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Effects of dual-tasking on control of trunk movement during gait: Respective effect of manual- and cognitive-task

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ABSTRACT

Trunk control during gait provides a stable platform for vision and head control. However, in dual-task gait, cognitive tasks result in increased trunk movements, reduced gait speed, and increased gait variability. Manual tasks have been associated with reduced gait speed, but their effects on trunk movement have not been fully investigated. Furthermore, the fear of falling (FoF) during dual-task gait remains relatively unstudied. We aimed to assess trunk movements during cognitive-task gait (CG) and manual-task gait (MG), and examine the effects of CG and MG on individuals with and without FoF. The participants were 117 healthy older adults. We used two triaxial accelerometers: one to record trunk movements at the L3 spinous process and one at the heel to measure initial contact. Participants counted backward by one (CG) or carried a ball on a tray (MG), and we calculated stride time variability and standardized root-mean-square trunk accelerations in the mediolateral (ML) and anteroposterior (AP) directions. CG significantly increased lower trunk oscillations in the ML ($t = 4.9$, $p < 0.001$) and AP directions ($t = 6.1$, $p < 0.001$). Conversely, MG significantly decreased trunk oscillations in the ML ($t = -5.9$, $p < 0.001$) and AP directions ($t = -8.3$, $p < 0.001$). The difference in trunk oscillations during CG in the ML direction was significantly larger in subjects with FoF than without FoF ($t = 2.6$, $p < 0.01$). We conclude that for the tasks we studied, CG and MG have different effects on trunk movement. Finally, FoF was associated with changes in trunk movement in the ML direction during CG but not MG.

1. Introduction

In normal gait, stable trunk movements contribute to successful locomotion. During walking, the control of trunk movement is prioritized and plays an important role in providing a stable platform for vision and head control [1]. Several reports suggest that the control of trunk movements requires attentional resources, and challenging attention-splitting conditions, e.g., dual-task walking, strongly affects trunk movement [2]. Dual-task-related gait changes help assess age-related changes in gait and trunk control that may lead to falls.

Two different types of task, a cognitive task and a manual task, have been used as an additional attention-demanding task in research on dual-task gait [3]. A cognitive task is chosen more often in dual task studies because it directly affects cognitive brain function and its performance can be easily quantified [2,3]. Many reports have demonstrated that a cognitive task affects gait patterns and trunk movements, e.g., reduced gait speed, increased gait variability and increased fluctuation of trunk movements in the horizontal plane [2,4,5]. A manual task is used less often than a cognitive task in dual task studies, because no standard manual task exists and its performance cannot be easily quantified. Some reports have demonstrated that a manual task, similarly to a cognitive task, affects gait patterns, e.g., reduced gait speed, but the effects of a manual task on trunk movement have not yet been fully studied [2,6].

Although both tasks induce similar gait pattern changes, the allocation of attention differs between cognitive-task and manual-task gaits. In the case of cognitive-task gaits, the attentional resources are split and allocated arbitrarily to each task; the

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additional cognitive task draws attentional resources away from gait, and gait movements fluctuate and oscillate [6]. However, when a simple goal-directed manual-task gait is performed, e.g. carrying a tray while walking, the dual-task-related reductions in gait speed are less apparent when compared with cognitive-task gait [7,8]. Resources for the control of walking and the performance of a manual task are both within the motor control system [2]. Together, these findings suggest that the attention allocated to walking movements in manual-task gait closely resembles that in normal gait (no task gait). Therefore, dual-task-related changes in trunk movements may differ between cognitive-task gait and manual-task gait, even if similar dual-task-related gait changes are observed.

Furthermore, dual-task gait may be affected by mental status, including a fear of falling (FoF) [9]. FoF is common among older adults with fall history and refers to the lack of self-confidence in performing normal activities without falling [10]. FoF induces gait pattern changes, including reduced gait speed and increased step width, and may influence the control of trunk movements during walking [11]. Gage et al. proposed that anxiety associated with FoF reduces the attentional resources available for gait control [9]. The effect of FoF on gait may therefore be more apparent in the dual-task gait condition. To our knowledge, only one study has investigated the effect of FoF on trunk movement during cognitive-task gait, and found no effect of FoF on trunk sway [12]. However, the effect of FoF on trunk movement in manual-task gait remains unclear.

Therefore, the first objective of this study was to assess the effects of a cognitive task and a manual task on trunk movements during gait. A second objective was to examine the effect of FoF on trunk movement in both dual-task walking conditions: cognitive-task and manual-task gaits.

2. Methods

2.1. Subjects

One hundred and seventeen healthy, community-dwelling older adults (51 male and 66 female, age 73.7 $\pm$ 4.0 years) were included in this study. Subjects were recruited through a local community center. Inclusion criteria were the ability to independently perform activities of daily living and absence of self-reported neurological or musculoskeletal conditions affecting mobility or balance. Exclusion criteria were acute illness or cognitive impairment as determined by the Rapid Dementia Screening Test [13] (RDST < 7). Current medications, history of falls during the previous year, and fear of falling (FoF: yes/no question, "Are you afraid of falling?") were recorded [14], and basic mobility was assessed with a Timed Up & Go test (TUG) and Five Chair Stand test (5CS) [15,16]. The Research Ethics Committee of Kobe Gakuin University approved the study (Approval No. HEB100806-1), and informed consent was obtained from all subjects prior to participation. Table 1 lists the demographic data of all subjects.

2.2. Apparatus

Two triaxial accelerometers were used—one for measuring trunk movements and the other for detecting initial contact of the foot with the ground during walking. For trunk acceleration measurements, one triaxial accelerometer (MVP-RF8-BC; size: 45 mm wide, 45 mm deep, 18 mm high; range: $\pm$ 4 G; weight: 60 g) (Microstone Co., Nagano, Japan) was attached over the third lumbar vertebra spinous process (L3) using a Velcro™ belt. L3 was selected to represent the lower trunk at the approximate center of mass during walking [17]. Trunk linear accelerations were measured in the anteroposterior (AP) and mediolateral (ML) directions while subjects walked along a walkway. The other triaxial accelerometer (MVP-RF8-BC) was attached to the heel on the subject's dominant side using surgical tape to detect the time of initial contact during walking. Before each measurement, we calibrated the accelerometers statically against gravity. All accelerations were sampled at 200 Hz and all acceleration signals were synchronized. After analog-to-digital conversion, signals were immediately transferred to a laptop computer.

2.3. Measurements

Subjects were instructed to walk on a smooth 20-m walkway at self-selected comfortable, very slow, slow, and fast speeds with no other task (reference no dual task). Subjects were then asked to perform the following tasks in random order, while walking at a self-selected comfortable speed: count backward by 1 from 100 (cognitive-task gait) and carry a ball (100 g, 7 cm diameter) on a round tray (50 g, 17 cm diameter, 1.5 cm high raised edge) with the dominant hand only (manual-task gait). Carrying a ball on the tray was chosen as the additional task, rather than the typical manual task of carrying a glass of water; the task complexity of carrying a ball remained constant during walking, while that of carrying a glass of water would change if water were spilled. Prior to testing, we explained how to perform both dual-task gaits until subjects understood precisely. No instructions were given regarding which task to prioritize during dual-task gait. One trial was performed for each of the six walking conditions (self-selected comfortable, very slow, slow, and fast speeds with no other task, and cognitive-task gait and manual-task gait). The time taken to walk over the central 10 m of the walkway (5–15 m) was measured using a digital stopwatch. Gait speed was calculated by dividing 10 m by the time taken. The sum total of numbers enumerated in the central 10 m of the walkway was measured for the cognitive-task gait. In the manual-task gait, all subjects were required to complete the walk without dropping the ball from the tray.

Table 1
Demographic data of subjects ($n = 117$).

Characteristics	Total subjects ($n = 117$)	Subjects without FoF ($n = 85$)	Subjects with FoF ($n = 32$)
Age (y)	73.7 $\pm$ 4.0	73.4 $\pm$ 4.0	74.5 $\pm$ 4.0
Sex, men/women (n)	51/66	42/43	9/23*
Height (cm)	154.9 $\pm$ 8.8	156.1 $\pm$ 9.0	151.8 $\pm$ 7.7*
Weight (kg)	56.1 $\pm$ 10.6	57.8 $\pm$ 10.8	51.9 $\pm$ 9.0**
Number of medications per day (n)	2.3 $\pm$ 2.0	2.3 $\pm$ 2.0	2.4 $\pm$ 2.0
Subjects who fell in previous year, n (%)	25 (21)	15 (18)	10 (31)
TUG (s)	6.6 $\pm$ 1.3	6.4 $\pm$ 1.1	7.1 $\pm$ 1.6
5CS (s)	8.8 $\pm$ 2.2	8.5 $\pm$ 2.0	9.3 $\pm$ 2.7
RDST	9.5 $\pm$ 2.5	9.6 $\pm$ 2.6	9.1 $\pm$ 2.4

Mean $\pm$ standard deviation, TUG, Timed Up & Go test; 5CS, 5 Chair Stand test; RDST, rapid dementia screening test; FoF, fear of falling.
* $p < 0.05$.
** $p < 0.01$.