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Effect of Yoga practice on reducing cognitive-motor interference for improving dynamic balance control in healthy adults

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ABSTRACT

Objective: The purpose of our study was to investigate the effects of Yoga on reducing cognitive-motor interference (CMI) for maintaining balance control during varied balance tasks.
Method: Yoga (N = 10) and age-similar non-practitioners (N = 10) performed three balance tasks including the Limits of Stability test (LOS – Intentional balance), Motor Control test (MCT – Reactive balance), and Sensory Organization Test (SOT –condition 6: inducing both somatosensory and visual conflicts) under single-task (ST) and dual-task (DT, addition of a cognitive working memory task) conditions. The motor performance was assessed by recording the response time (RT) and movement velocity (MV) of the center of pressure (CoP) on LOS test, weight symmetry (WS) of CoP on the MCT test and equilibrium (EQ) of CoP on the SOT test. Cognitive performance was recorded as the number of correct responses enumerated in sitting (ST) and under DT conditions. The motor cost (MC) and cognitive cost (CC) were computed using the formula ([ST-DT]/ST)*100 for all the variables. Greater cost indicates lower performance under DT versus ST condition.
Results: The Yoga group showed a significantly lesser MC for both MCT and SOT tests ($p < 0.05$) in comparison to their counterparts. The CC were significantly lower on LOS and MCT test for the Yoga group ($p < 0.05$).
Conclusion: Results suggest that Yoga practice can significantly reduce CMI by improving allocation and utilization of attentional resources for both balance control and executive cognitive functioning; thus resulting in better performance under DT conditions.

1. Introduction

Many daily activities need individuals to perform functional tasks requiring balance control concurrently with cognitive tasks.[1] Studies that have examined the attentional demands of the motor tasks during simultaneous performance of balance control and cognitive tasks (dual-tasking – DT), [2,3] had observed that the performance on either or both the tasks declines under DT conditions. These studies suggest sharing of central resources between balance and cognitive tasks, causes lesser attention to be focused on either one or both the tasks. This phenomenon is referred to as cognitive-motor interference (CMI).[4]

Dual-task studies have demonstrated a decline in performance of gait (gait speed, swing time, increased swing time variability) and cognition (executive function), dynamic balance (decrease in muscle response amplitude) and obstacle crossing (decrease in toe clearance and reactive time and increase in stepping time), demonstrating decline in performance of either one or both tasks when performed concurrently.[5–8] The pattern of interaction between integrating cognitive and motor tasks may depend on several factors, the type of cognitive task and the complexity of the balance control task.[9–10]

Many studies have demonstrated that Yoga training leads to improvement in balance control.[11–13] A systematic review indicated that Yoga improved performance on clinical balance control tests such as the Berg balance scale in both young and older healthy adults.[14] Another study compared the effect of a custom-designed Yoga program with Tai Chi training in healthy older adults and concluded that Yoga was as effective as Tai Chi for improving both static and dynamic balance control.[15]

Abbreviations: CMI, cognitive-motor interference; CoP, center of pressure; CNS, central nervous system; ST, single - task; DT, dual - task; LOS, limits of stability; MCT, motor control test; SOT, sensory organization test; RT, response time; WS, weight symmetry; EQ, equilibrium; MV, movement velocity; MC, motor cost; CC, cognitive cost; Y, yoga; NY, Non yoga.

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Furthermore, recent studies have reported that Yoga is effective in improving various higher cognitive functions such as executive control, mental flexibility, and working memory. A randomized controlled trial study examined the effects of an 8-week Hatha Yoga training on executive function, measures of task switching and working memory capacity in comparison with stretching-strengthening exercises in healthy older adults. The results showed a significant improvement in executive cognitive function, working memory capacity and mental set shifting and flexibility compared with their counterparts.[16] Another study demonstrated greater cognitive performance (increased accuracy) with an hour of Yoga practice, relative to aerobic exercise in healthy young adults on working memory function tested with the N-back task.[17] In spite of wide practice and balance control and cognitive benefits of Yoga, there has been no study yet evaluating the CMI under DT conditions, a necessary part to assess effects of Yoga practice.[18]

Thus, the purpose of this study was to investigate the effects of Yoga on CMI for maintaining balance control (intentional, reactive and both somatosensory and visual conflicts induced) while each of them is concurrently performed with a working memory function task. We hypothesized that the Yoga practitioners would perform significantly better in all the three balance control tasks in comparison to their age-similar non-practitioners in DT condition. Yoga practitioners would also have a significantly higher cognitive performance demonstrating decreased mutual CMI under DT conditions.

2. Method

Participants: Twenty individuals, including Ten Yoga practitioners, ten non-practitioners, similar in age, sex, height and education participated in this study. All participants were from the Chicagoland area. Yoga practitioners were recruited from Yoga centers and age-similar non-practitioners from the university student pool. All the participants reported that they practiced Hatha and Kundalini yoga (45–60 min/session, 2–3 sessions a week ≥1 year), which are the most popular forms of thought in the west. The study was approved by the Institutional Review Board of the University of Illinois. Informed consent was obtained from all the participants.

2.1. Protocol

Each participant completed three balance control tasks including the Limits of Stability test (LOS) (intentional balance), Motor Control test (MCT) (reactive balance), and posturography with conflicting somatosensory and visual information Sensory Organization test (SOT – condition 6) with and without a serial subtraction task.[19,20] The posturography task was conducted for condition 6, as the age-associated decline in equilibrium has been excessively reported in this condition. Further, the decrease in equilibrium scores has been correlated with increased risk of falls in older adults.[21] Participants also performed the three balance control tasks and the serial subtraction cognitive task in isolation while seated. The Equitest (Computerized Dynamic Posturography) system used in this study records the signals from the force-sensing surface and the computer processes the signals to quantity postural stability under various test conditions, normalized to participant's height and weight. These trials were defined as single-task (ST) and dual-task (DT) conditions. The details of each test are further described below.

2.1.1. Single task conditions

2.1.1.1. Limits of stability test (Intentional balance control task). The design, equipment and protocol for intentional balance control used in this study have been comprehensively detailed previously.[22] The outcome measures recorded by the software included movement velocity (MV) and response time (RT). Movement velocity was the average speed of the center of pressure movement in degrees per second. The Response time is calculated as the point in time at which the participants center of pressure (CoP) moves beyond the area occupied between the command to move and the onset of the individual's movement.

Formula: *Reaction time forward direction* $= \frac{0.5*S_{LF}+S_F+0.5*S_{RF}}{2}$ [23]

S = Score, S_{LF} = Score of left forward movement, S_{RF} = Score of right forward movement

2.1.1.2. Motor control test (MCT) (reactive balance control task). The design, equipment and protocol for the reactive balance control task is described elsewhere.[22] The outcome measure recorded by the software was weight symmetry (WS) and response time (RT). Weight symmetry quantifies the distribution of total body weight over each lower extremity during completion of the test. The response time was quantified as the time between translation (stimulus) onset and initiation of the individual's active response in milliseconds.

2.1.1.3. Sensory organization test (SOT – condition 6). Posturography task with conflicting somatosensory and visual information: Assessed by SOT protocol of the Equitest (Computerized Dynamic Posturography) on condition 6 with eyes open on sway- referenced support surface and surround (in this situation, the participants both somatosensory and visual information was distorted and the input from only the vestibular system was given). Participants initial starting position was similar to that of the starting position during LOS and MCT balance control protocol tests and participants wore the safety harness system. Participants were instructed to stand still and were asked to maintain their balance without taking a step or falling with eyes open on condition 6. Scores are based on the assumption that a normal individual can exhibit anterior to posterior sway over a total range of approximately 12.5 ° without losing balance. The equilibrium (EQ) score for each trial was calculated by comparing the angular difference between the individual's maximum anterior to posterior CoP displacements to this theoretical maximum displacement. The result was expressed as an inverse percentage between 0 and 100. Scores approaching 0 indicate sway amplitudes approaching the LOS with a value of 100 indicating perfect stability. A score of 0 indicates that the patient "fell" on that trial.

Equilibrium $= \frac{12.5^\circ - (\theta max - \theta min)\times 100}{12.5^\circ}$ [23]

2.1.1.4. Cognitive task. Each participant performed a test of executive function, serial subtraction task in a sitting position (single-task condition, ST). The serial subtraction task requires the transient holding and processing of new and existing information and can assess the working memory function. Participants were given predetermined numbers and asked to perform a serial subtraction (e.g. subtract 8 from 96 as many times as you can until stopped).[24]

2.1.2. Dual-task conditions

Under dual-task (DT) conditions, participants performed the three balance control tasks (LOS, MCT, and SOT tests) in conjunction with the serial subtraction task (Fig. 1). For the LOS test participants were asked to start serial subtraction from the given numbers as soon as they heard the start beep, while simultaneously shifting their weight in a given direction with feet in place. Similarly, for the MCT test they were asked to recite as many numbers as possible starting from the given numbers, while trying to maintain their balance and upright posture without taking a step or falling in response to sudden movement of the platform underneath their feet. For the SOT test, participants were asked to recite as many numbers as possible, while trying to maintain their standing balance with eyes open while the standing surface and the surrounding environment