EFFECTS OF DUAL TASK ON THE INTER-JOINT COORDINATION DURING STAIR ASCENDING IN OLDER ADULTS

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SUMMARY
Stair climbing is frequently performed in daily life, and it can be very challenging for elderly people. Additional task is a perturbation that alters gait pattern but it usually happens. The purpose of this study was to compare inter-joint coordination pattern and variability between single and dual task during stair ascending. No significant group differences were detected during stair ascending (SA) phase. However, compared to single task, dual task appeared distinctly relative phase from early to mid stance during transition phase. And significantly smaller deviation phase (DP) during stance of transition phase with cognitive task was found when a cautious movement was being made. In conclusion, while performing such a challenging motor task, additional task could alter the original stability of dynamical posture.

INTRODUCTION
Stair negotiation is a common form of locomotor task, much more demanding than level walking [10]. This is a particular problem in the elderly, with the incidence of injuries and falls on stairs increasing in old age [2]. Previous studies have compared the biomechanical characteristics of stair negotiation between young and older adults, involving ground reaction force [11], joint moment [5], foot clearance, electromyography [10] and whole body kinematics [9]. Therefore, stair negotiation has been shown to be more challenging in old adults than in young adults. Stair climbing is a complex motor task, which needs high level of inter-joint coordination of lower extremity. In motor control, stable coordination pattern has been considered a fundamental feature of consistent, functional action [1]. In addition, one condition frequently seen in daily life is dual task paradigm, which results in many falls in the elderly [4]. And dual task paradigms are used to examine the effect of cognitive tasks on primary activity such as walking. As previous studies have shown, the effect of cognitive task on gait stability shows decreased gait velocity and increased gait variability [4]. Accordingly, we speculated that stair ascending with additional cognitive task might bring about the alternative of inter-joint coordination. The aim of this study was to explore the dual task effect on inter-joint coordination pattern and variability during stair ascending in older adults. We hypothesized that the variability of the inter-joint coordination on dual task situation was greater than single task.

METHODS
Ten healthy elderly (seven males and three female; age: 73.1±5.1 years, height: 160.1±7.7cm and mass: 58.3±7.3 kg) were recruited for the purpose of the current investigation. They were free of neurological and low extremity musculoskeletal impairments. Kinematic data were acquired during stair ascending by capturing the trajectory of reflective markers using a ten-camera optoelectronic motion analysis system sampling at 100 Hz surrounding the testing area (Vicon, Oxford, UK). The motor task required participants to perform stair ascend (SA). The cognitive secondary task consisted of repetitively subtracting 7 starting figure from 40 to 100 randomly. Each subject walked at self-selected pace for each condition, which included single (only motor task) and dual (motor and cognitive task) task. Three trials for each condition were obtained. Two gait cycles (GC) were identified in each stair ascend trial to represent the floor-to-stair transition and SA phase [6]. Lower extremity joint (hip, knee and ankle) angle were calculated from kinematic data only in sagittal plane. Angular velocity in sagittal plane was calculated for each joint using the generalized cross-validatory spline method [13]. Angular displacements were normalized the minimum angular displacement to -1 and maximum angular displacement to +1. Angular velocities were normalized by the maximum absolute velocity during locomotion [6]. The phase portrait is a plot of each joint’s position versus its velocity. The resulting point data were used to calculated the phase angle \( \phi = \tan^{-1}(x/y) \) [8]. Continuous relative phase angle (RPA) represents the phasing relationship or coordination between the actions of the two adjacent joints [12]. RPA was calculated throughout the gait cycle by subtracting the phase angle of the two adjacent joints: \( \phi_{\text{hip-knee}} \) and \( \phi_{\text{knee-ankle}} \). The RPA curves for inter-joint relationship were averaged across trials and mean ensemble curves were generated for each condition. Besides, the deviation phase (DP) was calculated by averaging the standard deviations of the ensemble RPA curve points for stance and swing phase of each gait cycle and each condition. A low DP value indicates lower variability within trails and reflects a more stable inter-joint coordination. Paired-Sample T-test was applied to detect the effect of different conditions (single and dual task) for DP values. A significance level of 0.05 was set for all statistical tests.

RESULTS AND DISCUSSION
Comparing the phase portraits of single and dual tasks, three trajectories of lower extremity joints showed similar geometric form during SA and transition phase (Fig. 1). Evaluation of the graphical configuration of the RPA curves might indicate whether dual and single task situations were similar locomotive strategies or not. During SA phase, the coordination dynamics of the hip-knee and knee-ankle coupling relationship were similar in the two situations. This was evident from the similar configuration of the curves of the two conditions (Fig. 2a & 2b).
During transition phase, the hip-knee relative phase dynamics appeared to be quite different throughout the early-to-mid stance period in the two conditions (Fig. 2c). In the beginning of stance period, elderly had an in-phase relationship (close to 0°) when in dual task. However, in single task, elderly had an out-of-phase relationship (start at -80°). From approximately 15%-30% of GC, single task RPA curves maintained at about 0°, while dual task RPA curves maintained at around -50°, indicating that knee joint was changing more than hip joint. Besides, the coordination for the knee-ankle coupling was also different (Fig. 2d). In the early portion stance phase, elderly began around 0°, indicating an in-phase relationship in dual task, while elderly exhibited an out-of-phase relationship (value starting at 100°) in single task. There were additional differences at knee-ankle coupling. Similarly from 15%-30% of GC, dual task retained at around -150°, yet single task retained at around -200°.

Inspection of the timing of the minimums and maximums of the RPA curve indicated that the reversal in the coordination dynamics of hip-knee and knee-ankle couplings was similar in the two conditions (Fig. 2c & 2d). However, the magnitudes of the minimums and maximums were not similar. These phenomena showed that dual task resulted in altered relative phase dynamics of stance phase during transition phase.

Table 1: Means and standard deviations of the deviation phase (DP) values of the knee-hip and knee-ankle

<table>
<thead>
<tr>
<th>DP value</th>
<th>Stair ascend(SA)</th>
<th>Transition(floor to stair)</th>
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<tbody>
<tr>
<td></td>
<td>Hip-knee</td>
<td>Knee-ankle</td>
</tr>
<tr>
<td></td>
<td>Stance</td>
<td>Swing</td>
</tr>
<tr>
<td>Normal</td>
<td>75.8±32.5</td>
<td>19.2±6.0</td>
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<tr>
<td></td>
<td>169.4±25.0</td>
<td>41.5±20.9</td>
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<tr>
<td></td>
<td>Dual task</td>
<td>76.2±31.7</td>
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<td></td>
<td>139.8±17.2</td>
<td>50.1±24.3</td>
</tr>
<tr>
<td>p-value</td>
<td>0.98</td>
<td>0.95</td>
</tr>
<tr>
<td></td>
<td>0.02*</td>
<td>0.33</td>
</tr>
</tbody>
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**REFERENCES**