University of Alberta

The Effect of a Three-week Multisensory Training Program for Postural Sway Control

by

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ABSTRACT

Evaluating postural sway parameters can play an integral part in a rehabilitation program. One device capable of quantifying postural sway measures is the Chattecx Dynamic Balance System (CDBS). The purpose of the Study 1 was to determine the test-retest reliability and the discriminant validity of the CDBS. Forty non-injured females, ranging in age from 20 to 49 years (mean age 30.03 ± 6.95 years) were randomly assigned according to the hours spent per week practicing sporting activities. This study demonstrated that the CDBS revealed good test-retest reliability (ICCs > 0.80), but it did not have good discriminant validity in distinguishing the effect of hours spent at sporting activities per week for postural sway control between Group 1 (exercise five hours or more) and Group 2 (exercise less than five hours) when testing static and dynamic balance.

Study 2 used a randomized controlled intervention to investigate whether a three-week multisensory training program would lead to a decrease of postural sway. Twenty four non-injured young females, ranging in age from 20 to 49 years (mean age 32.17 ± 7.70 years) and twenty four non-injured elderly females, ranging in age from 60 to 80 years (mean age 64.21 ± 4.58 years) were randomly assigned either to training groups (i.e. young training group: YTG, and elderly training group: ETG) or control groups (i.e. young control group: YCG, and elderly control group: ECG) with no training. Before and after the training program, all four study groups were measured for overall sway (OS), medial-lateral sway (MLS), and anterior-posterior sway (APS) for six training factors using the CDBS.

At posttest, the results showed significant improvement in the trained groups when compared to the untrained groups for all three postural sway measures for all six training factors in contrast with the pretest values. However, the ETG did not show significantly greater improvement when compared to the YTG. The findings also demonstrated that the trained ETG improved in their total Berg Balance Test (BBT) scores after the training program when compared to the untrained ECG.

The three-week multisensory training program successfully improved postural sway control and functional balance ability for both the non-injured young and elderly females. It is recommended that when designing such programs, specific sensory systems have to be targeted in order to expect improvement (i.e. reduced sway).

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CHAPTER 1

INTRODUCTION

1.1 PROBLEM STATEMENT

Balance is a complex process involving the coordinated activities of the reception and integration of multiple sensory inputs, motor components for the planning and execution of movement, and biomechanical components. The position of the body in relation to gravity and its surroundings is sensed by combining visual, vestibular, and somatosensory inputs to achieve a goal requiring upright posture so that a fall does not happen. Optimal controls of balance in upright posture as well as postural stability are essential requirements for sports activities, daily activities, or for the prevention from musculoskeletal injury. [1,2]

Balance is defined as a state of body equilibrium or the ability to control and to maintain the center of gravity (COG) or the center of body mass over the base of support without falling in a given sensory environment with integration of the central nervous system (CNS). [3,4] Berg [5] attempted to define balance in three important components: the ability to maintain a position, the ability to voluntarily move, and the ability to react to a perturbation.

Mattacola et al. [6] stated that center of balance (COB) is the point between the feet where the "ball" (metatarsal heads) and heel of each foot has 25% of the body weight (Figure 1.1 and Figure 1.2). This point is referred to as the relative weight positioning over the four load cells as measured only by vertical forces.

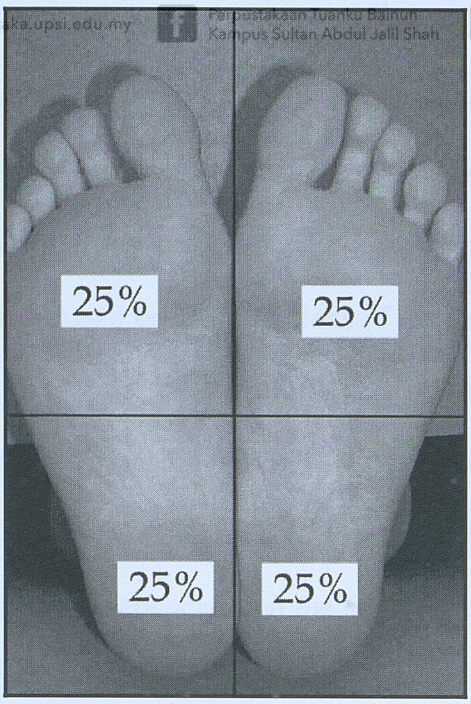

Figure 1.1: Bilateral stance: normal center of balance is the point between the feet where the "ball" and heel of each foot has 25% of the body weight.

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Figure 1.2: Single leg stance: normal center of balance is the point between the foot where the "ball" and heel of each foot is partitioned into four quadrants, each quadrant comprised of 25% of the body weight.

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Balance reactions occur to maintain or regain the center of gravity over the base of support. These automatic reactions occur during static positions such as sitting and quiet standing (static balance), and they occur during transition phases, that is, from one position to another position (dynamic balance) (e.g., sit to stand, walk, and turn). Balance response selection is based on the conditions of the perturbation (i.e. amplitude, velocity, and direction), the initial position of the individual (the position of the individual in space and the relationship of body parts to each other), environmental conditions (e.g. the stability of support surface, objects in the environment, and the condition of the lighting), past experiences, and the goal. The goal to be achieved is to maintain or regain the center of gravity over the base of support so the individual remains balanced. [7] Variables that may affect balance and that are constantly changing include: (a) the location of the center of gravity (COG), (b) the base of support, (c) the limit of stability, (d) the surface conditions, (e) the visual environment, (f) sensory input, (g) movement, and, (h) the intentions and task choices in producing changing demands on the systems that control balance. [8]

Balance is a multi-component and highly adaptable control process. When a balance of a healthy individual is challenged, the sensory inputs determining the COG position and the pattern of movement correcting the perturbation depend on the task conditions and the person's immediate past experience. An individual with one or more impaired sensory input or motor output component will attempt to compensate by adapting both the impaired and normally functioning components to suit the demands of the balance task. Balance movements involve primarily motions of the ankle, knee, and hip joints, which are controlled by the coordinated actions of ankle, thigh, and lower trunk muscles as a task of maintaining a person's center of gravity over the base of support. [9,10]

Postural control has been defined as the ability to maintain posture equilibrium in a gravitational field by keeping or returning the center of body mass over its base of support to attain the desired positions or movement without falling. [11-13] Although postural control is taken for granted, it is a complex process involving the coordinated actions of biomechanical, sensory, motor, and central nervous system components. [3] Postural control has been functionally divided into several different activities including maintenance of posture (standing and sitting), controlled movement of the body's center of mass, and response to external disturbances. [5] Postural control is an integral component of all movement. [11] The ability to maintain postural control under dynamic conditions is an important underlying component of physical activity or performance. [14] Dysfunction in postural control may cause functional loss as well as restricted mobility. Fluctuations in displacement also indicate the response of the central nervous system (CNS) to correct the body's COG to prevent imbalance. [15] Deviation from this center of balance in any direction represents postural sway. Postural sway is the distance expressed in centimeters that an individual travels away from his or her center of balance. [12]

The goal of postural control is to orient the body parts relative to one another and the external world without loss of balance. Unstable environments place greater demands on the postural control systems. [8] The more stable the environment, the lower the demand on the individual for balance and postural control. [8] Posture must be controlled both while the body is still (static equilibrium) and during movement (dynamic equilibrium). Stabilization of postural equilibrium is achieved by continuous afferent and efferent control strategies within the sensorimotor system with feedback from somatosensory, vestibular and visual inputs. [2] The afferent information is processed in the brainstem and cerebellum, and then motor commands are initiated. [16] If any of the sensorimotor feedback loops is suppressed or defective, body sway increases and concurrently, muscle activity increases to maintain balance. [17] In the dynamic states of natural behavior, voluntary movement can perturb postural equilibrium, but knowledge of these potential perturbations is built into the motor program and used to offset their adverse effects ahead of the event by anticipatory (feed-forward) motor action. [18] The anticipatory postural responses are controlled by multi-sensory feedback such as visual, somatosensory, and vestibular inputs. They are also controlled by the postural strategies for correction includes ankle, hip, and stepping strategies. [19] These postural adjustments act in advance to compensate for changes in posture and balance caused by the movement. Anticipatory responses are adaptable to task conditions and must be learned, but eventually, they operate automatically after being triggered by specific intended movements. The postural system is also equipped with stereotypical response patterns that are rapidly corrected for unexpected perturbations. Some of these responses are innate, while others have to be acquired through motor learning that involves the cerebellum. These responses are characteristically driven by immediate feedback from visual, vestibular, and somatosensory information. Postural control is complex and context dependent. Postural control is not organized as a single unit. Independent control of the position or orientation of segments such as the head, trunk, and forearm has been shown to exist.

Nashner [9] stated that the ability to maintain postural control and balance depends on information provided by visual cues, vestibular function, and somatosensory feedback (proprioceptive neural input) from structures in the lower extremities. The integrity and interaction of postural control mechanisms (i.e. visual receptors, vestibular systems, and proprioceptive mechanoreceptors) allow a wide range of movement and functions to be achieved without loss of balance. [8] If balance and postural control are not established following injury, then the individual will be susceptible to recurrent injury and balance and postural performance may decline.

Balance abilities are heavily influenced by higher level neural circuitry and by multiple body systems such as the cognitive, sensorimotor, and musculoskeletal systems. [20] The nervous system is influenced by and responsive to the demands placed on it by the tasks being accomplished and the environment in which those tasks are performed. [21-23] The ability to maintain balance requires the integration of proprioceptive input from the periphery with afferent information from the eyes (visual) and the vestibular apparatus in the inner ear. [24] Therefore, proprioception is a distinct component of balance. Numerous investigators have provided definitions regarding the terminology of joint sensation, or proprioception and kinesthesia. Most contemporary authorities define proprioception as a specialized variation of the sensory modality of touch that encompasses the sensation of joint movement (kinesthesia) and joint position sense. [25,26] They refer to proprioception as the inborn kinesthetic awareness of body posture including movement, tension, and changes in equilibrium. [27] Irrgang et al.[14] have defined proprioception (somatosensory) as the ability of the central nervous system to process received input from muscles, tendons, and joints and to translate the information in a meaningful way.

Proprioceptive input is the cumulative neural input from the mechanoreceptors in the muscles (i.e. muscle spindle receptors and Golgi tendon organs), joint capsules, ligaments, tendons, and skin (i.e. cutaneous receptors) that is conveyed to the central nervous system (CNS) through afferent neural pathways. [6,27] Proprioceptive feedback to the brain contributes to the body's ability to maintain postural stability. In addition, a loss of somatosensory function may lead to a loss of balance (i.e. increased postural sway) in otherwise healthy individuals. Normal balance is a combination of coordination and the individual's ability to maintain the body upright against the forces of gravity. Posture varies based on such factors as musculoskeletal structure, neurological functioning, heredity, and personality. [28]

Maintaining balance is a function of a number of sensory inputs to the CNS, including visual, vestibular, and somatosensory components. These three sensory inputs are required because no single sense can measure the COG position directly relative to gravity and the base of support. Vision measures the orientation of the eyes and head in relation to surrounding objects. The somatosensory input provides information on the orientation of body parts relative to one another and to the support surface. The vestibular input does not provide orientation information in relation to external objects. Rather, it measures gravitational, linear, and angular accelerations of the head in relation to inertial space. There is no single combination of the three senses that provides accurate COG information under all performance conditions. This is because one or more of the senses may provide information that is misleading or inaccurate for purposes