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Carotid flow pulsatility is higher in women with greater decrement in gait speed during multi-tasking

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ABSTRACT

Aim: Central arterial hemodynamics is associated with cognitive impairment. Reductions in gait speed during walking while performing concurrent tasks known as dual-tasking (DT) or multi-tasking (MT) is thought to reflect the cognitive cost that exceeds neural capacity to share resources. We hypothesized that central vascular function would associate with decrements in gait speed during DT or MT.
Methods: Gait speed was measured using a motion capture system in 56 women (30–80y) without mild-cognitive impairment. Dual-tasking was considered walking at a fast-pace while balancing a tray. Multi-tasking was the DT condition plus subtracting by serial 7′s. Applanation tonometry was used for measurement of aortic stiffness and central pulse pressure. Doppler-ultrasound was used to measure blood flow velocity and β-stiffness index in the common carotid artery.
Results: The percent change in gait speed was larger for MT than DT (14.1 ± 11.2 vs. 8.7 ± 9.6%, $p < 0.01$). Tertiles were formed based on the percent change in gait speed for each condition. No vascular parameters differed across tertiles for DT. In contrast, carotid flow pulsatility (1.85 ± 0.43 vs. 1.47 ± 0.42, $p = 0.02$) and resistance (0.75 ± 0.07 vs. 0.68 ± 0.07, $p = 0.01$) indices were higher in women with more decrement (third tertile) as compared to women with less decrement (first tertile) in gait speed during MT after adjusting for age, gait speed, and task error. Carotid pulse pressure and β-stiffness did not contribute to these tertile differences.
Conclusion: Elevated carotid flow pulsatility and resistance are characteristics found in healthy women that show lower cognitive capacity to walk and perform multiple concurrent tasks.

1. Introduction

Central arterial hemodynamics is gaining support as an important factor that contributes to reduced cognitive function [1,2]. Elevated stiffness of the central aorta, which occurs with aging or under pathological conditions, facilitates the transmission of excessive pressure and flow pulsatility to the carotid artery and cerebral circulation [3]. These hemodynamic characteristics are associated with brain tissue damage and cognitive deficits [4,5]. Accordingly, aortic stiffness [6,7] and pulse pressure [8,9] have been reported to relate with slower gait speed, a functional measurement sensitive to health status and cognitive function [10].

Gait performance depends more heavily on cognitive functions like attention and information processing when walking is combined with concurrent tasks since the simultaneously performed tasks will compete for shared neural resources. For example, walking while balancing an object, talking or performing other mental tasks like subtracting are considered dual-task conditions. Gait speed declines during dual-tasking [11,12] with the decrement in gait speed thought to reflect the cost that exceeds neural capacity to meet the demand of walking and performing the additional task(s). The reduction in gait speed is amplified when the simultaneously performed task is more complex indicating increased interference between the neural processes regulating gait and the concurrent task(s) [13]. More importantly, the change in gait speed during dual-tasking is larger in adults with clinical cognitive disorders as compared to healthy adults [14,15], and thus is sensitive to underlying cognitive impairment. To date, vascular function has not been examined as a potential contributor to the change in gait speed during dual-task walking. Based on the

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etiological role that central arterial hemodynamics play in cognitive impairment [3,4], it is possible that central vascular function may be an early factor associated with the capacity of the brain to divide attention and meet the demand of walking and performing other tasks.

The aim of this investigation was to examine whether central arterial hemodynamics differs between healthy adults with varying capacity to walk and perform multiple tasks. We hypothesized that central pulse pressure and/or flow pulsatility would be higher in adults with larger decrements in gait speed during dual- or multi-tasking. Healthy adults without mild-cognitive impairment were examined to reduce the significant influence of cognitive deficits on gait, thus allowing an investigation into other, possible preceding variables that may contribute to reduced gait performance.

2. Methods

2.1. Participants

Data collected for a previous study [16] was used for the present investigation. Thirty younger women between the ages of 30–45y (36 ± 4.9y) and 26 older women between the ages of 61–80y (69 ± 5.0y) were included in this study after providing written informed consent to participate. To be eligible, women had to show no signs of mild-cognitive impairment (score >25 on the Montreal Cognitive Assessment (version 7.1) [17], be a non-smoker, not obese (BMI $\leq$30 kg/m^2), no personal history of cardiovascular disease, diabetes, and not taking medications for blood pressure, cholesterol or hormone replacement therapy. While four participants had osteopenia, no participants had orthopedic limitations that visually affected gait (e.g., assistance devices or injury). Lastly, all participants had to show no signs of peripheral artery disease by having an ankle-brachial index >0.90 (range of lowest index values across legs: younger, 0.94-1.30; older, 1.00-1.30). The Institutional Review Board for the protection of human subjects at Texas Tech University Health Sciences Center approved the study prior to data collection.

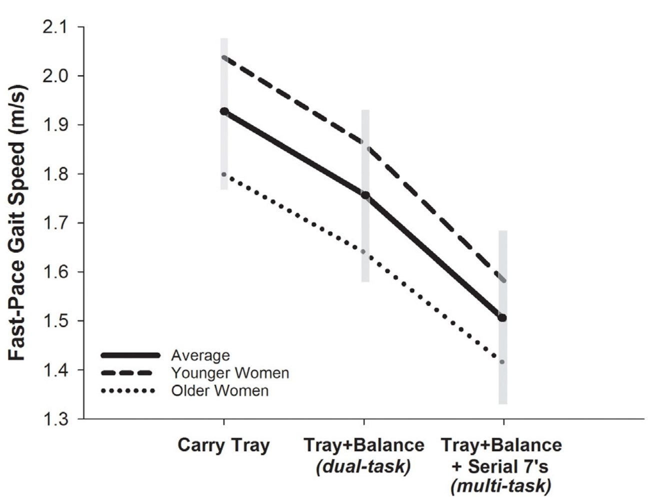

Fig. 1. Change in gait speed from the reference condition (carrying tray) to the dual-task (carry plus balance tray) and multi-task (balance tray plus serial subtractions) conditions. Shaded columns represent standard deviation for the average gait speed (solid line) derived from combining younger (dashed line) and older (dotted line) women.

2.2. Gait performance

Reflective markers were attached to participant's body at standardized landmarks using a Plug-In Gait full-body marker set (Vicon, Inc.). The reflective markers in combination with an 8-camera integrated motion capture system (Nexus 2.1, Vicon, Inc.; 100 Hz) permitted measurement of gait speed across a 12 m walkway consisting of a 3 m acceleration zone, 6 m calibrated measurement zone, and 3 m deceleration zone. Participants were asked to walk at a self-selected fast pace during three experimental conditions that were randomly presented. The reference condition was fast walking while holding a tray. The dual-task condition was fast walking while attempting to maintain the tray in a level position. Secured to the tray was a custom-designed leveling device consisting of a small steel ball bearing and a bulls-eye symbol. Participants were instructed to keep the ball bearing centered on the bulls-eye. Container leveling error (degrees of tilt relative to zero averaged across pitch and roll directions) was measured by tracking reflective markers using the motion capture system. The percent change in gait speed during dual-tasking was calculated using the equation, [(reference − dual task gait speed)/reference gait speed × 100]. The multi-task condition was the dual-task condition with an added task of subtracting by serial 7's. An audio recording permitted the scoring of the number of correct subtractions. The percent change in gait speed during multi-tasking was calculated using the equation, [(dual − multi task gait speed)/dual task gait speed × 100]. The order of gait conditions was randomized and participants performed three trials of each condition with the average gait speed used for analysis. A positive percent change indicates a slowing of gait speed during dual- or multi-tasking, whereas a negative percent change indicates faster gait speed.

2.3. Vascular function

To assess different metrics of central vascular function that have been implicated to play an etiological role in cognitive dysfunction, we collected indices in the aorta and common carotid artery. Aortic pulse wave velocity (PWV) is considered to reflect arterial stiffness or the reduced ability of the central aorta to dampen pressure as it travels to the systemic circulation. In the common carotid artery, carotid β-stiffness index was measured as a metric of local arterial stiffness, pulse pressure as a metric of elevated pressure transmission from the aorta, and lastly, flow pulsatility index was measured as it reflects both local and downstream alterations in vascular function.

Participants rested in the supine position for 10 min after which blood pressure waveforms were measured in the right radial artery and right common carotid artery using applanation tonometry (SphygmoCor PVx, AtCor Medical). An ensemble-averaged radial artery pressure waveform was calibrated to the average of two brachial blood pressure measurements taken using an automated device (HEM-907XL, Omron Healthcare). A general transfer function was used to synthesize a central aortic waveform from a series of radial artery pressure waves. Wave separation analysis of the aortic waveform allowed for estimation of aortic PWV. Lastly, carotid pulse pressure was estimated using an ensemble-averaged carotid artery pressure waveform that was calibrated to diastolic and mean blood pressure measured at the brachial artery.

Doppler-ultrasound (Vivid 7, GE Medical Systems) was used to measure blood flow velocity and diameter in the left common carotid artery with a 5–13 MHz linear transducer probe. Blood flow velocity was sampled in real time (1000 Hz) using a data acquisition system (Powerlab 8SP, ADInstruments). A 30 s clip of consecutive mean blood velocity waveforms were ensemble-averaged into one average mean blood velocity wave for