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Feature Article

The association between unilateral heel-rise performance with static and dynamic balance in community dwelling older adults

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A B S T R A C T

As a measure of both strength and muscle endurance of the plantar flexors, the unilateral heel rise (UHR) test has been suggested as a method to evaluate balance capabilities in older adults. Thus, the purpose of this study was to examine the association between UHR performance with biomechanical measures of balance in seniors. Twenty-two older adults completed two testing sessions. The first visit included UHR performance; the second visit included dynamic and static motion analysis. UHR performance was significantly associated with dynamic balance capability as measured by medial-lateral inclination angle during gait. As indicated by an analysis of center of pressure, there were significant associations between UHR performance and measures of static balance. Balance is influenced by plantar flexor performance as measured by the UHR test. We therefore suggest incorporating the UHR test in analyses of balance in seniors.

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Introduction

The increasing incidence of balance-related injuries among older adults is a public health concern.[1–3] According to the Center for Disease Control and Prevention, 1 in 3 adults 65 years and older fall each year. Twenty to 30% of these falls result in severe injuries, leading to $30 billion in annual direct medical spending.[4]

Maintaining balance encompasses the ability to stand motionless and to react to postural challenges by properly controlling the center of mass relative to the base of support. Balance is realized and sustained by an integration of sensory input from the visual, vestibular, and somatosensory systems, and subsequent motor output.[3,5,6] The ability to control balance degrades with age, in part due to gradual declines in muscular performance.[7–9] Therefore, a comprehensive balance examination should include an assessment of static and dynamic activities, as well as lower-extremity muscle endurance and strength.[2,3,6,10–12]

Previous examinations have reported linear associations between plantar-flexor performance with gait and balance capabilities in older adults.[13–18] Regarding endurance, Abdolvahabi et al (2011) demonstrated reduced balance ability following an ankle plantar-flexor and knee extensor fatiguing task in an analysis of 30 active older women.[17] Corroborating these findings, Davidson et al (2009) demonstrated a significant association between plantar-flexor fatigue and time to recover from a perturbation in healthy older and younger adults.[18] Ankle plantar-flexor strength also appears to be an important contributor to balance capabilities. For instance, recent investigations by Spink et al (2011) and Bok et al (2013) have revealed significant associations between plantar-flexor strength and measures of static and dynamic balance (postural sway, peak balance range, lateral-, and coordinated-stability).[13,16]

Expectedly, the association between plantar-flexor performance and balance is influenced by age. Wu (1998), for example, reported a significant age-related negative association between ankle plantar-flexor strength and head movements in response to a backwards perturbation on a platform.[14] Similarly, Laughton et al (2003) showed that older adults fallers exhibit significantly greater amounts of anterior-posterior (AP) sway and muscle activity during quiet standing compared with young subjects.[15] These findings indicate age-related declines in muscle, leading to diminished capability to control the center of mass.[14,15] The functional implications of these findings were demonstrated by Carty et al (2012). These researchers reported that seniors with lower limb muscle weakness of the ankle plantar-flexors were more likely to use multiple steps, compared with a single step, when recovering from a forward loss of balance.[5] These findings support the notion that

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ankle plantar-flexor performance influences laboratory measurements of balance, and highlights the importance of assessing plantar-flexor muscle performance when evaluating balance capabilities in older adults.

The manual muscle test is the most commonly used measure of strength performance in the clinic.[19–21] During manual muscle testing, patients are graded according to their ability to move voluntarily and resist an externally applied force by the practitioner.[19] Because of the small lever arms of the plantar-flexors across the foot (i.e. distance between muscle insertions and the ankle joint center), applying appropriate resistance can be challenging in healthy individuals.[22] Unsurprisingly, this creates a ceiling effect with manual muscle testing in individuals with normal strength.[23–26] Due to these limitations, the unilateral heel-rise test (UHR) has been implemented as a surrogate to manual muscle testing.[20,27] As the UHR test quantifies the number of repetitions a person can complete, it is an assessment of both muscular endurance and strength.[19,20,27]

Although the aforementioned studies have demonstrated that balance is independently associated with endurance and strength of the plantar-flexors,[13–18] no single test that incorporates both endurance and strength has been examined in relation to balance performance in community-dwelling older seniors. Therefore, the purpose of this study was to investigate the hypothesized positive association between balance performance and UHR repetition in healthy, independent, older adults.

Materials and methods

Participants

All participants were part of the Yoga Empowers Seniors Study (YESS): a single-arm, 32-week intervention study examining the biomechanics and physical adaptations associated with yoga participation by seniors. We report findings from the baseline evaluation, which included a battery of functional performance and balance-assessment outcomes. Complete data (for functional and balance-assessment measures) were available for twenty-two (6 males and 16 females) of the participants. The average age, height, and weight for these community-dwelling older adults was 71.0 ± 4.3 years, 1.67 ± 0.09 m, and 71.1 ± 15.9 kg, respectively. All participants resided in the greater Los Angeles area and were included if they were 65 years of age or older, were not high-level exercisers or frequent long walkers. For further details regarding the inclusion/exclusion criteria, please refer to Greendale et al (2012).[28] Informed consent was obtained from all participants on a format approved by the Institutional Review Board of the University of Southern California (USC).

Design & outcome measures

A cross-sectional secondary analysis of data from YESS was conducted. As a part of the baseline YESS protocol, participants attended the Musculoskeletal Biomechanics Research Laboratory (MBRL) at the USC Health Science Campus. The protocol consisted of two visits to MBRL, one-week apart. The first visit was approximately 1-h in length and consisted of functional performance measures, including the UHR test. An examination of the UHR test was of particular interest attributed to its potential for implementation as part of a comprehensive balance evaluation. The second visit consisted of a biomechanical assessment of gait and balance, as well as yoga participation. The total duration of the second visit was approximately 3 h.

Unilateral heel rise test

The UHR testing procedure and criteria for a successful repetition was predicated upon previous investigations by Lunsford and Perry (1995) and Jan et al (2005).[19,20] Initially, the height of a full heel-rise effort was assessed by asking the participant to perform a barefoot single-leg-stand on their dominant limb, defined as the leg with which they kick a ball. The participant was then instructed to stand tall on the ball of their foot with their heel as high off the ground as possible. Per the method of Yocum et al (2010), the level of the lowest edge of the heel was identified; then, the midway point from the heel to the floor was marked with masking tape on a wall.[27] For performance of the test, the participants were instructed to stand on their dominant limb, and raise their heel up and down as many times as possible at a pace of one heel-rise every 2 s, cued with a metronome.[19,20] The subjects were allowed to place a single-finger on the wall and were guarded by a practitioner for safety. The number of heel-rise cycles (i.e. the number of times the dominant heel reached the tape) was recorded. The test was terminated when the participant was unable to continue, they could no longer reach the tape, or were unable to maintain pace with the metronome. The (single) practitioner who administered the UHR test – a post-doctoral fellow in Biokinesiology – demonstrated strong reliability in this methodology.

Biomechanical assessment of balance

One week later, in order to examine center of mass profiles, participants were instrumented for a whole-body biomechanical analysis. Reflective markers were placed on a head band and over the following anatomical landmarks of the lower- and upper-extremities bilaterally: first and fifth metatarsal heads, malleoli, femoral epicondyles, greater trochanters, acromions, greater tubercles, humeral epicondyles, radial and ulnar styloid processes, and third metacarpal heads. Markers were also attached to the spinous process of the 7th cervical vertebrae, jugular notch, L5/S1, bilateral iliac crests, and bilateral posterior superior iliac spines. Based on these markers, a total of 15 body segments were modeled: the head, trunk, pelvis, the upper arms, forearms, hands, thighs, shanks, and feet. Non-collinear tracking marker plates were placed on each of these segments using previously documented procedures.[29,30] The research personnel involved with instrumentation – 2 PhDs, 2 Masters, and 2 PhD students – were reliable in their marker placement.

Three-dimensional coordinates of the body segments were recorded by an eleven-camera system at 60 Hz (Qualisys, Gothenburg, Sweden). Ground reaction forces (GRFs) were measured from separate force platforms at 1560 Hz (AMTI, Watertown, MA). With the use of Visual3D Version 4 (C-Motion Inc., Germantown, MD), standardized anthropometric data were used to calculate individual segment COM locations, and total body COM.[31] All balance measures were determined from a custom written program in MATLAB (The MathWorks; Natick, MA, USA).

Data analysis

Dynamic balance

Once instrumented, the participants were instructed by a practitioner to complete 2, 8-m walking trials, at their self-selected speed. The participants were guarded during gait activity by a Physician or Physical Therapist involved with the study. The center of pressure was determined from ground reaction forces. Peak and mean center of mass – center of pressure inclination angles in the medial-lateral direction were quantified during the stance-phase of gait.[32] Inclination angles were assessed using the methods of Lee and Chou (2006) and Silsupadol et al (2009).[32,33] A line between the participant's center of mass and the center of pressure of the

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