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The limits of stability and muscle activity in middle-aged adults during static and dynamic stance

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ABSTRACT

Balance control plays an important role in maintaining daily activity. However, studies on postural control among middle-aged adults are scarce. This study aims (i) to examine directional control (DCL) and electromyography activity (EMG) for different stability levels, and (ii) to determine left–right asymmetry for DCL and muscle activity among sedentary middle-aged adults. Twenty healthy, middle-aged adults (10 males, 10 females; age = 50.0 ± 7.5 yrs; body height: 1.61 ± 0.10 m; body mass: 70.0 ± 14.5 kg) participated in the study. EMG for left and right side of rectus femoris (RF), biceps femoris (BF), and medial gastrocnemius (MG) were recorded. Two-way repeated measures analysis of variance was used to assess the effect of dynamic level on DCL and EMG, whereas independent sample *t*-test was conducted to analyse the asymmetries of DCL and EMG for the left and right leg. When the dynamic tilt surface increased, DCL scores significantly decreased (except forward, forward–rightward, and backward–leftward direction) and only RF muscle indicated significant differences. Left–right asymmetry was found in BF and MG muscles. No significant gender difference was observed in DCL and EMG. These data demonstrated that increased dynamic tilt surface may increase the displacement of center of pressure of certain directions, and stimulate RF activity in dynamic stance among sedentary middle-aged adults. Further studies should be conducted to examine the dynamic stance and muscle activity of the lower limb in age-matched patient groups with balance abnormalities.

1. Introduction

Middle-age is the transition stage between young adult and elderly; people in this stage undergo physical, biological, and psychological changes (Jeong, 2010). Aging naturally deteriorates sensory systems, muscle mass, and further affects general balance. Poor balance is related to the risk of falling and injury in lower extremity (Maki et al., 2011; Winter, 1995). Falls may result in bone fractures and head injuries, induce fear of falling, and affect quality of life (Alexander et al., 1992; Sterling et al., 2001).

Changes in balance ability of middle-aged adults are associated with the deterioration of musculoskeletal system, cognitive tasks, and visual and vestibular systems (Seidler et al., 2010). Aging deteriorates physiological systems (Błaszczyk and Michalski, 2006); reaction time, speed of learning, and functional mobility are significantly lower in middle-aged adults than in younger ones (Bernard-Demanze et al., 2009). According to Fransson et al. (2004), middle-aged adults tend to have better response latency and motion complexity with eyes open. Hunter et al. (2000) noted that physical activity delays the impairment of age-related changes in muscle strength and the risk of obesity and falling are reduced. Anderson et al. (2016) reported increased core muscle activation after short-term training programs, which suggest improvement of muscle coordination and efficiency among middle-aged women.

Static and dynamic stance balances are used to assess independence of daily living activities. Dynamic stance balance is crucial for motor control and is dependent on center of gravity (CoG) control, weight shifting, and active muscles (Melzer et al., 2009; Pugh et al., 2011). Limits of stability (LoS) is used to control dynamic stance in fall risk screening and functional stability of healthy adults (Juras et al., 2008). The stance control of LoS refers to the maximum voluntary distance or angle in which an individual can regulate CoG in a given direction without losing balance (Horak et al., 2005). LoS stance control involves functional, anatomic, mechanical limit, and internal body shifting to maintain stability without changing the base of support (Kolarova et al., 2013).

Several studies investigated the upright stance performance of the general population. These studies mostly focused on young adults and the elderly. Limited research has been conducted on

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middle-aged adults. This group belongs to an important life stage because they face declining balance ability. This study provided the baseline for upright stance patterns and muscle activity in middle-aged adults to improve independent dynamic control and allow them to actively prepare for elderly life. Thus, the aim of this study was to determine the changes of directional stability and activation of lower limb muscle in static and dynamic stance for sedentary middle-aged adults. The symmetry of directional stability and muscle activation between left and right legs was also examined. We hypothesized that directional stability will decrease with increasing tilt angle of moving surface and muscle activation and displacement of center of pressure (CoP) will be symmetrical between left and right legs.

2. Methods

2.1. Participants

Twenty normal middle-aged adults (10 males, 10 females) were recruited (mean age = 50.0 ± 7.5 yrs; body height: 1.61 ± 0.10 m; body mass: 70.0 ± 14.5 kg) (Table 1). The following criteria were observed for inclusion of participants: (i) aged over 40–60 years, (ii) active and independent walkers with sedentary lifestyle, (iii) with normal vision, (iv) can perform normal activities independently, (v) without history of neurological, visual, vestibular, or balance impairments; (vi) without history of surgery to the lower limb, and (vii) with right dominant leg. The study was approved by the University of Malaya Medical Ethics Committee (MEC 895.7). After explaining experimental procedures and risks to the subjects, they gave their written consent for the study. Before the experiment, participants were required to complete the Berg balance scale to evaluate their daily balance functionality. The average Berg balance score obtained for this study was 55.9 ± 0.3.

2.2. Instrumentation

Biodex Balance System (Biodex Medical System Inc., Shirley, New York) was used to measure displacement of CoP. This system is composed of a circular platform that allows 0–20° of platform surface tilt in a 360° range of motion. Data were sampled at a frequency of 100 Hz. A microprocessor-based actuator adjusted the level of resistance of 8 springs to control the tilt degree of the circular platform for stability limit. Spring is made from music wire with a spring rate of 13.81 N/cm. Spring compression generates 88.9 N of force (Arnold and Schmitz, 1998). LoS test for the circular platform involves 12 dynamic stability levels that ranges from 1 (most unstable) to 12 (most stable). The measured parameter for LoS was directional control (DCL) scores for 8 predetermined target positions in the forward, backward, rightward, leftward, forward–rightward, forward–leftward, backward–rightward, and backward–leftward directions (Fig. 1A). Fig. 1B shows the calculation method for straight line distance to target for LoS. The following formula used to calculate LoS is applied:

$$\text{Score }\% = \frac{\text{Straight Line Distance to Target}}{\text{number of samples}}x100$$

Muscle activities were analyzed using the Trigno$^{\text{TM}}$ Wireless EMG System (Trigno$^{\text{TM}}$ Wireless, Delsys Inc., Boston, Massachusetts) and the Trigno parallel bar surface sensors ($37\ \text{mm}^3 \times 26\ \text{mm}^3 \times 15\ \text{mm}^3$, Trigno$^{\text{TM}}$ Wireless, Delsys Inc.). After the skin was cleaned and swabbed with alcohol to minimize skin resistance, electrodes with an adhesive skin interface were placed in the appropriate position. According to Surface Electromyography for Non-Invasive Assessment of Muscles Recommendations, electrodes were placed over left and right rectus femoris (RF), biceps femoris (BF), and medial gastrocnemius (MG) (Hermens et al., 1999).

2.3. Experimental protocol

All tasks for LoS in the Biodex Balance System were randomized to eliminate order effects. Participants stood barefoot on the Biodex Balance System. Electrodes were attached to them and their hands placed by their side. The position of the feet was standardized to minimize measurement error. The footprints of participants were marked for consistency of consecutive trials. Once the test commenced, participants were instructed to lean as far as possible in a particular direction. Real-time feedback was illustrated on the display screen of the Biodex Balance System. Eight directions were used for the LoS. Participants were required to control the cursor (shown on the display screen) to coincide with the target without lifting their feet or flexing their hips. A minimum of two-second holding time in the leaning position was required before participants could return the cursor to the initial position at the center. The stability level of LoS is defined as the stiffness of the foot platform (Biodex Medical Systems, 1999). Increased stability level pertains to the increase in the tilt angle of the moving platform, whereas platform stiffness decreases as stability level increases. The experimental task was performed using five platform stability levels, namely, 4, 6, 8, 10, and 12. These levels facilitated 14°, 11°, 7°, 4°, and 0° deflection from any direction. Level 12 was set as the control level. Two practice trials for each level were performed before the test commenced. Three consecutive trials were performed under each level of LoS, and a one minute rest period was allowed between trials. All participants were fitted with a harness to prevent falls during the test.

Table 1
Participant anthropometric characteristics.

	Men (n = 10)	Women (n = 10)
Age, yr	48.4 ± 12.1	50.1 ± 4.2
Weight, kg	74.1 ± 10.9	65.9 ± 74.1
Height, m	1.68 ± 0.05	1.54 ± 0.08
BMI, kg/m^2	26.2 ± 3.6	27.8 ± 6.7
Berg Balance Score	56 ± 0	55.9 ± 0.32

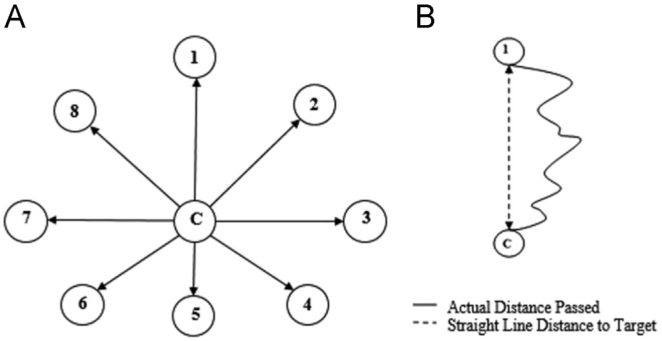

Fig. 1. The protocol of the LoS test. (A) LoS directions are defined as 1: forward; 2: forward–rightward; 3: rightward; 4: backward–rightward; 5: backward; 6: backward–leftward; 7: leftward; 8: forward–leftward. (B) The calculation of LoS with the resultant CoP displacement in the BBS.

2.4. Data analysis

For LoS, DCL scores for rightward, forward–right, and backward–rightward were averaged as the right side of DCL. Scores for leftward, forward–leftward and backward–leftward were averaged as the left side of DCL. The right and left side of DCL were used to determine the left–right asymmetry of DCL for different stability levels.

For all electromyography (EMG) channels, the raw EMG signal was collected at 4000 Hz and stored using EMGworks® Acquisition Software (Version 4.1.7, Delsys Inc., Boston, Massachusetts). The raw EMG signal was filtered using a fourth order Butterworth filter with 20–450 Hz filter to eliminate movement artefacts. For normalization, the root mean square (RMS) for 30 s of resting-state muscle activation in sitting posture was obtained as baseline value. After excluding EMG data from the first and last seconds, EMG values at the dynamic-stance state were converted to RMS. All RMS values calculated for RF, BF, and MG muscles at the dynamic-stance state were normalized with baseline values to provide an expression of relative muscle activation. The mean RMS of EMG values of three consecutive trials were averaged. Muscle activation in the left and right leg was compared for RF, BF, and MG.

2.5. Statistical analysis

Data were expressed as mean values ± standard deviations. The Kolmogorov–Smirnov test was used to identify data normality of distribution. The analysis of normality test showed that all data were normally distributed. Independent sample t-tests were conducted to identify differences in gender, left and right leg of DCL, and muscle activity. The alpha level for the t-test was set to 0.05. Two-way repeated measures ANOVA with 5×8 was used to examine differences between stability level and DCL. Two-way ANOVA with 5×6 (stability level x muscle activation) was tested to evaluate significant effects associated with stability levels and muscle activation of lower limb. F-ratio correction was applied with Greenhouse–Geisser (Epsilon, $\varepsilon < 0.75$) and Huynh–Feldt tests ($\varepsilon > 0.75$) if the data violated sphericity assumption ($p < 0.05$) in Mauchley's test. Post hoc Bonferonni test was implemented to identify significant differences in multiple comparisons. The alpha level for ANOVA was set at $p = 0.002$ after Bonferroni correction. Statistical tests were executed using SPSS Version 22.0 (SPSS for Windows, IBM Inc., Chicago, IL, USA).

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