Gait & Posture 39 (2014) 841–846

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Sequence of onset latency of body segments when turning on-the-spot in people with stroke

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ARTICLE INFO

Article history:
Received 2 February 2013
Received in revised form 24 October 2013
Accepted 14 November 2013

Keywords:
Turning
Onset latency
Balance
Stroke
Falls

ABSTRACT

Background: Turning around is a common activity of daily living. The location of a target may be known or unknown while angle and direction may vary prior to turning. A stroke can compromise coordination of body movement during turning.
Objectives: To investigate the effect of target predictability, turn angle and turn direction on the kinematic sequence of rotation of body segments in people with stroke and healthy controls when turning on-the-spot.
Methods: Ten people with stroke (age: 66 ± 10 years; 8 males) and 10 age-matched controls (age: 65 ± 8 years; 6 males) were asked to either turn to a specific light (predictable condition) or locate and turn to a random light (unpredictable condition) placed at 45°, 90° or 135° to the right or left when a light in front extinguished.
Results: People with stroke initiated movement of the segments significantly later than the controls ($p = 0.014$). The sequence of onset of rotation of the segments was not different between both groups. Target predictability affected the sequence of the segments; the eyes, head and shoulder started moving simultaneously when turning to unpredictable targets while the head and shoulder started moving before the eyes when turning to predictable targets. The sequence was also different across the three turn angles for each predictability condition. However, the sequence remained the same when turning to both sides in each group.

Conclusion Similarities between the groups may be because the time since the stroke was long and therefore some recovery of function may have occurred. Slowness of movement in people with stroke may predispose them to falls.

1. Introduction

Turning around to interact with the environment is a common activity of daily living. Impairment of the normal sequence of movement of body segments during turning may affect balance of an individual [1] and may lead to falls. Many studies have investigated the coordination of body segments during turning while walking in healthy young and older adults and have consistently shown a top-to-bottom sequence of initiation of rotation of the segments with the eye initiating the turn followed by the head, then trunk and finally the feet [2–5]. This sequence has been shown to be altered in people with stroke, however, the differences in sequence of the segments were mostly attributed to biomechanical factors that may be relevant during walking [1,6]. Not all activities of daily living involve turning while walking, activities such as turning to flush the toilet after use are carried out on-the-spot. There is currently no study that has investigated the coordination of body segments during turning on-the-spot in people with stroke. The aim of this study was therefore to investigate the sequence of rotation of body segments during turning on-the-spot in people with stroke compared to healthy controls.

Healthy young adults showed a clear top-bottom sequence of rotation of segments when turning on-the-spot to unpredictable targets and a more synchronous rotation of body segments when turning to predictable targets [5,7,8]. The horizontal movement of eye and head plays important role due to the fact that targets need to be located for interaction [9] and the environment is continuously being scanned to update information about obstacles that may be encountered [10]. Thus, the sequence of rotation of body segments may be different during turning on-the-spot to predictable and unpredictable targets as shown by previous studies [5,7,8]. The sequence of rotation of body segments during

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http://dx.doi.org/10.1016/j.gaitpost.2013.11.009

turning on-the-spot when turning to predictable and unpredictable targets depends on the ability to gather information from the environment through sensory receptors [1]. People with stroke may present with sensory problems [11], cognitive problems that may hinder comprehension of the sensory information [12] or motor problems that could affect implementation of the blueprint that is finally set [13]. We therefore hypothesize that the sequence of rotation of body segments seen in healthy individuals when turning to predictable and unpredictable targets during turning on-the-spot would be different in people with stroke.

The angle of a turn does not alter the sequence of onset of rotation of segments during turning on-the-spot in healthy young adults [7,8]. However turning to different angles require attention and cognition [14], factors that could be impaired in stroke. Therefore, we hypothesize that people with stroke would present with an altered sequence of segmental rotation while turning to different angles. People with stroke may present with weakness of one side of the body, postural asymmetries and abnormal reflexes that manifest while turning towards or away from the hemiplegic side [15]. Although turning to the left and right was not shown to alter the sequence of onset of rotation of segments during turning in healthy individuals [7,8], we expect the sequence to be different when turning towards and away from the hemiplegic side in people with stroke.

2. Methods

2.1. Participants

Our participants comprised ten people with a stroke (mean ± *SD* age: 66 ± 10 years; 8 males) and ten age-matched healthy controls (mean ± *SD* age: 65 ± 8 years; 6 males). Participants with a stroke had normal cognitive status assessed using the Mini-Mental State Examination [16] (mean ± *SD*: 29 ± 2 points out of 30), high functional status assessed using the Barthel Index [17] (mean ± *SD*: 91 ± 11 out of 100) and moderate to high balance status assessed using the Berg Balance Scale [18] (mean ± *SD*: 47 ± 6 out of 56). Six of the participants with a stroke had left-sided hemiplegia while four had right-sided hemiplegia. The mean number of years since having the stroke was 5 (*SD* = 3). The healthy adults were asked whether they had any self-reported mobility problems as part of the screening for the inclusion criteria. Their ability to understand and follow instructions was also observed during the test trials prior to data collection and through cognitive assessment with the Mini-Mental State Examination (mean ± *SD*: 29 ± 2).

Participants in both groups were excluded if they had visual or vestibular problems, were unable to stand and turn, and had any neurological or musculoskeletal disorders that could affect the way they turn (except the stroke in the participants in the stroke group). Those with a stroke were also excluded if they have had the stroke for less than six months, and had unilateral neglect as measured by the star cancellation test [19]. The study was approved by the local ethics committee and all participants gave informed consent.

2.2. Materials/procedures

The onset latency of the horizontal displacement of the eye was measured by VNG Ulmer (SYNAPSIS SA, Marseille, France), a high-frequency light-weighted, head mounted 1-camera eye-tracking system with a sampling rate of 100 Hz. The onset latencies of the head, shoulder, pelvis and feet rotations were measured using CODA motion analysis system (Charnwood Dynamics Ltd, Leicestershire, UK) with a sampling rate of 200 Hz. The Coda motion analysis system recorded the position of markers in three dimensions.

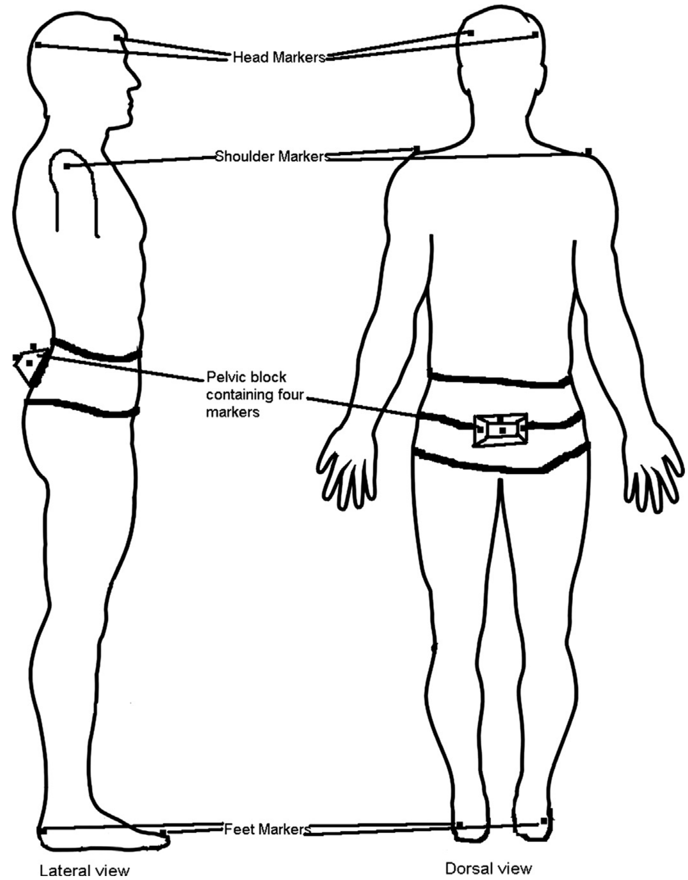

Fig. 1. Four sensory markers placed on the head, one on each shoulder, four placed on a truncated half pyramid attached to the pelvis and two on each foot.

Fourteen CODA markers including four attached to the frame of the eye-tracking camera that was mounted on the head (one inch above the lateral end of each eye and one on each side of the occiput), two on the shoulders (upper surface of the acromion on each side), four on the pelvis (markers were placed on a truncated half pyramid block attached to a belt placed over the posterior superior iliac spine) and two on each foot (over the first toe and on the heel at 45° to the midline of the subject in normal standing). The placement of the heel marker at 45° ensured that it was in view of either of the CODA systems in front and at the back of the participant throughout the turn, in particular it would not be visible at the end of the 90° turn if placed posteriorly on the calcaneus. The marker placement is shown in Fig. 1.

Lights (small red bulbs of about 1 cm in diameter attached to a stand) were placed in front and at 45°, 90° and 135° on each side at eye level of the participant at approximately 2 m distance (Fig. 2). Participants were asked to face the central light and were instructed to either locate and turn their whole-body to face the light that came up when the light in front extinguished (unpredictable condition) or they were asked to turn to a particular light (predictable condition).

Participants were required to turn to each of the six lights (45°, 90° and 135° to the right and left) in two conditions (unpredictable and predictable) resulting in 12 turns. The 12 turns were randomized and five sets of 12 turns were determined for each participant prior to the data collection. Thus each turn was repeated five times. It was anticipated that participants may make a mistake when turning towards initially non-visible targets (135° target) in the unpredictable tasks, these attempts were not used for analysis (as in the protocol of Hollands et al. [8]).