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The effects of various visual conditions on trunk control during ambulation in chronic post stroke patients

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ABSTRACT

Downward gazing is commonly observed among patients after a stroke during standing or walking as they struggle to maintain equilibrium. In this study, we aimed to evaluate the effects of fixed gazing and downward gazing on trunk control ability during gait. Sixteen subjects after a stroke (age: 51.3 ± 4.9 years) and seven healthy subjects (age: 65.1 ± 3.4 years) participated in this study. Participants walked 10 m at a comfortable speed while they faced forward (no gaze point), gazed forward (with a fixed gaze point), gazed downward, and gazed downward while concealing their legs. Trunk acceleration was measured using tri-axial accelerometers attached to the back of the upper (C7 spinous process) and lower (L3 spinous process) trunk. The coefficient of attenuation (CoA) of acceleration at the trunk was computed to assess trunk control ability. Results in the stroke group showed that the CoA during fixed-point and downward gazing was better than that while facing forward with no gaze point ($p < 0.001$). In the stroke group, the CoA during gazing downward with their legs concealed was worse than that during downward gazing. Our findings indicate that patients after a stroke might use visual information for reducing their neck oscillation (C7) during fixed-point and downward gazing. Our results indicate that the visual information during downward gazing might work the same as during fixed-point gazing.

1. Introduction

Individuals after a stroke have a fear of falling and tend to gaze downwards under unstable conditions such as standing and walking. These individuals have impairments of motor, sensory, and cognitive functions resulting from the stroke, and have difficulty maintaining balance without visual compensation [1]. Vision has an important role for controlling postural stability [2,3], as can be seen in some situations for healthy people and patients after a stroke. In healthy people and patients after a stroke, postural sway is significantly reduced when they focus on a nearby fixed gaze point compared to a far or no fixed gaze point [2,4,5]. In addition, Aoki et al. [6] reported that upright standing postural sway in patients after a stroke was small when they gazed downward compared to gazing far forward. These reports suggest that a near fixed gaze point, such as downward gazing, might provide visually-orienting information to individuals after a stroke and help to control their body sway during static standing and gait.

Head stabilization in space is considered to be important for achieving dynamic stability during gait because it provides a stable visual platform and keeps vestibular information exact [7,8]. It has also been shown that visual and vestibular information work together to stabilize head movement. In subjects after a stroke, oscillation derived from lumbar acceleration during gait is higher than that in healthy subjects [9]. This lumbar oscillation is generated by gait movement and is transmitted to the head via the trunk, while head oscillation is normally dampened by the trunk to achieve dynamic gait stability [10,11]. This ability to control the trunk can be assessed by the coefficient of attenuation of acceleration (CoA) [12]. CoA represents the ratio of oscillations at the lumbar and neck segments. Head stabilization is achieved by a complex process that dampens the oscillations transmitted by the trunk. Many joints of the spine act to passively attenuate the oscillation, and trunk muscles combine to actively attenuate it by integrating information from a variety of sources, generally known as the trunk righting reaction and the vestibulo-spinal reflex. A high CoA value means that the trunk is effectively attenuating the

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oscillation. There is a report that the CoA in the vertical (VT) and mediolateral (ML) directions show lower values in older subjects when compared to younger subjects [10]. The CoA is also lower in dual tasking gait than in normal gait [12,13]. The root mean square (RMS) of lumbar oscillations in the VT, anteroposterior (AP), and ML direction are relatively high in patients after a stroke compared to healthy people [9], but it is unclear to what extent vision influences the CoA during gait.

In studies on static standing in healthy subjects, fixed point gazing decreased postural sway, while downward gazing increased postural sway [2,3,5,14]. In subjects after a stroke, downward gazing decreased postural sway [6]. However, the effects of downward gazing and fixed gaze point on dynamic stability during gait in subjects after a stroke are not clear. Bonan et al. [15] reported that patients after a stroke relied on visual information when they attempted to maintain balance or to walk because of compensation for impairments of somatosensory or vestibular information. Thus, we hypothesized that the CoA in subjects after a stroke would improve when they gazed at a fixed point or downward, and it would degrade when they gazed downward with their feet obscured.

The purpose of this study was to investigate the effects of fixed point gazing or downward gazing on dynamic stability during gait. Since CoA represents only a ratio of each segment oscillation, we also examined the RMS of acceleration as an index of oscillation at the lumbar and neck regions [16,17].

2. Methods

2.1. Subjects

Sixteen chronic post-stroke hemiplegic patients who were treated at the Care and Training Center for Handicapped People participated in this study (stroke group, age [mean ± SD], 51.3 ± 4.9 years; height, 166.6 ± 8.2 m; weight, 61.7 ± 8.0 kg; visual acuity, 0.9 ± 0.3; males = 13; Table 1). The inclusion criteria for the stroke group were that they had experienced supratentorial hemorrhage/infarction, could walk without manual contact at least 20 m, scored at least 24 points on the Mini Mental Status Examination (MMSE), and could follow the instructions necessary to conduct the study. Patients were excluded if they had signs of unilateral neglect, an abnormal visual field, obvious orthopedic disease of the spine or lower limbs, or a neurological disorder of etiology other than stroke. Seven healthy older people were hired from a senior citizen's job placement center (control group, age, 65.1 ± 3.4 years; height, 161.4 ± 11.0 cm; weight, 61.1 ± 10.2 kg; visual acuity, 0.8 ± 0.2; male = 4) to serve as controls. Subjects in the control group were excluded if they had vertigo or dizziness, a history of vestibular neuritis, neurological disorders, or obvious orthopedic disorders of the neck, trunk, or lower limbs.

2.2. Ethics

The ethics committee of the University approved this study. All subjects gave written informed consent prior to participation.

2.3. Procedure

We used two tri-axial accelerometers (MVP-RF8-GC, MicroStone Co. Ltd.; Japan) with a sampling rate of 200 Hz. The accelerometers were placed on the skin surface with a double-sided tape and an elastic belt over the seventh cervical spinous process (C7) and the third lumbar spinous process (L3). We confirmed that the accelerometers were firmly fixated.

Subjects were asked to walk at comfortable speed along a 16-m walkway in a corridor (Fig. 1). There were some windows and doors but a plain white-colored wall. We used the data from the middle 10 m of the walkway for analysis. Subjects in the stroke group were allowed to use their cane and orthosis if they used them usually. Four visual conditions were applied to each subject in random order: walk as naturally as possible while keeping their face and eyes looking forward continuously (FF = facing forward); walk while gazing at a 10 cm black filled circle located at the subject's eye height level and 20 m away on a wide board (GF = gazing forward); facing downward with 35° head flexion and looking at about two steps forward on the floor (approximately 70–100 cm away from their feet) [18] (FD = facing downward); and facing downward in the same scenario as FD condition but with their feet concealed by a foamed styrol board which was horizontally attached at the level of their anterior superior iliac spine (CD = concealed downward). For the FD and CD conditions, we measured each subject's head position with a goniometer just before each trial and instructed them to maintain that position throughout the trial. The board size for the CD condition (450 × 450 × 10 mm, 120 g) was wide enough to conceal the subject's feet from their vision. Two trials were performed in each condition and subjects had at least 30 s of rest between trials. Ten-meter gait time was calculated from the time of acceleration data and the number of steps was determined from visually inspected lumber VT acceleration peaks. Gait speed was calculated as 10 m divided by gait time, stride length was calculated as 10 m divided by double step counts (stride), and cadence was calculated as step count divided by gait time. For measuring the global VT, AP, and ML direction of acceleration, we used the data correction method as described by Kavanagh et al. [19,20]. The data from a static stance prior to each gait trial indicated the misalignment tilt of the devices, and basic trigonometry was used for tilt correction. The acceleration signals were low-pass filtered using a dual pass zero lag Butterworth filter with a cut off frequency set at 30 Hz [19].

RMS values of VT, AP, and ML directions were calculated from the acceleration data at C7 and L3. The device axis would not be

Table 1
Clinical characteristics of stroke group [n = 16].

Time since stroke [years]	1.5 ± 0.9
Type of stroke [hemorrhagic/ischemic]	13/3
Hemiplegic side [right/left]	10/6
Use of cane [n]	15
Use of Ankle Foot Orthosis [n]	16
Lower limb sensory disorder [normal/slight/moderate/severe]	0/4/7/5
BRS of lower limb [II/III/IV/V]	1/5/9/1
BBS [point]	40.7 ± 9.3
FAC [3/4/5]	6/4/6

Abbreviations: BRS = Brunnstrom Recovery Stage; BBS = Berg Balance Scale; FAC = Functional Ambulation Category.