reported that Tai Chi: Moving for Better Balance (24 Tai Chi forms) decreased falls frequency and falls risk, and improvements may become evident after three months[21]. In addition, Tai Chi Moving for Better Balance has also been shown to have a positive net benefit and was cost saving to the participants[22]. In the cost-benefit analysis by Carande-Kulis and colleagues (2015), three effective community-based falls prevention programs were assessed to estimate the costs and benefits to the third-party payer[23]. According to the analysis, the benefits of all three interventions covered the implementation cost and exceeded the expected direct medical costs. Tai Chi: Moving for Better Balance had the highest return on investment of 509% for each dollar invested. In addition, it is the most appropriate of the three programs for healthy older adults. As a result, it could be beneficial for companies to implement or encourage employees to participate to help reduce injuries.

An adapted version of Tai Chi: Moving for Better Balance is called the YMCA's Moving for Better Balance. This program reduces the number of Tai Chi forms to eight, and the program runs twice a week for an hour for 12 weeks rather than three times a week for 26 weeks. The YMCA's Moving for Better Balance program is included with *Tai Chi: Moving for Better Balance in the CDC Compendium of Effective Fall Interventions* (2015), but the efficacy of this program has not been established[24].

The majority of studies examining the efficacy of programs to improve balance in older adults have focused on outcomes of balance measures (e.g. Timed Up-and-Go Test) and falls incidences. However, the physiological changes occurring as a result of these exercise programs is not fully understood. Thus, a primary focus of the current study was to examine physiological changes, both structural and neuromuscular, in the hip abductor muscles. The performance of hip abductor muscles is of particular importance given that they prevent falling to the side, which is especially dangerous given that lateral falls are more likely to result in hip fractures compared to falls forward or backward[25]. Thus, hip muscle strength, total reaction time, and proprioception in the frontal plane are particularly important to balance. In the current study, these factors were examined via the assessment of proximal thigh lean mass, hip proprioception, and gluteus medius muscle total reaction time. Total reaction time for the motor response to a stimulus can be decomposed into two time periods, premotor time and electromechanical delay[26]. Premotor time is the time for peripheral somatosensory transmission, the nervous system's recognition of the stimulus, and generation of the motor response plan[27]. Premotor time is known to increase with age and fatigue[28, 29,] Electromechanical delay is the time lapse between the onset of muscle electrical activation and onset of torque production, reflecting both electrochemical and mechanical processes of muscle contraction[30-36]. Numerous authors have reported increased electromechanical delay in older adults compared with young individuals for muscles of the lower extremities[37-39], including the hip abductors[40].

While increased lean mass would be an indicator of increased strength of the hip abductor muscles, decreased electromechanical delay and proprioception errors would indicate improvements in the neuromuscular system. The ability to "catch" one's balance is dependent on the muscle's ability to react quickly, which is a function of the sensorimotor loop, the afferent somatosensory signal as well as the efferent motor signal to the muscle itself. Specifically for balance, any increase in time between the motor signal and muscle contraction, would increase total reaction time of muscles involved in maintaining balance. Conversely, a decrease in this time delay would decrease reaction time and likely improve balance. However, there is no known evidence of augmented speed of either the sensory or motor components of the sensorimotor loop with muscle retraining exercise.

For this study, authors examined the effects of a 12-week, class-based supervised YMCA Moving for Better Balance program on the balance and the physiological mechanisms underlying improvements in balance. The primary outcome measure used to evaluate this research question was balance, and the secondary outcome measures were hip abductor muscle electromechanical delay, hip proprioception, and body composition. The authors hypothesized that, following the 12-week program, there would be improvements in balance due to decreased hip abductor muscle electromechanical delay, decreased proprioception error and an increase in lean mass.

2. Methods

2.1 Participants

Participants ($N = 16$) were recruited for this study via flyers and direct phone calls to individuals enrolled in the YMCA moving for Better Balance program in Asheville, NC. Two participants dropped out of the study and the YMCA Moving for Better Balance Program due to conflicts with the program schedule and a desire for a different type of program. Three participants were unable to return for post-intervention assessments because they were unavailable during the post assessment time period. This left a total of 11 participants (mean age 65.9 years, SD 7.3 years; 8 female) for data analysis.

Inclusion criteria for this study included individuals who met the requirements for the Moving for Better Balance program: 1) 60 years or older, ability to independently ambulate (did not depend on assistive device) with individual concern with stability and/or mobility which was self-described or 2) 45 years or older with a chronic condition that may impact stability and/or mobility. Participants were excluded from participating in this research if they: 1) weighed more than 450 pounds (iDXA scanner weight limit), 2) were pregnant or nursing (exclusion criterion specific to the iDXA scanner), or 3) were dependent on assistive devices (due to the physical requirements of Moving for Better Balance, those dependent on assistive devices cannot register for the program). This study was approved by the Human Subjects Committee at UNC Asheville and all participants provided informed consent prior to data collection.

2.2 Intervention

The YMCA Moving for Better Balance Program is a 12-week supervised, evidence-based falls prevention program. During the 12 weeks, the participants met with a certified Moving for Better Balance instructor in class twice per week for one hour. Instructors in the program taught participants eight adapted Tai Chi forms to improve strength, balance, and coordination. In addition to the eight forms, participants completed warm-up and cool down stretches. Participants were strongly encouraged to practice outside of class. For participants enrolled in this study, attendance to in-class meetings was tracked by instructors, and participants were asked to record their home practice time for each week. Prior to starting the program, participants were asked to complete a demographic questionnaire, and baseline measures were taken including balance and mobility, gluteus medius muscle contraction electromechanical delay, proprioception accuracy, bone density, and body composition. After completion of the Moving for Better Balance program, all baseline measures were repeated.

2.3 Measures

2.3.1 balance and mobility

Balance and mobility were assessed with four measures: the Brief BESTest, Activities-Specific Balance Confidence Scale (ABC) scale, the 30-second chair test, and the 4-stage balance test. Each participant completed the Brief BESTest, an 8-item, clinically-based assessment measuring anticipatory postural adjustments, compensatory postural responses, sensory orientation, stability in gait, and the timed up-and-go test. Reliability and validity of the Brief BESTest have been established[44-45]**.** Participants also completed the ABC scale assessing self-reported confidence during 16 activities related to mobility. Their total score was determined by averaging the scores of the 16 items. Reliability and validity of the ABC Scale have been previously established[46-48].

For the 30-second chair test, participants start seated in a chair with no armrests. The test determines how many times within 30-seconds an individual can fully stand up and then fully sit back down in the chair with their arms crossed over their chest. The reliability and validity of the 30-second chair test and normative data have been established[49-50].

The 4-stage balance test is a series of four static balance assessments where the foot positions are progressively more challenging to balance. For each test, the participant tries to hold the position for 10 seconds. For the last three positions, the participant repeats the test twice, once with the right foot and once with the left foot. In the first position, the participant stands with their feet placed together. The second position is the semi-tandem stand where one foot is slightly in front of the other foot. The third position is the tandem stand where one foot is completely in front of the other foot. Finally, the last position is a one-leg stand where one foot is raised off the ground. The reliability and validity of the 4-stage balance test has been established[51-52].

2.3.2 muscle contraction response times

Gluteus medius muscle electromechanical delay (Figure 1) was measured with a custom-built device measuring the time (in milliseconds) between the onset of electrical muscle activity and muscle torque production of the bilateral gluteus medius muscles, in response to a vibratory stimulus to the plantar surface of the ipsilateral foot.

Participants stood with a comfortable stance width on a platform lined with a safety railing to prevent falls or injury. A dynamometer secured to an adjustable arm was positioned so that it lightly touched the distal thigh at the level of the lateral femoral epicondyle, bilaterally. The dynamometer was lined with thin foam padding for comfort against the participant's leg. During the test, the participant stood on a steel plate, which delivered a vibratory stimulus to the plantar surface of either the right or left foot, in random order without replacement, every four seconds by a direct current motor (5 V, 5800 rpm, 250 ms). The participant was instructed to rapidly and maximally abduct the ipsilateral hip against the padded dynamometer immediately upon feeling a vibration under one foot. A single trial consisted of one second of rest (baseline data acquisition), followed by delivery of the 250 ms vibration, and subsequent hip abduction (torque data collection for up to 2.75 seconds) (Figure 1). Each participant completed 30 trials total.

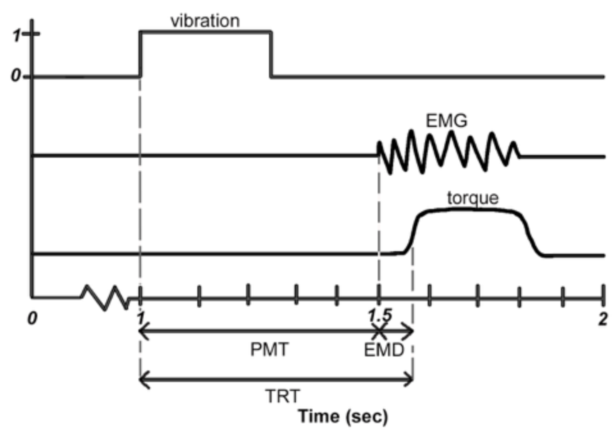

Figure 1. Electromechanical Delay

Figure 1. Illustrative example of task paradigm with vibration stimulus (on plantar surface of foot) and gluteus medius muscle contraction response times. Premotor time (PMT), electromechanical delay (EMD), and total reaction time (TRT). Adapted from reference 38.

Surface EMG (sEMG) data was acquired from the bilateral gluteus medius muscles using MyoWare Muscle Sensors (Advancer Technologies, LLC , Raleigh, NC). Electrode placement and skin preparation followed the SENIAM protocol[41]. Hip abduction isometric torque measurements were collected using a parallel beam load cell (HT TAL201) attached to the safety railing interior and positioned immediately adjacent to each of the participant's lateral distal thighs. MATLAB (MathWorks Inc., Natick, MA) code time-stamped each sEMG and torque sample and exported them to Excel. Once sEMG and torque onset values were determined, torque onset time was subtracted from the EMG onset time to determine the electromechanical delay value, so that *electromechanical delay = sEMG onset – Torque onset*. Electromechanical delay was calculated as the time difference between sEMG onset and torque onset when both signals were at 25% of their maximum activity.

2.3.3 proprioception function

The magnitude of proprioception error was measured on the participant's dominant side lower extremity with a custom-built device[42-43] that allows for rotation around the axis of a semi-goniometer to measure proprioception in the transverse plane at the hip joint. Proprioception was assessed by measuring the accuracy of actively pointing a marked line on the second toe to target angles along the semi-goniometer during two conditions, a vision condition and a no-vision condition. In the vision condition, participants viewed both their foot and the target angle; in the no-vision condition, an opaque curtain obscured the foot, requiring participants to rely on proprioception to complete the task. Ten vision condition target trials were followed by 10 no-vision target trials. Target angles were clearly visible to the participant and were located at 5° intervals, comfortably within their range of motion. The order of target angles was randomly pre-determined before the study commenced so that all participants received the same target angles in the same order. The tester both pointed to and named the target angle aloud to the participant and subsequently recorded the orientation angle of the marked toe to the nearest degree. In order to account for proprioceptive contribution to the task, the difference between error in the no-vision condition and error in the vision condition was be calculated for each target.

2.3.4 bone mineral density and body composition

Site-specific lean mass and bone mineral density was assessed using dual-energy x-ray absorptiometry (iDXA). This device has been validated for the assessments of several important health biomarkers including site-specific body composition (body fat and lean mass) and bone density in the whole body, lumbar spine, proximal femur, and wrist[53-56]. This is a common and painless procedure that involves lying supine on a padded table. To assess body composition, a full body scan was conducted. To assess bone density, site-specific scans were conducted at the neck of each femur, the lumbar spine, and the non-dominant forearm. All procedures were conducted in compliance with North Carolina Radiation Program regulations.

3. Statistical Analysis

Wilcoxon matched-pairs signed-rank tests compared pre- and post-intervention for changes in all measures.

4. Results

Wilcoxon matched-pairs signed-rank test comparisons of pre- and post-intervention (Table 1), showed significant improvements on the 4-stage balance test (*p*=0.008), the 30-second chair test (*p*=0.002), the timed-up-and-go (*p*=0.002), and the Brief-BESTest (*p*=0.003) following intervention (Figure 2). Participants also showed significantly decreased electromechanical delay of hip muscle contraction speed (*p*=0.028) and improvements in lower extremity proprioception (*p*=0.002) (Figure 3). Participants showed improvements on the ABC Scale, but the changes did not reach statistical significance (Figure 2). There were no changes in leg lean mass or bone density.

Table 1. Balance, Mobility, and Proprioception changes following intervention for participants who fully adhered to YMCA Moving for Better Balance Program (n=11)

	pre	post	Δ	p-value
Electromechanical delay (ms)	166.30 (35.01)	133.60 (27.01)	-32.70 (37.86)	0.027
Joint position sense error (deg)	5.96 (4.08)	2.33 (1.32)	-3.63 (4.23)	0.002
Brief-BESTest	16.55 (3.05)	20.64 (2.87)	4.09 (2.81)	0.0029
Activities-specific balance confidence scale	83.82 (11.48)	86.09 (11.84)	2.27 (6.72)	NS
Timed up and go (s)	9.58 (2.84)	7.39 (2.17)	-2.19 (1.25)	0.002
30-s chair test	11.41 (3.48)	15.36 (3.83)	3.96 (2.78)	0.002
4-stage balance test	8.64 (1.18)	9.72 (0.42)	1.08 (1.10)	0.0078

Mean (SD); Wilcoxon matched-pairs signed rank test exact p-value; NS=not significant

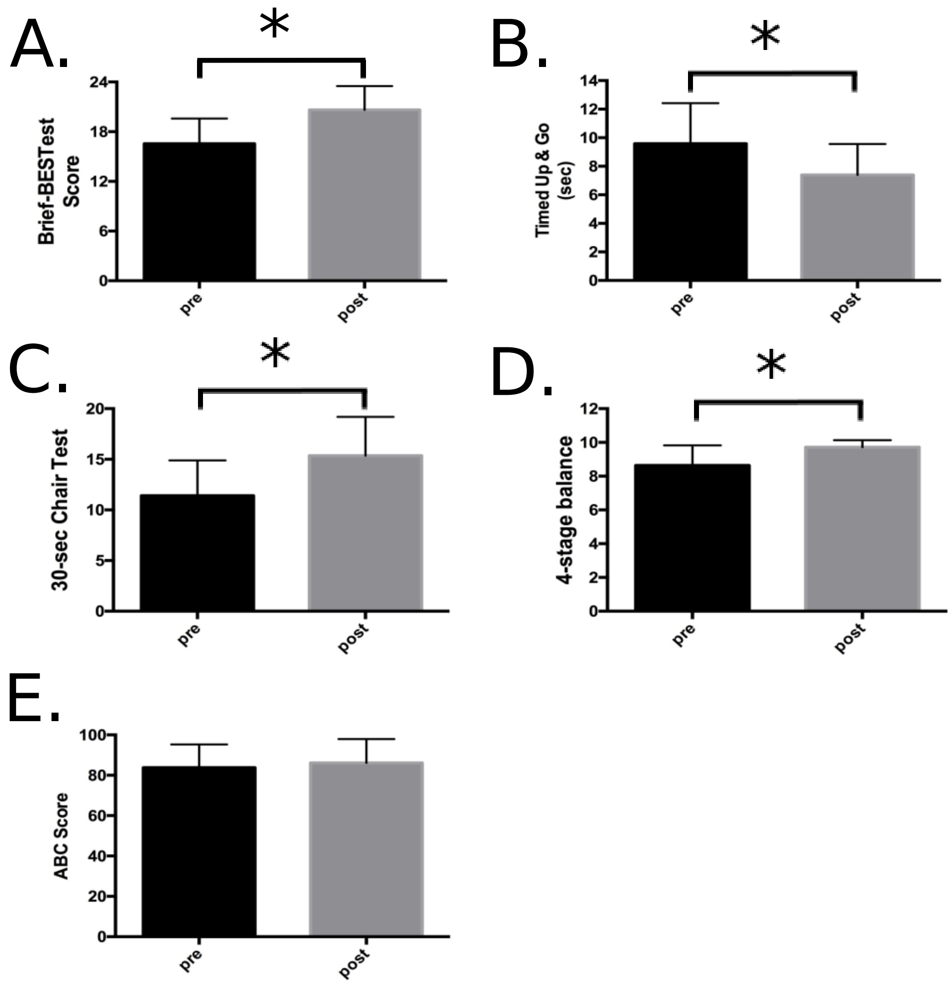

Figure 2. Balance and Mobility Results

Figure 2 Brief-BESTest score significantly improved post program (A). Timed Up & Go time (sec) sifnifcantly decreased post promgram (B). The number of repititions comleted in the 30-sec Chair Test significantly improved (C). The number of seconds partipants held the positions in the 4-stage balance test significantly imrpoved (D). The ABC score improved but did not reach significance (E). * < 0.05.

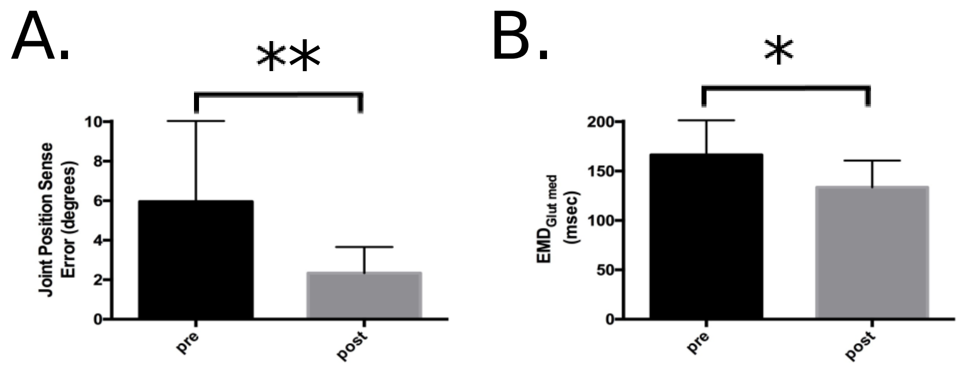

Figure 3. Electromechanical Delay and Proprioception Error Results

Figure 3 Proprioception, measured by joint position sense error (degrees), significantly decreased post program (A). Electromechanical delay (EMD) significantly decreased post program (B). * < 0.05; ** < 0.01.

5. Discussion

Given the risk of falls among older adults and the mortality associated with these falls, interventions targeting balance improvements in the older adult population are essential. Results from this study demonstrate that the YMCA's Moving for Better Balance program, one that primarily relies on Tai Chi exercises, can significantly improve measures of balance and sensorimotor function of the hip muscles, including electromechanical delay of the gluteus medius and hip proprioception.

A group of authors has examined the efficacy of a similar program using Tai Chi in older adults, and like the current study, found significant improvements in measures of balance[57]. At 3-months Li and colleagues (2005) saw scores on the Timed Up and Go (TUG) test decrease from 9.07 to 8.6 seconds. At 6 months, this time was down to 8.27. Scores for this test in the current study were similar at baseline (9.58 seconds) but decreased to an even greater extent after three months to 7.39 seconds.

The other measures of balance used by Li and colleagues (2005) were different than those used in the current study, and thus, comparisons are somewhat limited. Specifically, in the current study, a total score for the Brief BESTest was used to quantify balance, and participants saw a statistically significant improvement of 25% after this 3-month program. However, Li and colleagues (2005) differentiated scores on the Brief BESTest by the individual test (e.g. Right Leg-Stand, Left Leg-Stand) rather than quantify a total score. Improvements on these individual tests of the Brief BESTest ranged from 38% to 53%. Additionally, while the 4-Stage Balance Test was also used to quantify balance in the current study, and improvements averaged an increase of 13% post-intervention, Li and colleagues (2005) used the Berg Balance Scale and the Dynamic Gait Index which increased 7% and 8% post-intervention, respectively.

Some of the variation seen between this prior study and the current findings may be explained by different sample sizes and intervention intensity. That is, Li and colleagues (2005) had a larger sample (N = 125) complete the intervention compared to the current pilot study (N = 11). In addition, in the previous study by Li and colleagues (2005), participants completed the Tai Chi exercises three times per week compared to the current study where they completed Tai Chi two times per week. Regardless of the differences in results, both the current study and this prior study resulted in significant improvements in balance and thus, clearly demonstrate the efficacy of this type of intervention to improve balance in older adults. In fact, results from the current study demonstrate that the shorter, less intensive version of the Tai Chi program may sufficient to reap these benefits in balance and subsequent falls risk.

Interestingly, although both the current study and the prior study by Li and colleagues (2005) resulted in significant improvements in measures of balance, only participants in the previous study had significant decreases in fear of falling (from 0.62 to 0.37 after 3 months). In the current study, results from the Activities-Specific Balance Confidence Scale indicated no significant change in confidence in balance among participants. Something to consider is that these measures (balance and confidence in balance) were taken at the same time at the post-intervention visit. Thus, participants may not have been aware that they had balance improvements until they were tested. A future intervention may benefit from re-testing confidence pertaining to balance after participants received feedback that they have objective improvements in measures of balance.

The inclusion of physiological measures underlying improvements in balance and reductions in falls risk is a key addition that this study provides to the literature set. As with other studies, improvements in measures of balance were found post-intervention in this sample of older adults. In addition, there were also significant improvements in neuromuscular measures of the hip abductor muscles including a 20% decrease electromechanical delay and a 61% improvement in proprioception function. However, there were no significant improvements in lean mass in the legs among participants in this study. These findings indicate that the improvements in measures of balance were not a result of muscle hypertrophy, but were instead solely due to neuromuscular improvements. In fact, although statistical significance was not reached, decreases in leg lean mass were actually observed among participants in this study. Leg lean mass changes may actually aid in facilitating the improvements in neuromuscular measures at the hip abductor muscles. This may indicate muscle fiber size decreased. If this decrease occurred, with a smaller muscle fiber following Tai Chi intervention, the neuron to muscle fiber ratio is increased which may result in the ability for the sequence of events between the neuromuscular junction and actin-myosin contraction coupling to occur more quickly, as evidenced by the decreased electromechanical delay shown in the current study.

Taken together, the findings from this study demonstrate that the YMCA Moving for Better Balance program can be effective in improving balance among older adults. On a physiological level, these improvements appear to be a result of neuromuscular changes rather than hypertrophy of the muscle. These results provide support for the use of the YMCA Moving for Better Balance program for reducing risks of falls in older adults and may inform future intervention design that can target the neuromuscular system rather than focusing on muscle hypertrophy and strength. It is interesting to note that Tai Chi exercises are, by nature, slow movements, and yet, this type of training resulted in the "speeding up" of the neuromuscular connection. Interventions with a particular focus on quick lateral movements may result in even larger benefits in balance as their focus is on training the neuromuscular system rather than just strength of the hip abductor muscles.

The limitations of the current study must be considered when interpreting and generalizing results. First, the sample size of the current study is small, and there was not a control condition. Future studies with larger sample sizes and a control condition are recommended to further elucidate the potential benefits of this program and the underlying physiological mechanisms of changes in balance. In addition, all participants were self-selected and independently mobile. A future randomized controlled trial that would include participants with varying levels of mobility would better assess potential causal effects of the YMCA Moving For Better Balance on balance and its underlying sensorimotor physiological parameters. Nonetheless, this pilot study provides a physiological basis for balance improvements associated with increased physical activity, especially Tai Chi.

6. Notes

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