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Research article

The effects of cognitive versus motor demands on postural performance and weight bearing asymmetry in patients with stroke

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ABSTRACT

While several studies have investigated the interaction between postural control and secondary cognitive tasks in stroke patients, little is known about the influence of secondary motor task on postural control in these patients. The current research was designed to further examine dual-task performance by comparing the effects of cognitive versus motor dual-tasks on postural performance and weight bearing asymmetry (WBA) in stroke patients (n = 23) relative to healthy, matched controls (n = 22). All participants stood on dual-force plate under 5 conditions: (1) free standing; (2) simple cognitive task (easy Stroop) while standing; (3) difficult cognitive task (difficult Stroop) while standing; (4) simple motor task (holding a tray while a cylinder lying on its flat side) while standing; and (5) difficult motor task (holding a tray while a cylinder lying on its round side) while standing. The center of pressure (COP) measures was greater in stroke patients than healthy controls. Also, the WBA of the patients was greater than the controls. The COP measures increased when moving from single-task to cognitive dual-task conditions. No significant effect of motor dual-tasking was seen when moving from single-task to motor dual-task conditions. However, in contrast to cognitive dual-tasking, stroke patients and healthy controls employed different strategies during simultaneous performance of postural and motor tasks. It can be suggested that performing a motor task while standing requires greater attentional resources compared to performing a cognitive task while standing and this resulted in greater dual-task interference on motor performance in the stroke patients.

1. Introduction

Impaired postural control and weight-bearing asymmetry (WBA) in favor of the non-paretic limb are among the most common consequences of stroke patients [5,8,11,19] and probably have the greatest impact on activity daily living (ADL) independency and postural control. Improvement of both postural stability and weight distribution between limbs are, therefore, considered as an important goal in stroke rehabilitation that could result better motor function and greater ADL independency in the post-acute phase of stroke [8,11].

In most activities of daily living, it is often necessary to ambulate while performing simultaneous cognitive task (e.g. walking while thinking) or a motor task using the upper limbs (e.g. retrieving money from a pocket or texting) [17]. Therefore, the interaction between primary postural task and secondary cognitive/motor task has received considerable attention in recent physiotherapy researches [9]. Knowledge about the effects of cognitive/motor dual-task on postural performance may assist physiotherapists in incorporating dual-task paradigm into their evaluation and treatment techniques. Studies to determine the interaction between postural control and secondary cognitive tasks in stroke patients are well documented [2,3,10]. Briefly, the results were inconsistent across studies; while cognitive loading resulted in an increased postural sway in some studies [2], the results of other studies have shown decrease [3] or no change [10] in postural sway when the stroke patients performed dual-task. Although due to some methodological differences and the use of heterogeneous populations, a direct comparison between these studies is difficult, the nature and difficulty of the cognitive task and also disease severity could contribute to inconsistencies in the literature. Both Bensoussan et al. [2] and Bourlon et al. [3] used a cognitive task requires articulation while Hyndman et al. [10] used a cognitive task remembering a shopping list. Moreover, Bensoussan et al. used a simple arithmetic task while Bourlon et al. used both simple and complex verbal reaction time task. Regarding the disease severity, Hyndman et al. recruited the patients who were able to mobilize without assistance of another person while patients with ability to stand independently for 30 s and 120 s

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were included in Bensoussan et al. and Bourlon et al., respectively.

de Haart et al. provided the only study on the effect of secondary cognitive (arithmetic) task on WBA in patients with stroke [5]. During dual-task, patients further reduced the weight on their paretic limb, but no change was found in postural sway. To our knowledge, no study has yet reported the effects of secondary motor task on postural performance and WBA in patients with stroke. Moreover, none of the existing studies has examined the comparative effects of cognitive versus motor dual-tasks on postural control in this specific patient population. Knowing that whether the type of secondary task (cognitive or motor) could affect dual-task performance more, could help physiotherapists to educate patients about possible consequences and risks of performing cognitive or motor activities during standing [14]. Moreover, it may help clinicians to identify patients most susceptible to dual-task interference and to design a rehabilitation intervention to improve functionality of the patients [17].

Therefore, the current research was designed to further examine dual-task performance by comparing the effects of cognitive versus motor dual-tasks on postural performance and WBA in stroke patients relative to healthy, matched controls. We expected more postural sway and more WBA in the patients compared to controls. Also, we hypothesized that dual-tasking would lead to increased postural sway and WBA in stroke patients while no or less change is expected in matched control subjects. Based on previous researches comparing cognitive and motor dual-task interference during gait in older adults [17] and Parkinson patients [14], we hypothesized that in stroke patients, the motor dual-task would lead to greater increase in postural sway compared to cognitive dual-task. Also, due to the destabilizing effect of upper limb movement and the greater reliance on the non-paretic side in the patient group, we hypothesized that in stroke patients, the motor dual-task would lead to more reduced loading on the paretic limb (so more increased WBA) compared to cognitive dual-task.

2. Materials and methods

2.1. Participants

Twenty-two patients with hemiplegia (mean age, height, body mass index, and year of education: 55.8 ± 7.9 yr, 1.6 ± 0.08 m, 27.2 ± 3.5 kg/m^2, and 11.3 ± 3.9 yr, respectively; 15 male and 7 female) due to stroke were recruited for this database. All patients admitted to physiotherapy clinics from July 2014 until January 2016 were examined for inclusion/exclusion criteria. The inclusion criteria consisted of (1) at least 6-month post-stroke (The mean time since disease was 30.7 ± 42.2 months with the range of 6–120 months); (2) being able to stand independently for at least 60 s without any assistive device; (3) single unilateral lesion, as confirmed by brain imaging; and (4) WBA in favor of the non-paretic limb. To assess the WBA in favor of non-paretic limb, we used two digital scales with accuracy of 100 g (Xiami Mi Smart Scale, Xiaomi Inc. China). This assessment was performed in the standing position with one limb on each scale and open eyes. Patients were deemed to be asymmetric towards non-paretic limb if they bore more than 53% of body weight on the non-paretic limb [12].

The Persian Berg Balance Scale (BBS) [20] and Mini-Mental State Examination (MMSE) [1] were used to evaluate patient's functional balance and cognitive dysfunction, respectively. The BBS total score ranges from 0 to 56, with higher scores indicating a higher level of functional balance. The MMSE is a 7-item test of general cognitive function with a scoring range of 0–30; higher scores represent better cognitive ability. The mean BBS and MMSE obtained for the patients were 45.7 ± 7.7 points and 27.7 ± 1.4 points, respectively. The exclusion criteria consisted of (1) any musculoskeletal or neurological disorders except stroke; (2) hemispatial neglect as documented by the star cancellation test [4]; (3) uncorrected hearing or visual impairments; (4) MMSE less than 24 as cognitive disorders could result in difficulties to execute the cognitive task; (5) aphasia; and (6) psychiatric disorders. The control group should be able to walk independently and had no musculoskeletal, neurological or psychiatric disorders. Also, participants with uncorrected hearing or visual impairments, and MMSE less than 24 were excluded. The control group consisted of 23 (mean age, height, body mass index, and year of education: 54.7 ± 7.5 yr, 1.6 ± 0.10 m, 26.4 ± 3 kg/m^2, and 11.5 ± 2.6, respectively; 15 male and 8 female) participants. They were recruited from the staff community of the Ahvaz Jundishapur University of Medical Sciences. They were matched with the patients according to gender, age, height, body mass index, and years of education.

The local ethics committee approved the study and all the participants signed the informed consent form prior to their participation in the study.

2.2. Procedure

Participants stood barefoot with shoulder width apart on dual-plate force platform, with one foot on each plate (Bertec 4060-10, Columbus, Ohio, USA), their arms hanged at their sides and look straight ahead [13]. The two force plates were positioned close together without touching (i.e. <1 mm apart) [12]. An assistant stood beside the patients to prevent falling.

Two outcomes of interest in dual-task studies are (1) the effects of cognitive loading on postural performance and (2) the effect of postural conditions on cognitive performance [21]. Therefore, to evaluate the effects of cognitive/motor loading on postural performance and asymmetry index, 5 levels of postural conditions, i.e. free standing, standing with simple and difficult cognitive secondary task, and standing with simple and difficult motor secondary task were considered. Conversely, to investigate the effects of postural conditions on cognitive/motor performance, 4 levels of postural conditions, i.e. sitting with simple and difficult cognitive/motor task and standing with simple and difficult cognitive/motor task were considered. In the single-task conditions (free standing), participants were asked to stand while looking straight ahead. In the dual-task conditions, participants were asked to perform the cognitive (Stroop) or motor (maintain a tray with a cylinder) tasks while maintaining the standing position. Evaluating cognitive error and acceleration of the tray in sitting position was considered as a control condition for cognitive and motor performances, respectively.

In the Stroop task, participants were presented with color names printed in the same or different colors of ink [9,16]. Participants were instructed to look at the board in front of them to perform Stroop task. For the simple cognitive task conditions, the color of the ink was consistent with the color names. For the difficult conditions, the color of the ink was inconsistent with the color names. In all conditions, participants were instructed to report the color in which a color word was printed as fast and as accurate as possible. For example, if the word "red" was printed in "blue" ink, participants should say "blue" to be correct. The percent of correct responses provided within 60 s data collection was considered as cognitive performance. With regard to motor dual-task conditions, participants were instructed to stand upright with their upper arms at their sides and their elbows at 90 ° and hold a tray in which a cylinder (height of 17 cm and diameter of 5 cm) was lying on its flat side (considered as simple motor task) or its round side (considered as difficult motor task). In contrast to simple motor task, in difficult task conditions, the cylinder was free to roll in the mediolateral direction; its rolling was asked to maintain limited within two red lines drawn 8 cm apart in the bottom of the tray [15]. An embedded 3-axis linear accelerometer and gyroscope system with a digital data acquisition and feedback system was attached under the tray to quantify motor task performance. The inverse of mean absolute acceleration summed across 3 axes has been considered as motor performance stability index (MPSI). The stability of motor task increases when MPSI increases. The participants were instructed to not specifically prioterize either task in the dual-task conditions [3,10]. Before