Original Article

Tests revealing age-related changes in the functional performance of physically active older adults

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Abstract

Problem Statement: Limited physical functional performance as a consequence of aging is considered as a possible contributor to falls in older adults, even in physically active ones. **Purpose:** This study determines which clinical and laboratory tests simulating activities of daily living could distinguish age-related differences in functional performance of physically active older adults. **Material and Methods:** In this study, 30 participants aged 60–69 years (23 females and 7 males; age 65.5 ± 1.9 years; height 168.0 ± 10.4 cm; weight 74.7 ± 13.0 kg) and 20 participants aged 70–79 years (14 females and 6 males; age 74.9 ± 5.0 years; height 166.7 ± 10.5 cm; weight 70.2 ± 12.7 kg) underwent battery of clinical and laboratory tests. Time to complete the five-repetition sit-to-stand test (5RSTS), maximal reaching distance in the frontal and sagittal plane and centre of pressure (CoP) sway in the anteroposterior (AP) and mediolateral (ML) directions during bipedal stance were evaluated. In addition, CoP sway and its AP and ML components during stair descent (CoP_{AP} and CoP_{ML}) and in the first 5 s of re-stabilization (CoP_{AP-5} and CoP_{ML-5}) were evaluated. **Results:** Older adults over 70 years of age achieved significantly longer time in the 5RSTS test (12.3%, $P = .035$, $d = .632$) and had significantly higher values of CoP sway in the first 5 s of re-stabilization (CoP_{AP-5} 19.4%, $P = .003$, $d = .889$; CoP_{ML-5} 15.7%, $P = .044$, $d = .593$) compared to those aged 60–69 years. **Conclusions:** Differences in balance control attributable to ageing were more readily seen under more challenging conditions. Only the 5RSTS test and stair descent from one step onto a compliant surface test were able to reflect differences in functional performance between two groups of physically active older adults.

Key Words: standing balance, reach tests, sit-to-stand, stair descent, falls

Introduction

Physical functional performance is defined as the ability to integrate the musculoskeletal, neuromuscular and cardiovascular systems into coordinated, efficient movements that people do in their daily lives (Cress et al., 1996). In case of older adults, this mainly concerns movements and activities of daily living. For instance, lower limb strength is a measure of physical performance, whereas the ability to descend stairs or stand up from the chair represents physical functional performance.

As indicated above, important prerequisites for optimum physical functional performance are muscular strength, cardiovascular endurance and balance qualities. With age-related alterations to the neuromuscular and sensorimotor systems, activities of daily living can become progressively more demanding to the extent that they become the challenging tasks for many elderly adults, even for high-functioning ones (Akram & McIlroy, 2011; Kanehisa & Fukunaga, 2014; Miyoshi et al., 2005). Moreover, an impaired ability to correct balance disturbances and/or to generate adequate force/power during movements experienced in everyday life predisposes older adults to a higher incidence of falls (Chari et al., 2017; Pavol et al., 2002; Startzell et al., 2000). The problem with falls in this population is not simply their high incidence; it lies in mild or severe fall-related physical injuries (Rubenstein, 2006). Further, falls that do not result in physical injuries can result in 'post-fall syndrome', including loss of mobility and independence and a more sedentary lifestyle (Royal College of Physicians, 2011). A sedentary lifestyle increases the risk of mortality from all causes; doubles the risk of cardiovascular diseases, obesity, and diabetes; and increases the risk of colon cancer, high blood pressure, osteoporosis, lipid disorders, and mental illnesses (WHO, 2002). It should be noted that the falls and associated injuries occur not only in the weak and disabled elders but even in the healthy and physically active individuals (Gryfe, Amies & Ashley, 1977; Pavol & Pai, 2002).

Considering that activities of daily living are one of the biggest contributors to falls in older adults, assessment of physical performance under conditions reflecting movements experienced in everyday life is essential. Many studies use available clinical and/or laboratory tests to assess the effect of age on functional performance in older adults with various types of diagnoses or health restrictions. On the contrary, it is not known which of these tests are sufficiently sensitive to detect age-related changes in physical functional performance of older adults in apparently good state of health and physical activity.

To this effect, this study was designated to determine the tests that simulate the activities of daily living and distinguish age-related changes in the functional performance of physically active older adults.

Materials and Methods

Participants

The population targeted was elderly adults (age ≥ 60 years) who were free of orthopaedic, neurological, and cardiovascular disorders and/or total joint replacement. A total of 50 older adults met eligibility criteria and were divided into two groups: 60–69 years old ($n = 30$; 23 females and 7 males; age 65.5 ± 1.9 years; height 168.0 ± 10.4 cm; weight 74.7 ± 13.0 kg; BMI 26.4 ± 3.2 kg/m²; no of falls = 3) and 70–79 years old ($n = 20$; 14 females and 6 males; age 74.9 ± 5.0 years; height 166.7 ± 10.5 cm; weight 70.2 ± 12.7 kg; BMI 25.1 ± 3.0 kg/m²; no of falls = 8). Participants were physically active, participating in organized physical activities and sports for at least two 60 min sessions per week and walking for more than 2 hours a day. Their physical activity level was screened by interview; this, however, was not an inclusion criterion. An informed consent form was signed by all participants. The study protocol was approved by institutional ethics committee and the procedures followed were in accordance with ethical standards for human experimentation in compliance with the 1964 Helsinki Declaration and its later amendments.

Tests and Procedures

Five-Repetition Sit-To-Stand Test (5RSTS)

Participants started this test from a sitting position with their feet comfortably on the floor during the whole test and with their back against the upright backrest of a chair. Floor to seat height was 47 cm. They were instructed to cross their arms over their chest and then to stand up all the way and sit down, as fast as possible, five times without using their arms. Timing began on the command ‘go’ and ended when the participant’s buttocks touched the chair on the fifth repetition. Time to complete the test was recorded as the participant’s score and was used for the analysis. Based on the study of Bohannon (2011), the test-retest reliability of the 5RSTS test can be interpreted as good to excellent (0.64 to 0.96.) in most populations and settings.

Functional Reach Test

The functional reach test is a clinical test that measures forward reaching ability from a bilateral stance (Duncan et al., 1990). Participants stood parallel to a wall with their feet in a comfortable position behind a line perpendicular to the wall. Their upper limb closer to the wall was positioned with their shoulder flexed to 90 degrees parallel to the wall, with their elbow extended and their hand in a fist. The position of the knuckle of their middle finger was marked on the wall (point 1). The subject was then instructed to keep their feet flat on the floor and lean forward as far as possible without losing their balance, touching the wall, bending their knees, rotating or flexing their trunk, or taking a step. The position of their knuckle was marked again at the point of furthest reach along the wall (point 2). Functional reach in a forward direction was defined as the distance in cm between point 1 and point 2. Two attempts using their right limb were recorded, and the better attempt was analyzed. Good to excellent reliability (ICC = 0.75–0.99) was previously reported for this test in older community dwelling population (Bennie et al., 2003; Giorgetti, Harris & Jette, 1998; Rockwood et al., 2000).

Lateral Reach Test

The lateral reach test is a clinical test that measures reaching ability to the side in a bilateral stance (Brauer, Burns & Galley, 1999). Participants stood with their back as close as possible to the wall and with their feet comfortably placed on the floor. They were asked to abduct their arm to 90 degrees and extend their elbow. The position of the tip of their middle finger was marked on the wall (point 1). The subject was then instructed to reach sideways as far as possible without overbalancing, taking a step, bending their knees, rotating or flexing their trunk, or touching the wall. The position of the tip of their middle finger was marked again at the point of furthest reach along the wall (point 2). Lateral reach was defined as the distance in cm between point 1 and point 2. Two measures on their right and left sides were recorded and the better attempt on each side was analyzed. Excellent test-retest reliability (0.90–0.99) was previously reported for the lateral reach test (Brauer S, Burns Y & Galley, 1999; Takahashi, Ishida & Yamamoto, 2006).

Standing Balance

In biped balance test, participants stood barefoot on force platform (AMTI OR6-5, Advanced Mechanical Technology, Inc., Watertown, MA, USA; sampling frequency 200 Hz) in a comfortable upright posture with their eyes open and their arms alongside their body. They were instructed to minimize postural sway for 30s during the test. Force plate recording began immediately after the participants stabilized their posture. The mean center of pressure (CoP) sway from three measures in the anteroposterior (AP, CoP_{AP}) and mediolateral (ML, CoP_{ML}) directions were used for further analysis. The same test was also performed on an

unstable surface of a foam mat (Airex Balance Pad, Airex AG, Sins, Switzerland; height 6 cm, width 50 cm, depth 41 cm) placed on top of the force platforms.

Stair Descent On a Compliant Surface

Balance control was assessed during and after stair descent from a one-step wooden staircase (height 20.8 cm, width 46.0 cm, depth 38.4 cm). It was placed in front of two force plates (AMTI OR6-5) covered by a foam pad (Airex Balance Pad). Participants started from an upright position on the top step and were instructed to step down at their preferred speed. Stair descent was initiated with the dominant limb, followed by the non-dominant limb onto the same level (step-by-step strategy) with subsequent quiet standing (re-stabilization phase) for 30 s.

The test was repeated three times. Based on the initial screening, the participants did not use handrails during stair locomotion in their daily lives. Accordingly, to obtain data under the most realistic conditions, stair descent was performed without the use of handrails. Therefore, two assistants stood at each side of the participant and provided security in case of loss of balance.

Data Analysis

The stair descent phase was defined by the ground contact of the dominant limb and non-dominant limb. The ground contact (of the limbs with the mat) was defined as the instant when the vertical component of the ground reaction force (vGRF) measured by the force plate exceeded 10 N. A vGRF value of 10 N is often used as a threshold for contact in gait-related studies (O'Connor et al., 2007; Ghousayni et al., 2004). Because the force plates used for the measurement generate a low level of background noise, 10 N was a reasonable threshold value to avoid missing relevant data and was high enough so that noise was not misinterpreted as actual contact. Sway, calculated as the standard CoP in the AP and ML directions, was assessed during this phase.

The onset of the re-stabilization phase was defined as ground contact of the non-dominant limb. The re-stabilization phase lasted for 30s, but the CoP sway in both directions was only analyzed for the first 5 s (CoP_{AP-5} ; CoP_{ML-5}). Previous studies suggested that the first 5 s after postural perturbations are crucial when assessing balance control in older adults (Jonsson, Seiger & Hirschfeld, 2004; Tsang et al., 2016). The CoP sway coordinates in the AP and ML directions were filtered using a fourth-order low-pass Butterworth filter with a cut-off frequency of 10 Hz. Subsequently, the mean CoP sway in each direction was computed. Data analysis was performed using MATLAB software (v. 2018a, MathWorks, Inc., Natick, MA, USA).

Statistical Analysis

The Shapiro-Wilk test was used to assess data distribution, and the data was found to follow a normal distribution. Independent sample t test was used to determine differences between groups. Statistical analyses were performed using SPSS for Windows, version 25 (SPSS, IBM Corporation, Armonk, NY, USA). An alpha level of .05 was considered significant for all analyses. The effect size was evaluated using Cohen's d (large effect $d > 0.8$, medium effect $0.5 < d < 0.8$, small effect $d < 0.5$). Variables are presented as mean $\pm$ standard deviation (SD).

Results

Groups did not differ significantly in their baseline characteristics ($P > .05$).

Older adults aged 70–79 years achieved significantly longer time in the 5RSTS test than those aged 60–69 years (12.3%, $P = .035$, $d = .632$) (Fig. 1). In addition, they had significantly higher values of CoP sway in both directions in the first 5 s after stair descent compared to those aged 60–69 years (CoP_{AP-5} 19.4%, $P = .003$, $d = .889$; CoP_{ML-5} 15.7%, $P = .044$, $d = .593$) (Fig. 2 and Fig. 3).

Fig. 1. Mean time to perform sit-to-stand test for older adults aged 60–69 and 70–79 years.

Fig. 2. Mean CoP sway in the AP direction during the first 5 s after stair descent for older adults aged 60–69 and 70–79 years.

Fig. 3. Mean CoP sway in the ML direction during the first 5 s after stair descent for older adults aged 60–69 and 70–79 years.

Based on the previously reported reference values for the 5RSTS test (Bohannon, 2006), we can state that 20 (66.7%) older adults aged 60–69 years and 12 (60%) older adults aged 70–79 years displayed ‘normal performance’. The remaining 10 (33.3%) participants aged 60–69 years and 8 (40%) participants aged 70–79 years exceeded the upper limits of the reported norms, indicating worse than average performance. In addition, 1 (3.3%) participant from the younger group of older adults and 5 (25%) participants from the older group required over 15 s to complete the test, which is considered a threshold value associated with a 74% greater risk of recurrent falls in older adults over 65 years (Buatois, Miljkovic & Manckoundia, 2008).

Statistical analysis failed to show significant differences between the groups in the functional reach test (60–69 vs 70–79 years; 23.9 ± 7.0 cm vs 25.9 ± 5.0 cm; $P = .297$, $d = .318$) and lateral reach test to the right and left sides (60–69 vs 70–79 years; 17.9 ± 3.8 cm vs 17.6 ± 3.8 cm, $P = .803$, $d = .079$; 18.1 ± 4.3 cm vs 17.2 ± 4.1 cm, $P = .475$, $d = .213$). In addition, there were no significant differences between the groups in CoP sway in either direction during stair descent (60–69 vs 70–79 years; $\text{CoP}_{\text{AP}} 39.4 \pm 24.7$ mm vs 38.1 ± 22.8 mm, $P = .714$, $d = -.054$; $\text{CoP}_{\text{ML}} 24.1 \pm 17.7$ mm vs 30.9 ± 30.7 mm, $P = .614$, $d = .287$). In addition, no significant between-group differences in CoP sway in either direction were identified during quiet stance on firm (60–69 vs 70–79 years; $\text{CoP}_{\text{AP}} 4.3 \pm 1.2$ mm vs 4.4 ± 1.1 mm, $P = .308$, $d = .086$; $\text{CoP}_{\text{ML}} 1.8 \pm 0.8$ mm vs 2.2 ± 0.9 mm, $P = .244$, $d = .476$) and foam surfaces (60–69 vs 70–79 years; $\text{CoP}_{\text{AP}} 8.7 \pm 1.9$ mm vs 9.3 ± 1.7 mm, $P = .308$, $d = .329$; $\text{CoP}_{\text{ML}} 5.6 \pm 1.8$ mm vs 5.9 ± 1.1 mm, $P = .449$, $d = .192$).

Discussion

Participants aged 70–79 years were significantly less efficient at correcting AP and ML CoP sway during the first 5 s after stair descent and needed longer time to complete the 5RSTS test than participants aged 60–69 years. These findings could point to a limitation in the transition from dynamic to static state and vice versa with advancing age. Impairments in transition movements may put older adults at a higher risk for falls (Vander Linden, Brunt & McCulloch, 1994).

Stair descent balance control was assessed in two distinct phases: a dynamic and a static phase. We found a limitation with advancing age in balance control in both directions during the first 5 s after stair descent. It is generally known that older adults are less efficient at using ankle strategy which is key to AP balance control (Porter&Nantel, 2015). Less efficient AP balance control during step-by-step stair descent predisposes older adults to a higher incidence of falls, which generally occur in the anterior direction (Bosse et al., 2012; Studenski, Duncan&Chandler, 1994; Williamson&Fried, 1996). On the other hand, less attention is typically paid to ML balance control in relation to stair locomotion despite the fact that increased sideways motion is also associated with a greater risk of falls in this population (Lord et al., 1999; Maki, Holliday&Topper, 1994). After stair descent, higher values of CoP sway in ML direction than AP direction were found in both groups of participants. This could be a result of reduced efficacy of foot and ankle proprioceptive inputs due to the foam mat support surface. It is known that a compliant support surface, such as a foam mat, can disturb normal stepping patterns and movement strategies (Marigold&Patla, 2005). The significant changes in ML balance control identified in the first 5 s of re-stabilization may also partly result from an inability of older adults to rapidly stabilize the head, trunk, and arms in the frontal plane while stepping down. During the transition from double- to single-limb stance, the base of support is significantly reduced such that the center of mass (CoM) rapidly falls downward and laterally toward the unsupported swing side (Johnson et al., 2004).

It is noteworthy that stepping down is performed not only during stair descent, but also in many other everyday activities, such as stepping down from a curb, alighting from public transport, or walking downhill. Moreover, it is not always performed on a firm and stable surface such as in a real-life situation. Compliant surfaces such as carpet, grass, sand, or snow can further challenge the already disturbed somatosensory feedback and balance control in older adults (Allum et al., 2002; Marigold&Patla, 2005; Moghadam et al., 2011). In such circumstances, stepping down can more easily lead to falls.

Another finding was that group of older adults over 70 years of age required significantly longer time to complete the 5RSTS test than those aged 60–69 years. On average, the sit-to-stand (STS) movement is executed at least 45 times per day by most community-dwelling people (Bohannon, 2006). During the STS transition, the CoM of the body is moving forward and upward. For older adults, it may be a challenge to control and stabilize their moving CoM repeatedly and dynamically, especially at the end of the STS movement. In particular, the CoM forward motion must be precisely controlled to successfully maintain AP stability and, therefore, to prevent falls (Akram&McIlroy, 2011). Considering individuals' results in relation to fall risk, 25% of participants aged 70–79 years required over 15 s to complete the test. Older adults who take more than 15 s to complete the test have a 74% greater risk of recurrent falls than those who take less time, independent of other major risk factors, including a history of falls (Buatois et al., 2008). In addition, the same number of participants (25%) aged 70–79 years had scores in the functional reach test which indicated a moderate risk of falls. It should be noted that 25% of the older adults in our study aged 70–79 years reported falls in the previous 3 months before study enrollment. However, these falls occurred mostly during sports activities. Even though the older adults in our study were physically active, our findings indicated a risk of falls in 25% of them. A possible reason for this could be a lack of physical training specificity. The physical activity performed by our participants was predominantly aerobic (i.e., walking, cycling, hiking, aerobics, and swimming), which is typical for this population (Andrieieva et al., 2019). However, this type of physical activity has no impact on the musculoskeletal and neuromuscular system and, therefore, on the sit-to-stand.

The ability to descend stairs and the ability to stand up from a chair once or repeatedly are basic requirements for daily locomotion but these are nevertheless some of the most challenging and hazardous daily activities performed by older adults (Akram&McIlroy, 2011; Cluff&Robertson, 2011; Kanehisa&Fukunaga, 2014; Reeves et al., 2008). Compared to other everyday activities such as walking or reaching for objects, these activities impose higher neuromuscular and sensorimotor demands to control the body's CoM during movement (Akram&McIlroy, 2011; Bosse et al., 2012; Kanehisa&Fukunaga, 2014; Lee&Chou, 2007). It is well known that aging deteriorates these systems, thus increasing the risk of falling. As it was previously observed, lower limb strength is one of the most important factors that affect sit-to-stand and stair descent locomotion (Bohannon et al., 2010; Tiedemann, Sherrington& Lord, 2007).

Conclusions

Of the whole testing battery, only the 5RSTS test and stair descent test were able to distinguish differences in functional performance between two groups of physically active older adults aged over 60 years of age. The results of both tests indicated a limitation with advancing age in the activities with higher demand on transition from dynamic to static state and vice versa. Physicians and physiotherapists should therefore preferentially use these tests to detect age-related changes in physical functional performance and to prevent falls. These findings could be also very important to be considered when planning for physical programs for older adults.

Conflict of interest statement - None declared.

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