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Kinematic variability of the head, lumbar spine and knee during the "walk and turn to sit down" task in older and young adults

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ABSTRACT

This study investigates the kinematic variability of the head, lumbar spine and knee during the various walk and turn to sit phases in older and young adults. Sixteen older adults and eighteen young adults were recruited for this study. Each subject performed the "Walk and turn to sit down" test. A 16-channel telemetry system with electrogoniometers and an inclinometer was used to record the kinematic data. The turning step was divided into braking, mid-stance, swing and terminal load phases for kinematic analysis. The results showed that the older adults had a lower displacement angle and velocity of the lumbar spine, head and knee during different turning phases than the young adults. However, older adults performed turning with a higher variability in angular velocity of head flexion than the young adults during the turning step. The onset of lumbar movement and lateral flexion of the head occurred significantly earlier in older adults than in the young adults during turning.

Conclusion: Older adults more cautiously control their motion by changing their trunk movement amplitude, velocity and timing in relation to their lower extremity movements during turning. The larger variability in angular velocity of head flexion may imply that older adults cannot precisely estimate the required movement for smooth turning.

1. Introduction

"Walking and turning to sit down" is a movement that is commonly performed in daily living [1–4]. Most falls experienced by elderly persons occur during walking or in positional transitions [5,6]. Previous studies have used the "change travel direction" or "standing turning" task to analyse walking speed, step width, centre of mass (COM) motion [7,8] and sequence of body segment [4] motion during the turning step. These studies indicate that older adults use the same segmental sequence as young adults [4], but older adults reduce walking speed and increase step width just prior to the turn, combined with delaying centre of mass motion [7]. Other studies have indicated that older adults exhibit changes in the segmental spinal range of motion associated with postural instability while turning [8,9]. Changing direction during locomotion requires coordinated control of the three-dimensional motion of the head, trunk and lower limbs. Head stabilization and motion coordination between the head and trunk may help to balance the body and provide a stable base for visual control of navigation [7,10,11]. Healthy older adults have reduced maximal range of motion in these segments due to the natural ageing process and may therefore perform activities closer to their maximal motion capacity during turning. Therefore, the neuromuscular system needs to adjust onset timing and amplitude of motion in order to maintain balance. Previous studies have investigated head [10], lumbar and hip motion [8], as well as total rotational movement [4], while walking on a curve. Studies reporting on control of the head, lumbar region and knee motion involved in different phases of turning to sit down are as yet scarce.

The variability of motor strategy in an individual's gait pattern may be regarded as a sign of adaptability for successful locomotion, or a sign of impaired postural control [9,12]. Previous studies involving older individuals have revealed increased step variability [13–16] and decreased efficiency of limb motion and muscle activity [17] during straight gait. One study indicated that frail older people had lower medio-lateral but higher vertical and antero-posterior trunk variability than the healthy group during straight gait [9]. Another study indicated that variability of knee kinematics during walking was positively related to number of falls in patients with knee osteoarthritis [18]. It has been recommended that different gait variability measures representing different constructs should be included in gait analysis to enhance our understanding of motor adaptation in older adults [17].

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The impulse of the ground reaction force during turning has been found to be significantly greater compared to that observed during straight gait, indicating a need for increased support, medial shifting, braking and propulsion [19,20]. This may indicate a tendency for the joint motion and muscle activity to be more variable during a turning task. The purpose of this study was to compare the kinematic variability in frontal and sagittal planes between older and young adults during different phases of turning to sit down. Understanding these differences could be beneficial to practitioners for utilising turning as a task to improve motor function, and to evaluate risk of falling.

2. Materials and methods

2.1. Subjects

Sixteen older adults (OA, 8 males, 8 females, age: 72.9 ± 5.5 years; mean height: 156 ± 7.0 cm; mean weight: 60.4 ± 9.7 kg; mean BMI: 24.6 ± 3.2 kg/m^2) and eighteen young adults (YA, 8 males, 10 females, age: 20.9 ± 0.5 years mean height: 162 ± 7.7 cm; mean weight: 53.8 ± 8.9 kg; mean BMI: 20.4 ± 2.1 kg/m^2) were recruited from local communities. All were able to walk independently and follow guided movements. Participants were required to have no history of stroke, arthritis, musculoskeletal lesions affecting the trunk or lower limbs, spinal or lower extremity surgery and no self-reported falls within the past six months. Prior to the study, all participants gave informed consent, and the procedures were approved by the local institutional ethics committee.

2.2. Walk and turn to sit test

Subjects were asked to sit on a chair with back support (the chair was 48 cm high, 45 cm deep and had a back height of 40 cm) with their heels contacting the ground. At the sound of an alarm, the subjects were asked to stand up and walk 3 metres, turn to the left and return to the chair to sit down at their comfortable walking speed. For safety and control of step variability [1,2], the participants were asked to practice turning with their right leg first, and then take four steps before returning to the target chair, referring to the markers on the ground (Fig. 1a). During the following three tests (formal), the participant was not restricted as to which foot was used to perform the turn, and the second trial was used for gait analysis. One foot switch was attached to the heel on the right sole, and another was placed under the 1st metatarsal to monitor the gait cycle. The kinematic changes in the sagittal and frontal plane of the head were monitored using inclinometers (two dimensional inclination sensor, Noraxon U.S.A. Inc.) located on the right side of a hat (Fig. 2). A positive value was assigned to head flexion and a negative value was assigned to head extension in the sagittal plane. Head motion in the frontal plane was defined as positive when the head was side-bending to left, and negative when the head was side-bending to the right [21] (Fig. 2). The angular displacements of the lumbar spine and knee were monitored using electrogoniometers (Noraxon U.S.A. Inc.) located on the lumbar spine and the lateral side of the right knee [22,23] .The kinematic signals were synchronised by a 16-channel telemetry system (Noraxon U.S.A. Inc.) with a 1500 Hz sampling frequency.

2.3. Joint kinematic and variability analysis

Based on the video recordings and the foot switch signals, the turning step prior to sitting down was selected for kinematic and variability analysis. The turning step of the right side was further divided into 4 phases (Fig. 1b): braking (the time from right heel strike until the left toe was lifted), mid-stance (the time from when the left toe was lifted until the right heel was lifted), swing (the time from when the right heel was lifted until right heel strike),

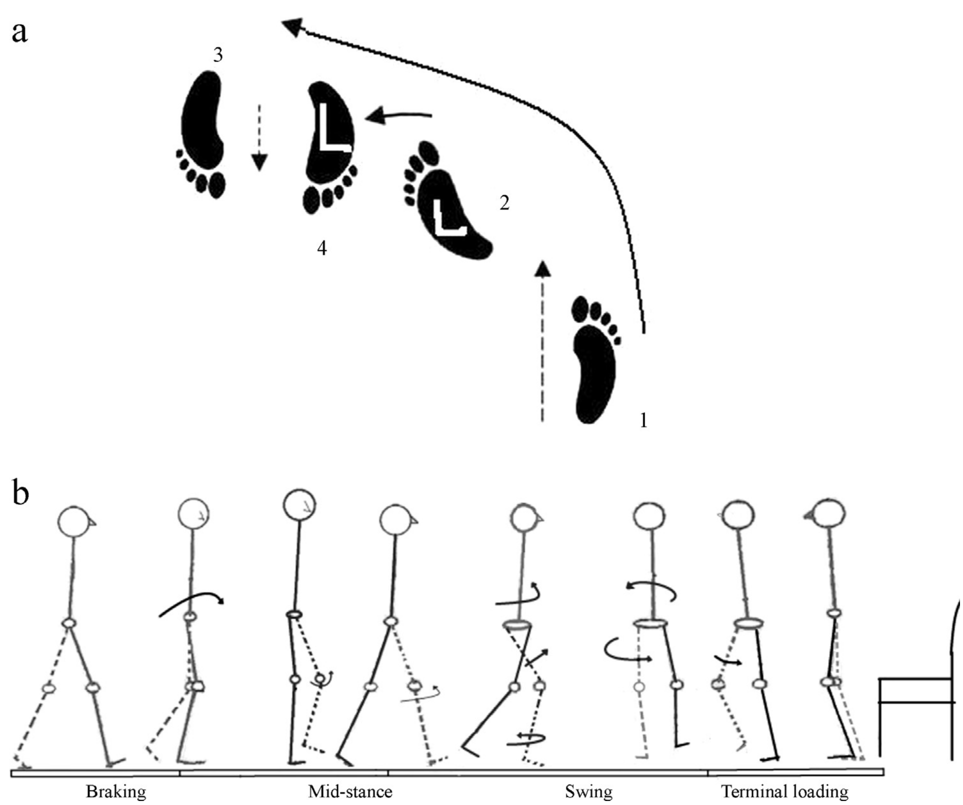

Fig. 1. The step and phases of turning (a) the referring markers on the ground on practice turn and (b) different turning phases: solid segment lines referring to right leg, dashed segment lines referring to left leg.