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The association between fear of falling and gait variability in both leg and trunk movements

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ABSTRACT

The aim of this study was to explore whether FoF was associated with variability in both leg and trunk movements during gait in community-dwelling elderly. Ninety-three elderly people participated in this study. Each participant was categorized into either Fear or No-Fear group on the basis of having FoF. The participants walked 15 m at their preferred speed. The wireless motion recording sensor units were attached to L3 spinous process and right posterior surface of heel during gait. Gait velocity, stride time and stride length were calculated. Variability in lower limb movements was represented by coefficient of variation (CV) of stride time. Trunk variability was represented by autocorrelation coefficients (AC) in three directions (vertical: VT, mediolateral: ML and anteroposterior: AP), respectively. Gait parameters were compared between groups, and further analyses were performed using generalized linear regression models after adjustment of age, sex, fall experience, height, weight, and gait velocity. Although gait velocity, mean stride time and stride length did not differ significantly between groups, stride time CV and all ACs were significantly worse in the Fear group after adjustment for variables, even including gait velocity (stride time CV: $p = 0.003$, $\beta = -0.793$; AC-VT: $p = 0.011$, $\beta = 0.053$; AC-ML: $p = 0.044$, $\beta = 0.075$; AC-AP: $p = 0.002$, $\beta = 0.078$). Our results suggest that fear of falling is associated with variability in both leg and trunk movements during gait in community-dwelling elderly. Further studies are needed to prove a causal relationship.

1. Introduction

Fear of falling (FoF) refers to a lack of self-confidence that normal activities can be performed without falling [1]. The prevalence of FoF ranges up to 60% in the community-dwelling elderly [2–4] and is even higher in given populations—especially in women or men with a previous history of falls [3]. Factors associated with FoF are psychological problems [5] and poor physical performance [6,7]. Moreover, FoF results in limitations in activities of daily living (ADL) and decreased quality of life [8].

Most falls among older adults occur during movement, such as walking, and it is therefore important to assess the relationship between FoF and gait. Changes in gait that are associated with FoF in the elderly and have been reported consistently in previous studies are reduction in gait velocity [9–11], shortening of stride length [10–12], and increase in step width and prolongation of double-support time [10,11]. Gait variability, a measure of the consistency of movement [13], may provide a more sensitive measure of the risk of falls [14], functional decline, and various adverse health outcomes than do routine spatiotemporal measures such as gait velocity [15]. Gait variability is therefore used as a clinical index of gait stability [16]. The results of studies of the

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relationship between FoF and gait variability have been inconsistent. Reelick et al. [9] found that gait variability did not differ significantly between those with and without FoF. On the other hand, Rochat et al. [17] reported that FoF was associated with gait variability. The former conducted an analysis adjusted for gait velocity, whereas the latter did not. Gait variability was linked with gait velocity [18]. Beauchet et al. showed that walking at slow velocity increases stride-time variability [18]. The variability in these findings indicates that there is a need to clarify the association between FoF and gait variability, with adjustment for gait velocity.

To assess gait variability in the clinical setting, the body can be divided functionally into two units, namely "passenger" (head, neck, trunk, and arms) and "locomotor" (the two lower limbs and the pelvis) [19]. The trunk—a component of the passenger unit—sits upon the locomotor unit and acts mainly to help to maintain body equilibrium spatially during gait [20]. Propulsion of the body during gait is the primary role of the locomotor unit. Because the locomotor unit shifts constantly during gait, the trunk must maintain body equilibrium in these relatively unstable positions; therefore, the trunk movement during gait should be assessed. Moreover, the trunk, being the largest segment of the body, is easily influenced by inertial force from the movement of the locomotor unit and is itself unstable during gait. For these reasons, when gait variability is evaluated it is important to assess not only leg movements but also trunk movement during gait. However, few studies have explored the association between FoF and trunk movement during gait [9].

The aim of this study was to explore the cross-sectional association between FoF and gait variability, including both the temporal and spatial aspects of trunk movement, during gait in the community-dwelling elderly. Our hypothesis was that both lower leg and trunk movements during gait would be associated with FoF, independent of gait velocity.

2. Methods

2.1. Participants

We recruited elderly subjects who were community-dwelling and independent in ADL ($n = 120$). Inclusion criteria were age $\geq$65 years and the ability to walk independently without an assistive device; 119 participants met these criteria. Participants were excluded if they had a history of neuromuscular disease that affected gait or scored less than 8 on the Rapid Dementia Screening Test (RDST) [21]. In addition, participants who did not complete our assessment were excluded. There were 93 participants (38 men and 55 women) in the final analyzed sample (mean age [standard deviation: SD]; 73.1 [4.1] years; height, 155.2 [8.8] cm; weight, 56.5 [11.0] kg). Ethical approval for the study was given by the Ethics Committee of the Kobe University Graduate School of Health Sciences. All participants were properly informed about the study and signed written consent forms, in accordance with the Declaration of Helsinki, before their participation.

2.2. Fear of falling and other measures

FoF was assessed through the question "Are you afraid of falling? Yes – No". Participants who responded "Yes" were assigned to the Fear group, and those who responded "No" were assigned to the No-Fear group. This format has the advantages of being straightforward and making it easy to generate prevalence estimates [22]. Fall events during the past 12 months were checked. We also assessed the following background characteristics by using a questionnaire: age, sex, number of years of education, self-reported medical history (arthritis, hypertension, diabetes mellitus, heart disease, cardiovascular disease, respiratory disease), and number of medications. The Geriatric Depression Scale (GDS) [23], a 15-item yes/no questionnaire, was used to evaluate depression. Scores can range from 0 to 15, with higher scores indicating more depressive symptoms. Lower extremity performance was measured by using timed repeated chair stands (5-chair-stand test, 5CS) [24]. Participants were asked to stand up and sit down five times from a chair as quickly as possible, keeping their arms folded across their chests.

2.3. Gait measurement

Participants were instructed to walk at preferred speed along a 15-m smooth, horizontal walkway. A 10-m section of the walkway was marked off by two lines, one positioned 2.5 m from each end, to allow space and time for acceleration and deceleration. Walking time in the middle 10 m was measured with a stopwatch, and gait velocity was expressed in meters per second. Trunk and lower limb movement during gait was measured by using two wireless motion-recording-sensor units (MVP-RF8, MicroStone Co., Ltd., Nagano, Japan), one fixed to a belt at the level of the L3 spinous process and one attached to the posterior surface of the right heel with surgical tape. Acceleration and angular velocity could thus be measured without restricting the subject's movement. We considered it likely that the accelerometers attached to the body would be in variable states of inclination caused the body's curvature. To correct for any potential effects of this inclination, we calibrated the accelerometer before each walking trial to take into account the static gravity component. All signals were sampled at 200 Hz and synchronously wirelessly transferred to a personal computer via a bluetooth personal area network.

2.4. Data analysis

Signal processing was performed with MATLAB (The MathWorks Co., Release 2008, Cybernet Systems Co., Ltd., Tokyo, Japan). Before the analysis, all acceleration and angular velocity data were high-pass filtered with a cutoff frequency of 1 Hz and then low-pass filtered with a cutoff frequency of 20 Hz. To compute temporal gait parameters, we analyzed heel acceleration and heel angular velocity data. On the basis of pilot testing to determine temporal parameters by using heel acceleration data, a heel contact event was identified as a vertical acceleration peak. These events were used to calculate each stride time and to compute the mean stride time and the coefficient of variation (CV) of stride time. We used the CV of stride time to estimate the variability of lower limb movement as only a temporal parameter. The CV was calculated by using the formula: CV = (standard deviation/mean) $\times$ 100. Stride length was computed by multiplying mean stride time by gait velocity. Because the CV of stride time was a measure of variability based on only a temporal parameter, we analyzed other measures of variability by using trunk acceleration to add a spatial element. Trunk acceleration data for each direction, namely vertical (VT), mediolateral (ML), and anteroposterior (AP), were analyzed to evaluate the variability of trunk movement, as computed by using an unbiased autocorrelation procedure [25]. An unbiased autocorrelation coefficient (AC) is an estimate of the regularity of a time series by cross-correlation with itself at a given time shift; it is independent of the amount of data managed. A perfect replication of the gait cycle signal between neighboring strides will return an AC of 1, and no association will give a coefficient of 0.

2.5. Statistical analysis

Characteristics of participants were compared between groups (No-Fear and Fear) by using a chi-squared test for categorical