

The Effects of Postural Threat on Cognitive Strategies Used to Maintain Upright Stance

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Abstract

It is well established that postural threat modifies postural control, although little is known regarding the underlying mechanism(s) responsible. It is possible that changes in postural control under conditions of elevated postural threat result from alterations in cognitive strategies. The purpose of this study was to determine the influence of elevated postural threat on cognitive strategies and to determine the relationship between postural control, psychological, and cognitive measures. It was hypothesized that elevated postural threat would cause a shift to more conscious control of posture. It was also expected that a relationship between fear of falling and postural control would exist that could be explained by changes in conscious control of posture. Forty-eight healthy young adults stood on a force plate at two different surface heights: ground level (LOW) and 3.2m above ground level (HIGH). Center of pressure (COP) summary measures calculated to quantify postural control were the mean position (AP-COP MP), root mean square (AP-COP RMS) and mean power frequency (AP-COP MPF) in the anterior-posterior direction. Trunk sway measures calculated in the pitch direction were trunk angle and trunk velocity. Psychological measures including perceived balance confidence, perceived fear of falling, perceived anxiety, and perceived stability were self reported. As a physiological indicator of anxiety, electrodermal activity was collected. The cognitive strategies assessed were movement reinvestment and attention focus. A modified state-specific version of the Movement Specific Reinvestment Scale was used to measure conscious motor processing (CMP) and movement self-consciousness (MSC). An attention focus questionnaire was developed to assess the amount of attention directed to internal and external sources. An effect of postural threat on cognitive strategies was

observed as participants reported more conscious control and a greater concern or worry about their posture at the HIGH postural threat condition as well as an increased internal and external focus of attention. In addition changes in postural control, psychological, and physiological measures were found. The participants leaned away from the edge of the platform, the frequency of their postural adjustments increased, and the velocity of their trunk movements increased. Participants felt less confident, more fearful, more anxious, and less stable with an accompanying increase in physiological anxiety.

Significant correlations between perceived anxiety, AP-COP MP, and cognitive measures revealed a possible relationship that could be mediated by cognitive measures. It was found that with greater conscious motor processing, more movement self-consciousness, and a greater amount of attention focused externally there was a larger shift of the mean position away from the edge of the platform. This thesis provides evidence that postural threat can influence cognitive strategies causing a shift to more conscious control of movement which is associated with leaning away from the edge of the platform. Shifting the position of the body away from the direction of the postural threat may reflect a cognitive strategy to ensure safety in this situation due to the inability to employ a stepping strategy when standing on an elevated platform.

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CHAPTER ONE – LITERATURE REVIEW

Postural control is a complex sensori-motor task which requires the integration of sensory input from visual, vestibular, and somatosensory receptors into appropriate motor responses (Massion, 1994; Winter, 1995; Maki & McIlroy, 1996; Horak, 2006).

Research has implicated a number of structures needed for optimal postural control with recent focus on the role of the cerebral cortex (Jacobs & Horak, 2007; Maki & McIlroy, 2007). Evidence for the involvement of the cerebral cortex is derived from changes in postural control with alterations in postural set (i.e. prior experience and instructions), attention requirements, and other psychological factors (Horak, Diener, & Nasher, 1989; Woollacott & Shumway-Cook, 2002; Yardley & Redfern, 2001). In particular, fear of falling has been shown to influence postural control, however the underlying mechanisms for this relationship are still unknown. One possibility is that a fear of falling may influence posture by inducing a shift in the cognitive strategies used to maintain upright stance, resulting in a more conscious control of posture.

1.1 *Fear of Falling*

Fear of falling is a specific type of anxiety that has often been defined as a decreased confidence, or falls-related efficacy, in the ability to avoid a fall (Legters, 2002). Others argue that although fear of falling and falls-related efficacy are similar, they are ultimately separate constructs (Li, McAuley, Fisher, Harmer, Chaumeton, & Wilson, 2002). Thus, a more appropriate definition for fear of falling may be a concern or worry about falling (Legters, 2002). Fear of falling is associated with impaired postural control in older adults (Maki, Holliday, & Topper, 1991) and neurologically impaired populations such as Parkinson's disease (PD) (Adkin, Frank, & Jog, 2003). It is difficult

to determine the actual influence of fear of falling on postural control in these populations as other physical, psychological, or cognitive factors may confound the findings. One way that has been used to isolate the effects of fear of falling on postural control is to manipulate postural threat by increasing the surface height at which young healthy adults maintain upright stance.

1.2 *Postural Threat*

1.2.1 *Postural Control Effects*

Research has consistently shown that the presence of a postural threat, evoked by changes in surface height, can modify postural control. It has typically been found that participants adopt a cautious strategy during quiet standing (Carpenter, Frank, & Silcher, 1999; Carpenter, Frank, Silcher, & Peysar, 2001a; Adkin, Frank, Carpenter, & Peysar, 2000; Brown, Polych, & Doan 2006; Laufer, Barak, & Chemel, 2006; Carpenter, Adkin, Brawley, & Frank, 2006), anticipatory postural control (Adkin, Frank, Carpenter, & Peysar, 2002), reactive postural control (Brown & Frank, 1997; Carpenter, Frank, Adkin, Paton, & Allum, 2004), gait (Brown, Gage, Polych, Sleik, & Winder, 2002a; Gage, Sleik, Polych, & Brown, 2003), and clinical balance tests (Hauck, Carpenter, & Frank, 2007).

Postural threat has been shown to alter strategies for the control of upright stance in terms of center of pressure (COP), center of mass (COM), and electromyography (EMG) measures. A number of studies have used COP summary measures to quantify the changes in postural control and have consistently reported a decrease in the amplitude and increase in the frequency of postural adjustments as well as a shift of the mean position of the COP posteriorly away from the edge of the platform (Carpenter et al., 1999; Carpenter et al., 2001a; Adkin et al., 2000; Brown et al., 2006; Laufer et al., 2006;

Carpenter et al., 2006; Hauck et al., 2007). In addition to these modifications of the COP, it has also been documented that the COM has reduced amplitude and increased frequency of displacement, as well as a posterior shift away from the edge of the platform (Brown & Frank, 1997; Carpenter et al., 2001a, Brown et al., 2006). Changes in muscle activity of the lower limbs has also been documented as there is a increased activity in the tibialis anterior and rectus femoris and decreased activity in the gastrocnemius and soleus muscles when standing on an elevated surface (Carpenter et al., 2001a, Brown et al., 2006). Carpenter et al. (2001a) confirmed the presence of a stiffness strategy by modelling the body as an inverted pendulum and determining that the stiffness constant increased, based on the difference between the COP and COM, when faced with a postural threat. These studies provide evidence of a stiffening strategy during quiet standing when faced with a postural threat as the central nervous system (CNS) minimizes movement of the COM via the COP which is controlled by the ankle plantarflexors and dorsiflexors and the hip abductors and adductors in the anterior-posterior (AP) and medial-lateral (ML) directions, respectively (Winter, Patla, Prince, Ishac, & Gielo-Periczak, 1998; Gage, Winter, Frank, & Adkin, 2004).

Similar alterations in behaviour have been observed when investigating anticipatory and reactive postural control as well as gait and functional tasks as participants adopt a more cautious strategy when faced with a postural threat. When standing at the edge of an elevated surface, in addition to a posterior shift of the COP, there was a documented decrease in the anticipatory postural adjustment, decrease in the forward movement, and fewer successful completions of the task (Adkin et al., 2002). Postural threat also modifies reactive postural control (Brown & Frank, 1997; Carpenter

et al., 2004) as at the elevated surface height the displacement of the COM was decreased. Gait characteristics have been shown to be altered by postural threat as there is a reduction in lower limb joints angles and velocities, increased tibialis anterior and gastrocnemius activation, slower gait velocity, longer double limb support, and shorter stride length (Brown et al. 2002a, Gage et al., 2003). Recently, it has been shown that the influence of postural threat can also modify performance on clinical postural control tests as participants demonstrated impaired performance as depicted by a shorter duration for one leg stance and decreased displacement of the COP during a maximal reach test when standing at an increased surface height (Hauck et al., 2007).

The results of the above mentioned studies have consistently shown a cautious behaviour in terms of safety when faced with a postural threat but fail to replicate the decrements in postural control seen in older adults who report a fear of falling (Maki et al., 1991). This result may be attributed to the fact that the height at which participants are required to stand is not high enough to evoke the fear of falling in young healthy participants that is felt by older adults who have a fear of falling in everyday life. Recently, it has been shown that non-fearful and fearful participants display different alterations in postural control when standing at heights of 3.2m (Davis, Campbell, Adkin, & Carpenter, 2009). Although both groups leaned away from the edge and increased frequency of postural adjustments with increasing surface height, the fearful participants leaned further away from the edge and had higher frequency adjustments compared to the non-fearful participants. Interestingly, the fearful participants had an increased amplitude of postural adjustments with increasing surface height while the non-fearful participants showed a decrease in amplitude of postural adjustments. This study was the first to use a

surface height paradigm to replicate the findings of impaired postural control in fearful participants by Maki et al. (1991). Similar results of increased COP amplitude have been observed when individuals stand at heights higher than 3.2m, however these studies never directly measured fear of falling (Nakahara, Takemori, & Tsuruoka, 2000; Simeonov & Hsiao, 2001; Simeonov, Hsiao, Dotson, & Ammons, 2003).

1.2.2 *Psychological and Physiological Effects*

In addition to changes in postural control, a number of physiological and psychological effects have been documented when faced with a threat to posture. A number of studies have shown an increase in physiological responses that are indicative of increased arousal and anxiety such as galvanic skin conductance (Adkin et al., 2002; Brown, Sleik, Polych, & Gage, 2002b; McKenzie & Brown, 2004; Brown, Polych, & Doan, 2006) and blood pressure (Carpenter et al., 2006).

Several psychological changes have also been documented as well when presented with a postural threat. With increasing surface height, participants reported feeling less confident (Adkin et al., 2002; Carpenter et al., 2004; Carpenter et al., 2006; Hauck et al., 2007), more fearful of falling (Davis et al., 2008), more anxious (Adkin et al., 2002; Carpenter et al., 2004; Carpenter et al., 2006; Hauck et al., 2007), and less stable (Adkin et al., 2002; Simeonov et al., 2003; Hauck et al., 2007) on a variety of tasks. These findings are associated with changes in postural control. However, the causal nature of this relationship is unknown. For example, changes in affect may lead to changes in postural control or it may be that changes in postural control lead to changes in affect. The findings of increased fear of falling and anxiety are congruent with the findings of physiological anxiety. However, the findings of perceived stability do not

consistently match the findings of actual stability. Objective measures of stability have shown that participants are more steady when faced with a threat as there is a decrease in the amplitude of postural adjustments, but report feeling less stable (Adkin et al., 2002; Hauck et al., 2007). Hauck et al. (2007) found a significant negative correlation between amplitude of postural adjustments in the AP direction and perceived stability as a decrease in amplitude was associated with feelings of instability. With increasing height, during quiet stance, the stiffening strategy is adopted; however participants report feeling less stable at the higher height even though the amplitude of sway is less than ground level (Hauck et al., 2007). Simeonov et al. (2003) found that when surface height was increased to 3m, participants were less stable in terms of objective balance and reported feeling less stable as increased frequency of AP sway and sway velocity was associated with increased perceived instability. From this finding the authors concluded that participants evaluated their stability based on the frequency of postural adjustments.

1.2.3 Cortical Processing Effects

There is evidence to suggest that postural threat is capable of modifying the cortical processing of postural control. It has been documented that when standing under conditions of elevated postural threat the Hoffman reflex is attenuated (Sibley, Carpenter, Perry, & Frank, 2007). The authors suggested that this reduction may have been due to an increase in supraspinal control of posture as pre-synaptic inhibition from cortical centers may have played a role in the modulation of the spinal reflex. The cortical response to postural perturbations has also been shown to be influenced by a postural threat (Adkin, Campbell, Chua, & Carpenter, 2008). It was found that in response to unpredictable perturbations a significantly larger negative potential of the early cortical responses was

detected, which is associated with error detection between actual and expected states, under conditions of postural threat compared to no threat. This suggested that there is greater cortical processing of sensory information when experiencing a postural threat. These studies demonstrate that higher level function can be modified by the experience of elevated postural threat, specifically the involvement of the cortex in postural control.

1.2.4 *Cognitive Effects*

Although much research has investigated the effects of postural threat on the postural, psychological, and physiological behaviour, little research has been done to address the effects of postural threat on cognition. Researchers found that when faced with a dual task situation with increased postural threat participants adopted a more cautious gait pattern and increased auditory probe reaction times (Gage et al., 2003). Gage et al. (2003) argued that this increase in reaction time during gait was indicative of increased attentional demands of gait and an increase in the allocation of attentional resources to gait. It was suggested that postural threat causes attention to be directed to gait to ensure stability. The researchers reasoned that increased probe reaction times during gait were evidence of an internal focus of attention. However, attention focus was not measured directly but rather inferred. Postural threat has been shown to influence dual task performance when standing under conditions of elevated threat (Brown et al., 2002b). It was found that performance for the Brooks Spatial Letter Task improved in the young adults and decreased in the older adults when faced with a postural threat. The authors determined this difference in dual task performance was due to the fact that the older adults prioritized postural control more than younger adults at the high surface height. It was also found in older adults that with an elevated postural threat, performing

the secondary task resulted in a decrease in COP area compared to no secondary task. It may be possible that in young adults a more extreme surfaces height, similar to those used by Davis et al. (2009), may evoke a similar prioritization of posture. Together these two studies suggest that when faced with a postural threat cognitive and attentional factors are altered and it has been suggested that greater attentional resources may be devoted to the control of posture.

1.3 *Cognitive Appraisal and Coping Strategies*

Although consistently it has been shown that postural threat can influence postural control, the mechanisms responsible for these alterations are unknown. It is possible that the task constraints imposed by a postural threat influence psychological state which modify cognitive aspects of performance. For example, when faced with a postural threat participants feel fearful and anxious and as a result try to consciously control their posture in an attempt to ensure safety. Lazarus and Opton (1966) have described a framework in which cognitive appraisal of a situation results in a coping strategy to modify behaviour. Cognitive appraisal is how a person evaluates a specific situation or threat based on the characteristics of the threat and their own psychological structure (i.e., beliefs, resources, knowledge, motivation, etc.). After a situation has been appraised by a person as threatening, it leads to a coping process in which the person attempts to reduce the perceived threat and ensure safety. Changes in cognitive strategies during the control of posture may represent a coping strategy based on the perception of threat. Differences in the appraisal of threat and subsequent cognitive strategies may explain the postural modifications between low and high postural threat and also between participants based on their own appraisal of the threat (Davis et al., 2008).

1.4 *Cognitive Strategies*

Cognitive strategies are consciously controlled processes that can be implemented by an individual in an attempt to enhance motor performance (Singe & Chen, 1994). It has been suggested that these cognitive strategies can either be beneficial or harmful to motor performance (Masters & Maxwell, 2008).

1.4.1 *Movement Reinvestment*

Norman and Shallice (2000) have argued that a task can be performed either automatically or controlled, depending on the amount of information processing resources directed towards the task. It is generally believed that once a motor skill is learned and automatic that it will be optimally performed with little conscious control (Magill, 2004). Masters and colleagues have used the term reinvestment to describe conscious control of a motor skill (Masters & Maxwell, 2008). The term reinvestment was first used by Deikman (1969) to describe a process of deautomatization caused by directing attention towards actions and perceptions. It has been suggested that individuals who tend to partake in reinvestment would be more likely to attempt conscious control and experience decreased performance, especially under stressful conditions (Masters, Polman, & Hammond, 1993). The Reinvestment Scale (RS) was developed to measure an individual's tendency to consciously control actions when performing a motor skill (Masters et al., 1993). High reinvestment was related to decreased performance on a golf putting task and a tendency to choke under pressure in tennis and squash players (Masters et al., 1993). However, this scale contained items that were not specific to movement but rather contained items that were reflective of emotions and cognitions. As a solution, the Movement Specific Reinvestment Scale (MSRS) was developed to measure the tendency

to consciously control movement specifically (Masters, Eves, & Maxwell, 2005; Masters & Maxwell, 2008). The MSRS has two subscales that measure movement self-consciousness and conscious motor processing. Movement self-consciousness reflects the amount of worry or concern regarding movement while conscious motor processing reflects the amount of conscious control of movement. Currently, the MSRS has been used to quantify differences in trait reinvestment between different clinical populations. Researchers have found that stroke patients reinvest more than age-matched controls (Orrell, Masters, & Eves, 2002), elderly fallers reinvest more than elderly non-fallers (Wong, Masters, Maxwell, & Abernethy, 2008), and reinvestment in PD patients was correlated with disease duration (Masters, Pall, MacMahon, & Eves, 2007). Wong et al. (2008) also found that the conscious motor processing subscale was a better discriminator between fallers and non-fallers than the movement self-consciousness subscale. PD and stroke patients also scored higher on the conscious motor processing subscale than the movement self-consciousness subscale (Orrell et al., 2002; Masters et al., 2007). Therefore, conscious motor processing may be more important than movement self-consciousness in determining motor skill performance. Due to the nature of the experimental design used in these studies, the authors were unable to determine if reinvestment, possibly due to falls-related anxiety, led to impaired motor control or if impaired motor control led to increased reinvestment (Wong et al., 2008).

These general and movement specific reinvestment scales measure general trait-like tendencies to adopt conscious processing. It is the authors' premise that those who are naturally high in reinvestment will be more likely to fail under stressful conditions (Masters & Maxwell, 2008). Although not yet examined, it is possible that reinvestment

may also be a state-like process whereby stressful situations may cause an increase in conscious processing (Masters & Maxwell, 2008). It has been suggested that pressure situations increase self-consciousness which in turn decreases the performance of motor skills due to alterations in attention focus (Baumeister, 1984; Lewis & Linder, 1997; Pijpers, Oudejans, & Bakker, 2005). For example, Pijpers et al. (2005) used a height manipulation to induce pressure and anxiety in wall climbers and suggested that the decrements in performance at the higher height were the result of an inward focus of attention on body movement. A major limitation of these studies is the lack of a measure of attention focus and as such the conclusions are based on the assumption that attention is shifted to conscious control of movement. Although the majority of the literature regarding motor performance is limited in its objective assessment of shifts in attention focus other areas of psychology do lend support. Evidence suggests that highly anxious individuals, especially when in a high pressure situations, will suffer from test anxiety due to shifts in attention focus to inappropriate task-irrelevant sources (Wine, 1971).

1.4.2 *Attention Focus*

While these studies have investigated attention focus as either automatic or controlled, another area of inquiry has investigated how conscious control can be directed to different sources (Magill, 2004). Research over the past decade has documented that instructions to adopt an external focus of attention, such as thinking about the body's effect on an apparatus or environment, enhances motor control and learning compared to adopting an internal focus, such as thinking about the body's movement (Wulf, 2007). For example, when learning a golf swing, instructions to focus externally on the movement of the club resulted in more effective learning than instructions to focus

internally on the movement of the arms (Wulf, Lauterbach, & Toole, 1999). This beneficial effect of an external focus of attention, compared to an internal attention focus or no instructed focus as all, has been observed when participants perform a wide variety of sport skills (e.g., golf, tennis, etc.) and balance tasks (Wulf & Prinz, 2001; Wulf, 2007). The benefits of an external focus of attention also have been demonstrated in learning balance tasks (Wulf, Höb, and Prinz, 1998; Shea & Wulf, 1999; Wulf et al., 2001; Wulf & McNevin, 2003; McNevin et al., 2003; Totsika & Wulf, 2003). External focus instructions enhanced learning of ski simulator, stabilometer, and pedalo tasks compared to no specific instructions or internal focus instructions.

The constrained action hypothesis has been proposed to explain the benefits of an external focus of attention (Wulf, 2007). This hypothesis states that an external focus allows for movement to occur more automatically while an internal focus constrains the motor system resulting in less automatic movement. Evidence supporting the constrained action hypothesis can be found in a number of areas. It has been found that auditory probe reaction times were longer when performing a balance task with internal focus instructions compared to external focus instructions (Wulf, McNevin, & Shea, 2001) and control conditions where no specific instructions were given (Vuillerme & Nafati, 2007). This was evidence that an external focus provided for more automatic processing which allowed attention resources to be directed to the probe reaction task whereas an internal focus required attention resources resulting in slower probe reaction times. Wulf and colleagues have documented an increase in movement frequency when balancing on a stabilometer which suggests that the motor system is controlling movements more automatically with larger degrees of freedom (McNevin, Shea, & Wulf, 2003). Another

line of evidence involves electromyography analysis. It has been found that an external focus not only results in better performance but also more efficient muscle activity when performing a biceps curl or a basketball shot (Vance, Wulf, Töllner, McNevin, & Mercer, 2004; Zachry, Wulf, Mercer, & Bezodis, 2005). These studies are evidence that an external focus allows for automatic motor control whereas an internal focus constrains motor control.

In addition to influencing the learning of motor tasks, attention focus instructions have also been shown to influence postural control. Vuillerme and Nafati (2007) found that attention focus instructions to focus on an internal source can influence the control of upright stance. Participants were either given no instructions or were instructed to consciously “intervene” in postural control. It was observed that consciously intervening in postural control did not alter the center of gravity (COG). However, the amplitude and frequency of movement of the difference between the COP and COG (COP-COG), which has been assumed to be linked to ankle stiffness, was found to be increased with instructions to consciously control posture. The authors concluded that this increase in ankle stiffness was an inefficient and less automatic strategy for upright stance.

The effectiveness of external focus instructions is related to the difficulty of the task (Wulf, Töllner, & Shea, 2007). No difference was observed between external, internal, and control groups when standing on two legs on normal or foam support with eyes open. However, when the tasks increased in difficulty to standing on one leg and standing on two legs on a rubber disk, the external focus instructions resulted in decreased amplitude of postural adjustments compared to internal or control instructions, which were not different from each other. It was suggested that the benefit of external

focus instructions was only observed during difficult tasks because of conscious intervention. During the easier tasks there was little conscious intervention directed towards the task therefore instructions had little impact on performance. However, during the more difficult tasks, participants felt unstable and attempted to consciously intervene in balance control. The authors suggested that external focus instructions may minimize the debilitating effects of conscious intervention (Wulf et al., 2007).

The majority of these studies have used young healthy participants but evidence is now emerging to show that external focus instructions also may be beneficial for clinical populations. External focus instructions have been shown to improve postural control in PD patients (Landers, Wulf, Wallmann, & Guadagnoli, 2005). Participants performed three balance tasks (standing eyes open on normal support, eyes closed on normal support, and eyes open on sway referenced support) under different attention focus instructions (control, internal, and external). The researchers found that in patients with a history of falls, external focus instructions resulted in increased stability compared to internal and control instructions but only when standing with sway referenced support. External focus instructions also improved balance rehabilitation in participants who have suffered an ankle sprain more than internal focus instructions (Laufer, Rotem-Lehrer, Ronen, Khayutin, & Roznberg, 2007). Both groups showed improvements in stability while training with the Biodex Stability System although the gains were greater in the group given external attention focus instructions. Attention focus instructions have also benefited stroke patients during functional reach tasks as instructions to focus externally on the object, compared to instructions to focus internally on hands and arms, resulted in shorter movement time and higher peak velocity when moving a can from a shelf to a

table, an apple from a shelf to a basket, and an empty coffee mug from a table to a saucer (Fasoli, Trombly, Tickle-Degnen, & Verfaellie, 2002).

The results of these studies suggest that cognition can play an important role in the control of movement, including maintaining upright stance. Therefore, the effects of postural threat on postural control may be explained by shifts in cognitive strategies, resulting in a more conscious control of posture.

CHAPTER TWO – RATIONALE, PURPOSE, and HYPOTHESES

2.1 *Rationale*

It has consistently been shown that postural threat, as evoked by changes in surface height, can modify postural control. When faced with a postural threat during upright stance, a cautious, stiffening strategy is adopted as there is a documented decrease in the amplitude and increase in the frequency of postural adjustments as well as a leaning away from the edge of the platform. There are also a number of documented psychological and physiological changes that occur when faced with a postural threat as participants report feeling less confident, more fearful of falling, more anxious, and less stable with an accompanying increase in physiological anxiety. Although the postural, psychological, and physiological changes have been consistently documented in a number of studies, the exact mechanism responsible for the postural control modifications is still unknown. There is evidence to suggest that certain situations which cause changes in affect can alter cognitions and in turn influence motor performance (Pijpers, 2005). Research into the influence of attention focus instructions has demonstrated that altered cognitive strategies are capable of influencing postural control (Vuillerme & Nafati, 2007). Currently, the influence of postural threat on cognitive strategies is unknown. No studies have yet attempted to quantify the cognitive strategies adopted by participants when standing under conditions of elevated threat. Furthermore, the relationship between postural control, psychological, and cognitive measures has yet to be determined. A relationship may exist between postural control, psychological, and cognitive measures that could explain the changes in postural control seen when faced with a postural threat.

2.2 *Purpose*

The main purpose of this thesis was to investigate the effect of postural threat on cognitive strategies used to maintain upright stance. Postural threat was manipulated by changing the surface height at which individuals stood. Cognitive strategies were assessed through self-report measures (i.e., movement reinvestment and attention focus). The second purpose of this thesis was to determine if the relationship between the changes in psychological measures and postural control measures could be explained by changes in cognitive strategies in response to a postural threat.

2.3 *Hypotheses*

It was hypothesized that participants would engage in more conscious control of posture when standing under elevated postural threat on a high surface (Brown et al., 2002b; Gage et al., 2003; Wong et al., 2008). In addition to these changes in cognitive strategies it was expected that the typical changes in postural control, psychological, and physiological measures would occur (Carpenter et al., 2004, Davis et al., 2009). In terms of postural control it was hypothesized that there would be a shift in mean position away from the edge of the platform, a decrease in amplitude of postural adjustments, and an increase in the frequency of postural adjustments when faced with a postural threat. In terms of trunk sway it was expected that there would be a decrease in trunk pitch angle displacement and increase in trunk pitch velocity, as similar changes have been found for the COM when standing under conditions of elevated threat (Carpenter et al., 2001a; Brown et al., 2006). It was also expected that participants would feel less confident, more fearful of falling, more anxious, and less stable with an accompanying increase in

physiological anxiety when standing at an increased height. It was also hypothesized that this increase in the conscious control of posture when threatened would mediate the relationship between the changes in psychological measures and postural control.

CHAPTER THREE - METHODOLOGY

3.1 *Participants*

Fifty-nine healthy young adults (27 males; age mean \pm standard deviation; 25.2 \pm 4.2 years) volunteered to participate in this study. All participants provided written informed consent prior to any experimental procedures as approved by the UBC Clinical Research Ethics Board (H06-70316) and the Brock Research Ethics Board (#08-271) (Appendix A). Exclusion criteria included any self-reported neurological, vestibular, or musculoskeletal conditions that could interfere with balance or any self-reported extreme fear of heights.

3.2 *Procedure*

Postural threat was manipulated by changing the surface height at which individuals stood. This was done using a 2.13m x 1.52m hydraulic lift platform (M419-207B10H01D, Penta-lift, Canada) with a force plate (#K00407, Bertec, USA) placed at the edge of the platform. Participants performed one 60s quiet standing trial at ground level (LOW) and at a surface height of 3.2m above ground level (HIGH) (Carpenter, Frank, Winter, & Peysar, 2001b). Surface height was presented in ascending order with participants standing at the low height first followed by the high height to maximize postural threat (Adkin et al., 2000). A device mounted to the lower back (L2-3) was used to measure trunk sway (SwayStar System, Balance Int. Innovations GmbH, Switzerland) (Allum & Carpenter, 2005). As a measure of physiological arousal, electrodermal activity (EDA) was collected using disposable Ag/AgCl electrodes placed on the thenar and hypothenar fascia (2502 Skin Conductance Unit, Cambridge Electric

Design, UK). For all standing trials participants were fitted with a harness which only provided support in case of a fall, although none were observed. Participants stood barefoot with arms at their sides on a force plate and were instructed to stand as still as possible and fixated on a visual target at eye level 3.87m in front of them. Foot position was kept constant for all trials with toes placed at the anterior edge of the force plate with feet shoulder width apart. Shoulder width was determined by each participants' foot length. A practice trial was performed first at ground level to minimize possible first trial effects related to anxiety (Adkin et al., 2000) and to reduce any possible priming effects of the questionnaires. Between each trial participants were given a seated rest. For each trial a number of measures, including perceived balance confidence, perceived fear of falling, perceived anxiety, perceived stability, movement reinvestment, and attention focus were assessed through the use of questionnaires. Figure 1 shows a timeline for experimental procedures.

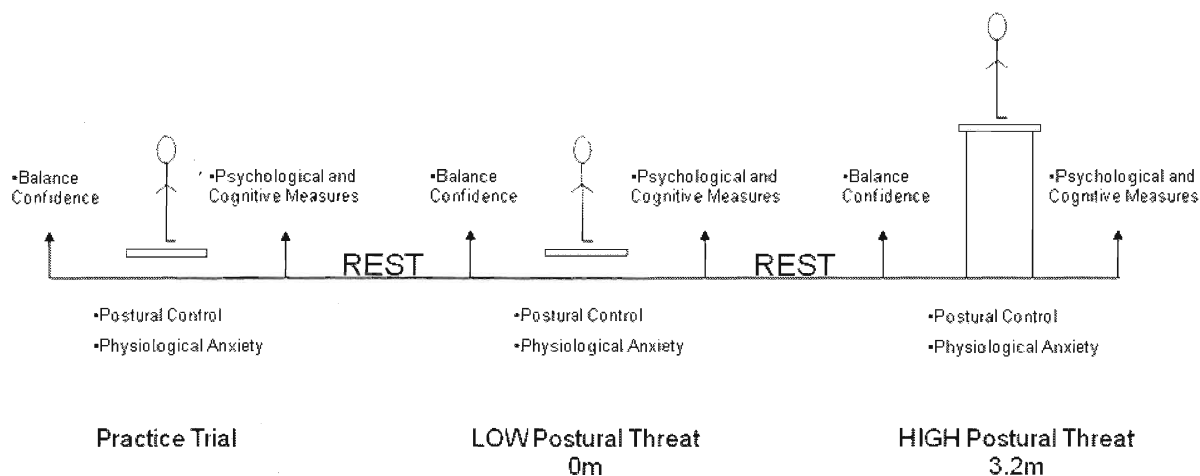


Figure 1. Timeline of experimental procedures.

3.3 *Dependent Measures*

3.3.1 *Postural Control Measures*

From the force plate, ground reaction forces and moments were sampled at 100 Hz and low pass filtered offline using a 5 Hz dual-pass Butterworth filter. Mean position of the COP was calculated in the AP direction and subtracted from the COP signal to measure the magnitude of lean toward or away from the edge of the platform. From this unbiased signal AP-RMS and AP-MPF were calculated. The center of pressure (COP) summary measures, calculated in the anterior-posterior (AP) direction, were mean position (AP-COP MP), root mean square (AP-COP RMS), and mean power frequency (AP-COP MPF) of COP displacement. AP-COP MP represents the average location of the COP of the trial. AP-COP RMS reflects the amplitude of the postural adjustments. AP-COP MPF is a measure of the frequency or rate of postural adjustments. Trunk sway was assessed using the SwayStar SystemTM. The device contains two angular velocity transducers which measure trunk movement in the pitch (forward-backward) and roll (side to side) directions. Peak-to-peak excursions in the pitch direction for both trunk angular displacement (PA) and velocity (PV) were measured in this study. COP and trunk sway measures were only calculated in the AP or pitch direction as the effects of postural threat have been shown to be strongest in this direction (Carpenter et al., 1999; Adkin et al., 2002; Davis et al. 2009).

3.3.2 *Psychological and Physiological Measures*

At each height, perceived balance confidence, perceived fear of falling, perceived anxiety, perceived stability, and EDA were assessed. Before each trial, participants reported how confident they were that they could stand as still as possible and maintain

balance for 60s on a scale of 0% (not at all) to 100% (completely) (McAuley & Mihalko, 1998; Carpenter et al., 2004; Carpenter et al., 2006) (Appendix B). After each standing trial, participants reported how fearful of falling they felt during the task on a scale of 0% (not at all) to 100% (completely) (Appendix C). Perceived anxiety was measured using a modified 16-item questionnaire (Smith, Smoll, & Schutz, 1990; Adkin et al., 2002; Carpenter et al., 2004; Carpenter et al., 2006) (Appendix D). This scale assessed perceptions of anxiety based on somatic (6 questions), worry (4 questions), and concentration (6 questions) elements. Participants rated each of the 16 items on a scale of 1 (I did not feel this at all) to 9 (I felt this extremely). Somatic and worry related elements were summed to provide an estimate of overall perceived anxiety. Participants also reported how stable they felt during the task on a referenced scale of 0% (not at all) to 100% (completely) (Schieppati, Tacchini, Nardone, Taratola, & Corna, 1999) (Appendix E). The extremes of the scale corresponded to standing on one leg with eyes closed (0%) and standing on two legs with feet apart grasping a bar (100%). Each of these tasks were experienced prior to the start of testing by participants. In order to estimate physiological arousal EDA was measure. EDA was sampled at 1 kHz. Mean EDA was calculated offline the first 30s of each trial. These measures have been validated and shown to have good test-retest reliability under similar testing situations (Hauck et al. 2008).

3.3.3 *Cognitive Measures*

To assess state specific reinvestment the Movement Specific Reinvestment Scale was modified (see Appendix F and G for original and modified MSRS, respectively). This modification was done so that items reflected state aspects of cognition instead of trait measures. A similar modification was done by Adkin et al. (2004) and Carpenter et

al. (2006) by modifying the trait anxiety scale of Smith, Smoll, and Schutz (1990) to reflect state anxiety measures. Participants rated each item on the movement self-consciousness (3 items) and conscious motor processing (4 items) subscales on a scale of 1 (strongly disagree) to 6 (strongly agree). For each subscale, items were summed to produce a score for CMP (maximum of 24) and MSC (maximum of 18). To determine where participants were directing their attention when standing, participants rated how often they thought about controlling movements of their body (internal focus) and controlling pressure exerted on the platform (external focus). Each item was rated on a scale of 0% (rarely) to 100% (extremely) (Appendix H). These two items were used to assess internal and external focus as it has been shown that instructions to focus internally on the pressure under the feet results in impaired postural control compared to instructions to focus externally on the pressure exerted onto the support surface (Landers et al., 2005; Wulf et al., 2007).

Before Trial	During Trial	After Trial
Perceived Balance Confidence	AP-COP Mean Position	Perceived Fear of Falling
	AP-COP RMS	Perceived Anxiety
	AP-COP MPF	Perceived Stability
	Pitch Angle	Conscious Motor Processing
	Pitch Velocity	Movement Self Consciousness
	Electrodermal Activity	Internal Focus External Focus

Table 1. Postural control, psychological, physiological, and cognitive measures assessed before, during, and after each standing trial.

3.4 *Statistical Analysis*

To determine the effect of postural threat, three separate one-way repeated measures multivariate analyses of variance (MANOVA) were performed on the postural control, psychological and physiological, and cognitive measures. Postural threat was the within subjects factor (2 levels: LOW vs HIGH). The dependent measures groupings were AP-COP MP, AP-COP RMS, AP-COP MPF, PA, and PV for postural control, perceived balance confidence, perceived fear of falling, perceived anxiety, perceived stability, and EDA for psychological and physiological measures, and CMP, MSC, internal focus, and external focus for cognitive measures. Significant MANOVA results were analyzed post hoc using univariate analyses of variance (ANOVAs). The level of significance for all analyses was set at $p < 0.05$.

To determine the relationships between the dependent variables, bivariate Pearson's correlations of differences scores (HIGH - LOW) were performed. The level of significance was set at $p < 0.05$. Correlations were examined to identify relationships between the postural control, psychological and physiological, and cognitive measures for possible mediating relationships.

To determine if the relationship between psychological measures and postural control measures could be explained by cognitive measures, a mediation analysis was performed using the single mediator model (MacKinnon, 2008). This model assumes that the direct relationship between an independent and dependent variable can be explained indirectly by a mediating variable. To calculate mediation, two bivariate regressions (direct and causal effects) and one multiple regression (indirect effects) were

performed. A direct effect was calculated by predicting a dependent variable from an independent variable. An indirect effect was calculated with an independent and mediator variable predicting a dependent variable. The causal effect was determined by predicting the mediating variable from the independent variable. Figure 2 shows the path requirements for mediation. According to MacKinnon (2008), a mediation effect can occur even if a significant direct effect is not found. In this instance, mediation may still occur if the indirect effect was significant and the independent variable has a significant causal relationship with the mediating variable. If these requirements were met, the statistical significance of the mediated effect was calculated. The mediated effect was calculated by dividing the estimate of the mediated effect by the standard error of the mediated effect. The estimate of the mediated effect was equal to the difference between the unstandardized coefficients between the independent and dependent variables for the direct and indirect effect ($c - c'$). The standard error of the estimated mediated effect is the calculated by the Sobel test $\sqrt{(a^2s_b^2 + b^2s_a^2)}$. The level of significance was set at a p-value of 0.05 so if the mediated effect was greater than 1.96, the mediating variable significantly explains the relationship between the independent and dependent variable. The p value of the mediated effect was calculated in MATLAB 7.5.0 using the cumulative distribution function (t_{CDF}) of the t-test.

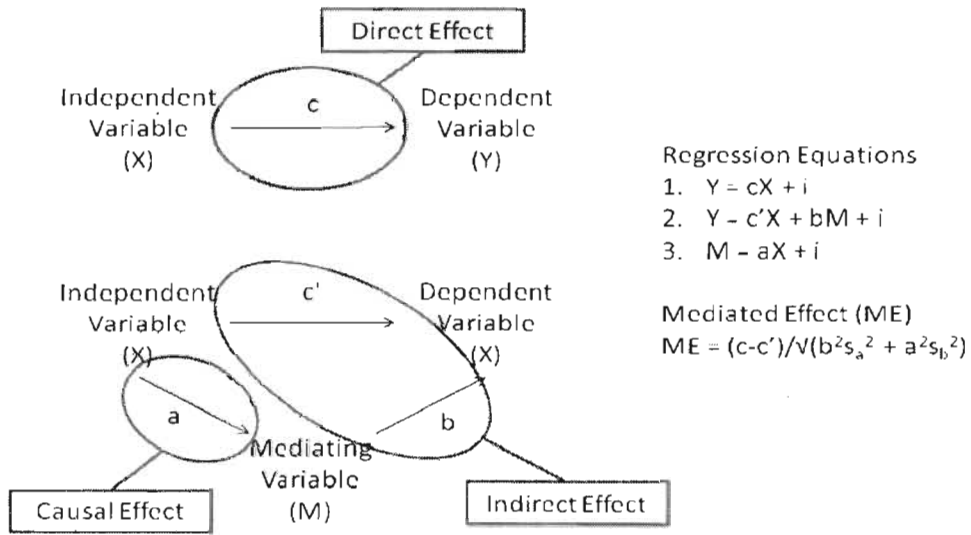


Figure 2. Graphical representation of the path diagrams and equations used for a single mediator model.

CHAPTER FOUR - RESULTS

4.1 *Data Screening*

4.1.1 *Outliers*

Eleven participants were removed from the analysis based on excessively large movement at ground level as reflected by large AP-COP RMS scores (greater than 0.70cm). This resulted in a final data set of 48 participants (24 males, mean \pm standard deviation age 24.8 ± 3.9 years) that was used for the remainder of statistical analyses.

Variables were screened for univariate and multivariate outliers for the LOW and HIGH postural threat as well as the difference scores. Univariate outliers were identified using standardized scores (z-scores). A z-score greater than or equal to 3.29 was identified as an outlying value and was replaced by the next closest value in the range (Tabachnick & Fidell, 2007). There were thirty-four instances where an outlier was identified and replaced.

Next, the data was inspected for multivariate outliers, which are cases that have a strange combination of scores on two or more variables. Multivariate outliers were identified using Mahalanobis distance. This criteria was evaluated against χ^2 with degrees of freedom equal to the number of variables of interest ($n = 14$) at $p < 0.001$ for LOW, HIGH, and differences scores. Any case with a Mahalanobis distance ≥ 36.1 was deemed a multivariate outlier. All values were below this value and as such no multivariate outliers were present.

4.1.2 Normality

Variables were screened for normality by examining skewness and kurtosis values with a p-value of 0.001 used to determine significance of skewness and kurtosis. Significance was determined by dividing the skewness or kurtosis statistic by the standard error of the skewness or kurtosis statistic. Table 2 reports the skewness and kurtosis values for all dependent measures. At the LOW postural threat PV, balance confidence, fear of falling, perceived anxiety, perceived stability, MSC, and external focus measures were significantly skewed. Balance confidence, fear of falling, and MSC measures were also significantly kurtotic. At the HIGH postural threat AP-COP RMS, PV, EDA, and MSC measures were significantly skewed. All variables were non-significantly kurtotic at the HIGH postural threat condition. When examining the difference scores between the HIGH and LOW postural threats, balance confidence and EDA measures were skewed while CMP measure was significantly kurtotic. According to Tabachnick and Fidell (2007) transformation is not recommended if the scale on which measures are assessed is meaningful as interpretation would be hindered. As this was the case, transformation of variables was not performed. Also, it was thought that although some measures were non-normal that they represented participants' true perceptions and behaviours.

Dependent Measure	LOW		HIGH		Difference Score	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
AP-COP MP	-0.35	0.99	-0.52	1.34	0.40	-0.55
AP-COP RMS	0.15	-0.73	1.31 *	2.26 *	0.50	0.14
AP-COP MPF	0.87	0.21	0.64	-0.33	0.10	0.33
Pitch Angle	0.68	0.05	0.78	0.71	-0.51	0.82
Pitch Velocity	1.47 *	1.94	1.40 *	1.70	0.08	0.50
Balance Confidence	-2.38 *	5.52 *	-0.81	-0.13	-1.14 *	0.93
Fear of Falling	2.68 *	5.38 *	0.30	-1.03	0.36	-1.00
Perceived Anxiety	1.75 *	2.10	0.70	-0.63	0.88	-0.24
Perceived Stability	-1.13 *	0.65	-0.78	-0.22	-0.91	1.11
Electrodermal Activity	0.61	0.47	1.32 *	0.88	1.33 *	1.18
Conscious Motor Processing	0.47	-0.61	0.22	-0.96	1.00	2.40 *
Movement Self-Consciousness	1.70 *	2.24 *	1.47 *	1.39	0.67	1.28
Internal Focus	1.08	0.44	0.11	-1.20	0.39	0.23
External Focus	1.32 *	1.03	0.69	-0.70	-0.15	1.29

Table 2. Skewness and kurtosis values for all dependent measures for the LOW and HIGH postural threats and the difference scores (HIGH – LOW). Standard error for skewness was 0.343 while the standard error for kurtosis was 0.674. * indicates significant skewness or kurtosis at $p < 0.001$.

4.1.3 *Linearity*

Only the linearity of the difference scores from HIGH to LOW were analyzed as were the only measures used in the correlation and mediation analysis. Linearity was assessed using bivariate scatterplots. Visual inspection did not reveal any nonlinear relationships.

4.1.4 *Multicollinearity*

Multicollinearity among the differences scores between HIGH and LOW were assessed through bivariate Pearson's correlations. Dependent measures that were highly correlated ($r > 0.9$) were considered multicollinear variables (Tabachnick & Fidell, 2007). Examination of Pearson's correlations did not reveal any multicollinear relationships between any the dependent measures.

4.2 *MANOVAs*

Table 3 displays mean values and standard error of the mean for all dependent measures at LOW and HIGH postural threat.

Dependent Measure	LOW (mean \pm SEM)	HIGH (mean \pm SEM)
AP-COP MP (cm)	15.45 \pm 0.22	16.88 \pm 0.23
AP-COP RMS (cm)	0.429 \pm 0.017	0.420 \pm 0.021
AP-COP MPF (Hz)	0.22 \pm 0.02	0.32 \pm 0.02
Pitch Angle (deg)	1.85 \pm 0.09	1.87 \pm 0.09
Pitch Velocity (deg/s)	3.50 \pm 0.23	3.94 \pm 0.26
Balance Confidence (%)	93.13 \pm 1.79	70.63 \pm 3.17
Fear of Falling (%)	1.04 \pm 0.45	41.04 \pm 4.22
Perceived Anxiety	12.42 \pm 0.55	35.02 \pm 2.93
Perceived Stability (%)	92.50 \pm 1.79	65.83 \pm 3.75
Electrodermal Activity (uMhos)	-2.68 \pm 0.11	-1.12 \pm 0.28
Conscious Motor Processing	10.17 \pm 0.61	12.92 \pm 0.65
Movement Self-Consciousness	5.48 \pm 0.51	6.10 \pm 0.60
Internal Focus (%)	23.75 \pm 3.39	43.54 \pm 3.78
External Focus (%)	23.54 \pm 3.88	32.92 \pm 4.19

Table 3. Mean and standard error of the mean (SEM) values for all dependent measures at the LOW and HIGH postural threats.

4.2.1 Postural Control Measures

The MANOVA for postural measures revealed a significant effect of postural threat ($F(5,43) = 14.18, p < 0.0001$). For the AP-COP summary measures, a significant main effect of postural threat was observed for AP-COP MP ($F(1,47) = 54.75, p < 0.0001$) and AP-COP MPF ($F(1,47) = 17.22, p < 0.0001$). Participants leaned further away from the edge of the platform and moved at an increased frequency of postural

adjustments for the HIGH postural threat condition. A significant main effect of postural threat was not found for AP-COP RMS ($F(1,47) = 0.11, p = 0.744$). Figure 3 shows the effects of postural threat on AP-COP summary measures. For the trunk sway measures, only PV was significantly influenced by postural threat ($F(1,47) = 4.65, p = 0.036$). PV was increased when standing at the HIGH postural threat condition. PA did not show a significant main effect of postural threat ($F(1,47) = 0.07, p = 0.790$). Figure 4 displays effects of postural threat on trunk sway measures.

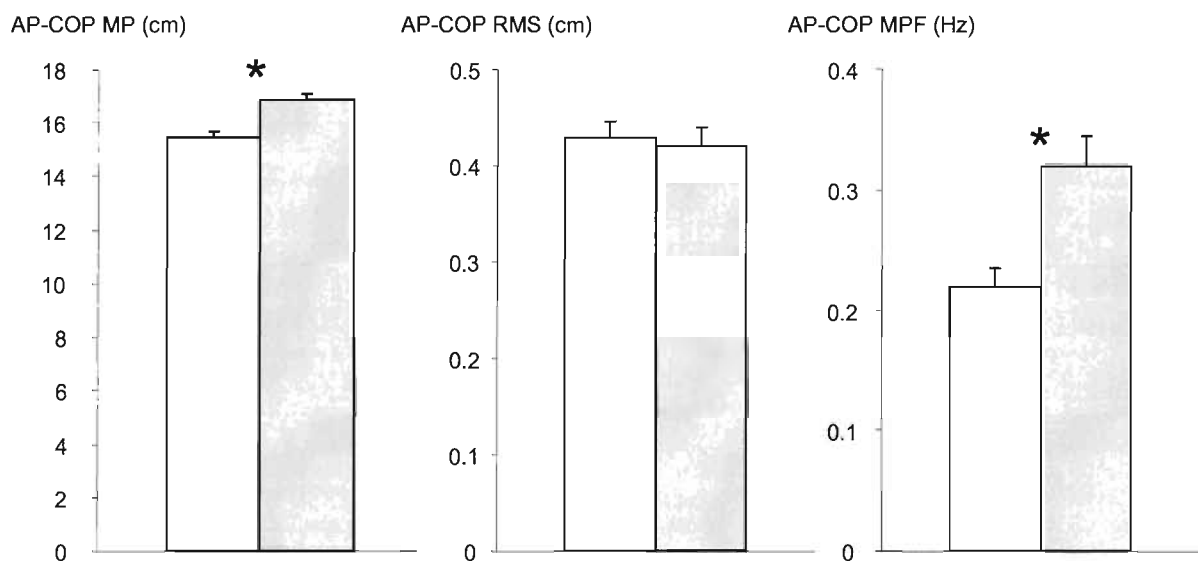


Figure 3. Effects of postural threat on the COP summary measures of A) AP-COP MP, B) AP-COP RMS, C) AP-COP MPF. Open bars indicate LOW postural threat while gray bars indicate HIGH postural threat. * indicates $p < 0.0001$. Error bars represent the standard error of the mean. AP-COP MP reflects the distance from the edge of the platform with a larger distance indicating a shift away from the edge of the platform.

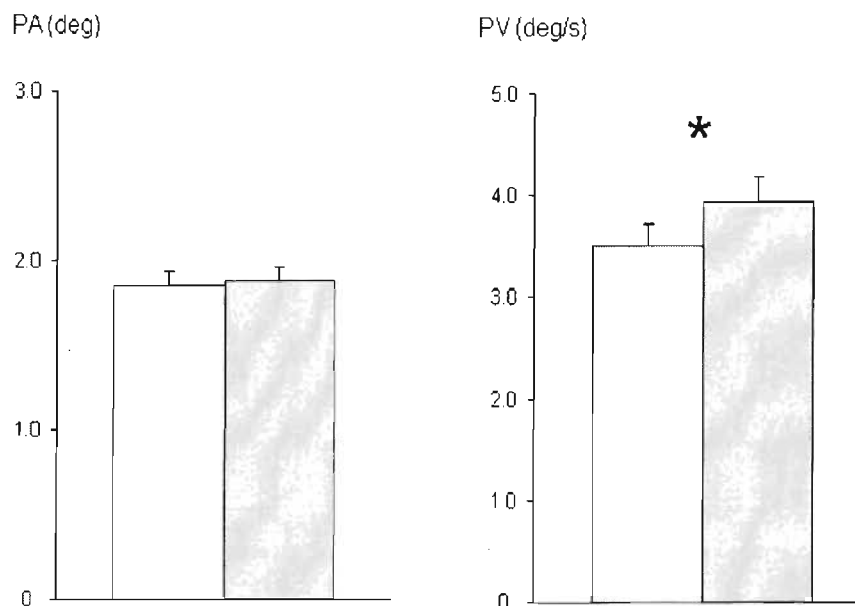


Figure 4. Effects of postural threat on the trunk sway measures of A) Pitch Angle and B) Pitch Velocity. Open bars indicate LOW postural threat gray bars indicate HIGH postural threat. * indicates $p < 0.0001$. Error bars represent the standard error of the mean.

4.2.2 Psychological and Physiological Measures

For psychological and physiological measures, MANOVA revealed a significant main effect of postural threat ($F(5,43) = 23.23, p < 0.0001$). When standing at HIGH postural threat condition, participants reported feeling less confident ($F(1,47) = 62.41, p < 0.0001$), more fearful of falling ($F(1,47) = 89.79, p < 0.0001$), more anxious ($F(1,47) = 64.45, p < 0.0001$), and less stable ($F(1,47) = 68.51, p < 0.0001$). An examination of EDA indicated that participants were significantly more physiologically anxious when standing at the HIGH postural threat condition ($F(1,47) = 49.43, p < 0.0001$). Figure 5 depicts the effects of postural threat on the psychological measures and physiological measures.

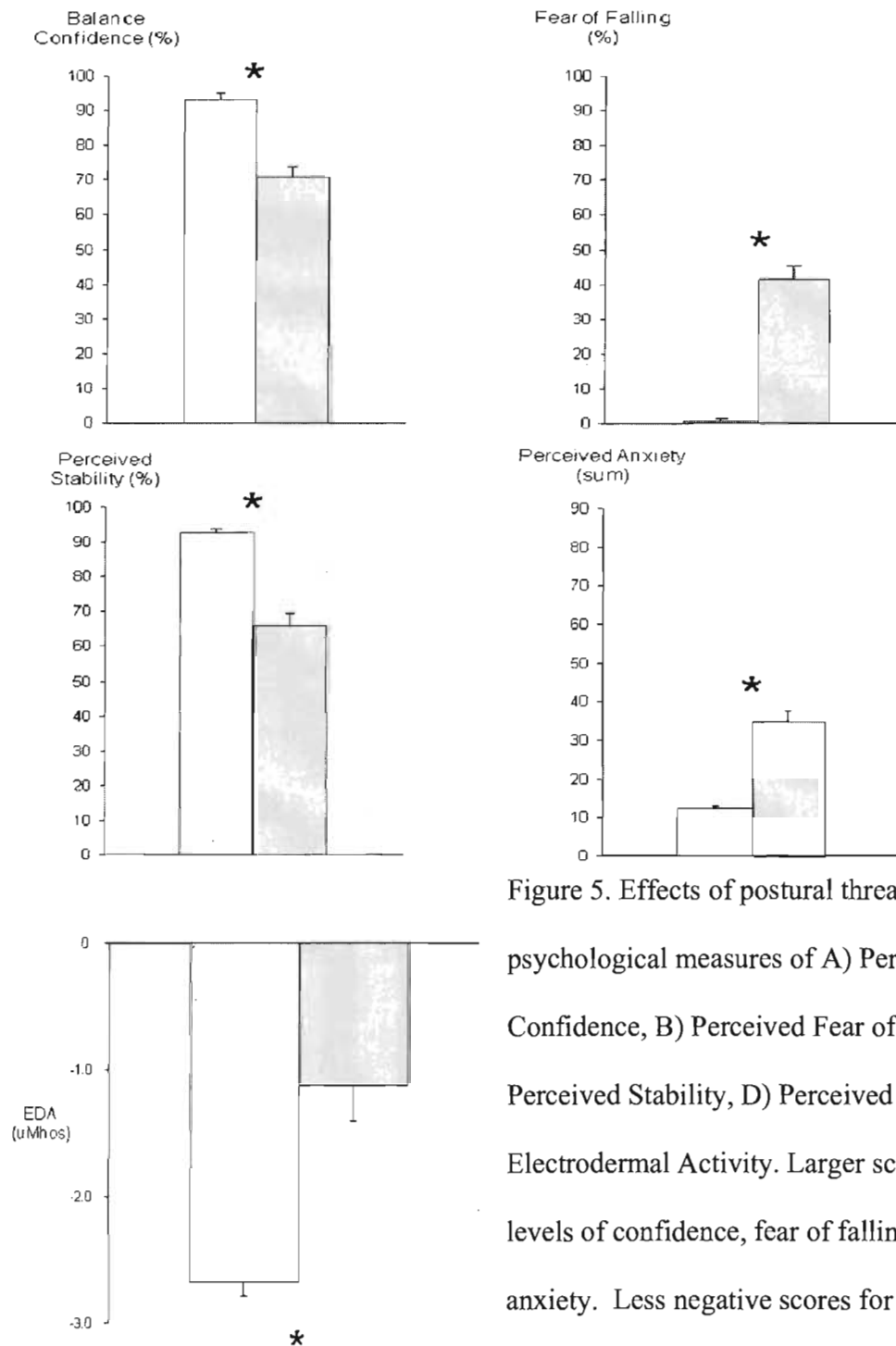


Figure 5. Effects of postural threat on the psychological measures of A) Perceived Balance Confidence, B) Perceived Fear of Falling, C) Perceived Stability, D) Perceived Anxiety and E) Electrodermal Activity. Larger scores indicate higher levels of confidence, fear of falling, stability, and anxiety. Less negative scores for electrodermal activity are indicative of increased physiological arousal. Open bars indicate LOW postural threat while gray bars indicate HIGH postural threat. *

4.2.3 Cognitive Measures

MANOVA revealed a significant main effect of postural threat ($F(4,44) = 7.40$, $p < 0.0001$) for the cognitive measures. There was a significant effect of postural threat for CMP ($F(1,47) = 19.41$, $p < 0.0001$), MSC ($F(1,47) = 4.25$, $p = 0.045$), internal focus ($F(1,47) = 23.20$, $p < 0.0001$), and external focus ($F(1,47) = 4.90$, $p = 0.032$). When threatened, participants reported that they consciously controlled their posture more, felt more self conscious about their posture, and focused more attention both internally, on to the pressure exerted under the feet, and external, on the pressure exerted onto the platform. Figure 6 shows the effects of postural threat on the cognitive measures. At both LOW and HIGH postural threat, adequate internal consistency was found for both CMP ($\alpha = 0.787$ and 0.780 , respectively) and MSC ($\alpha = 0.930$ and 0.914 , respectively).

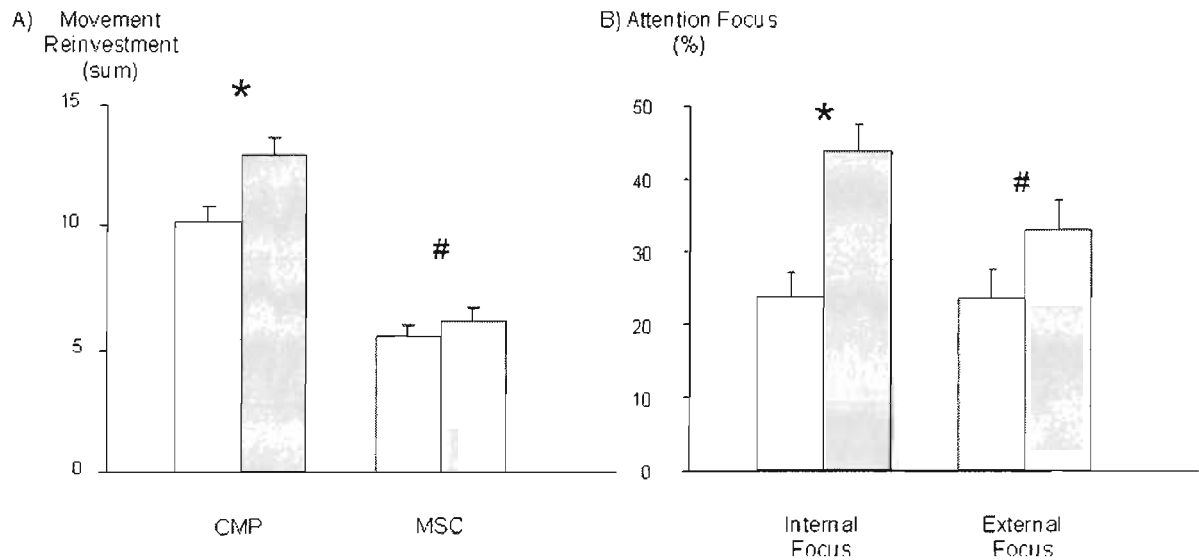


Figure 6. Effects of postural threat on the cognitive measures of A) Movement Reinvestment and B) Attention Focus. CMP reflects conscious motor processing (higher scores indicate more conscious control of movement, maximum score = 24). MSC reflects movement self consciousness (higher scores indicate more worry or concern for movement, maximum score = 18). Open bars indicate LOW postural threat while gray bars indicate HIGH postural threat. # indicates $p < 0.05$. * indicates $p < 0.0001$. Error bars represent the standard error of the mean.

4.3 Correlation Analyses

4.3.1 Relationship between Postural Control Measures

Table 4 shows the relationships between postural control measures. There was a significant correlation between the change in AP-COP RMS and AP-COP MPF ($r = -0.453$, $p = 0.001$) and the change in AP-COP RMS and PA ($r = 0.387$, $p = 0.007$). A larger decrease of the amplitude of postural adjustments was associated with a larger increase in the frequency of adjustments as well as a larger decrease in trunk displacement in the AP direction. No other significant relationships were observed between any of the other postural control measures.

	AP-COP MP	AP-COP RMS	AP-COP MPF	Pitch Angle	Pitch Velocity
AP-COP MP	-	-0.192	0.112	-0.194	-0.116
AP-COP RMS		-	-0.453**	0.387**	0.085
AP-COP MPF			-	-0.016	0.18
Pitch Angle				-	0.276
Pitch Velocity					-

Table. 4. Relationship between postural control measures. Correlations between difference scores (HIGH – LOW) for variables. * Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

4.3.2 Relationship between Psychological and Physiological Measures

Table 5 shows the relationships between psychological and physiological measures. There were a number of significant relationships between the psychological and physiological measures. The change in perceived fear of falling was related to the changes in balance confidence ($r = -0.512$, $p < 0.0001$), perceived anxiety ($r = 0.810$, $p < 0.0001$), and perceived stability ($r = -0.748$, $p < 0.0001$). A larger increase in fear of falling was related to greater feelings of less confidence, more anxiety, and less stability. The change in balance confidence was related to perceived anxiety ($r = -0.614$, $p < 0.0001$) and perceived stability ($r = 0.495$, $p < 0.0001$). A larger decrease in confidence was related to a larger increase in perceived stability and larger decrease in perceived stability. Perceived stability was related to changes in perceived anxiety ($r = -0.723$, $p < 0.0001$). Greater feeling of instability was related to greater feelings of anxiety. The change in EDA was related to balance confidence ($r = -0.326$, $p = 0.024$), fear of falling ($r = 0.327$, $p = 0.023$), perceived anxiety ($r = 0.463$, $p = 0.001$). A larger increase in physiological activity was associated with a larger decrease in confidence and larger increase in fearful of falling.

	Balance Confidence	Fear of Falling	Perceived Anxiety	Perceived Stability	Electrodermal Activity
Balance Confidence	-	-0.512**	-0.614**	0.495**	-0.326*
Fear of Falling		-	0.810**	-0.748**	0.327*
Perceived Anxiety			-	-0.723**	0.463**
Perceived Stability				-	-0.204
Electrodermal Activity					-

Table 5. Relationship between psychological and physiological measures. Correlations between difference scores (HIGH – LOW) for variables. * Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

4.3.3 Relationship between Cognitive Measures

Table 6 shows the relationships between cognitive strategies. There was a significant relationship between the changes in CMP and MSC ($r = 0.508$, $p < 0.0001$). A greater increase in conscious control of movement was associated with greater increases for the concern of movement. A significant relationship was found between the change in internal and external focus ($r = 0.557$, $p < 0.0001$). A larger increase in the amount of attention focused towards the pressure under their feet was associated with a larger increase in the amount of attention focused towards the pressure exerted on the platform. The change in CMP was significantly related to changes in internal ($r = 0.498$, $p < 0.0001$) and external focus ($r = 0.557$, $p < 0.0001$). A larger increase in the conscious

control of movement was related to a larger increase in the amount of attention focused internal, on the pressure exerted under the feet, and external sources, on the pressure exerted onto the platform.

	CMP	MSC	Internal Focus	External Focus
CMP	-	0.508**	0.498**	0.557**
MSC		-	0.253	0.250
Internal Focus			-	0.557**
External Focus				-

Table 6. Relationship between cognitive strategies. Correlations between difference scores (HIGH – LOW) for variables. * Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

4.3.4 Relationship between Postural Control and Psychological and Physiological Measures

Table 7 shows the relationships between postural control and psychological and physiological measures. There was a significant relationship between the change in AP-COP MP and the change in perceived anxiety ($r = 0.337$, $p = 0.019$) and perceived stability ($r = -0.326$, $p = 0.024$). Leaning further away from the edge of the platform was associated with a large increase for perceived anxiety and a large decrease in perceived stability. The change in AP-COP MPF was significantly associated with the change in balance confidence ($r = -0.371$, $p = 0.009$). A large increase in the frequency of postural adjustments was related to a larger decrease in confidence. The change in PA was significantly correlated to the changes in balance confidence ($r = 0.287$, $p = 0.048$) and perceived anxiety ($r = -0.307$, $p = 0.034$). A large decrease in trunk displacement was

related to a large decrease in confidence and a large increase in perceived anxiety. No other significant relationships were observed between any of the other measures. The relationship between perceived anxiety and AP-COP MP can be seen in Figure 7.

	AP-COP MP	AP-COP RMS	AP-COP MPF	PA	PV
Balance Confidence	-0.149	0.096	-0.371**	0.287*	-0.233
Fear of Falling	0.23	-0.089	0.209	-0.239	-0.049
Perceived Anxiety	0.337*	-0.147	0.265	-0.307*	0.043
Perceived Stability	-0.326*	-0.012	-0.252	0.109	-0.014
Physiological Arousal	0.187	-0.004	-0.252	0.109	-0.014

Table 7. Relationship between postural control and psychological and physiological

measures. Correlations between difference scores (HIGH – LOW) for variables. *

Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

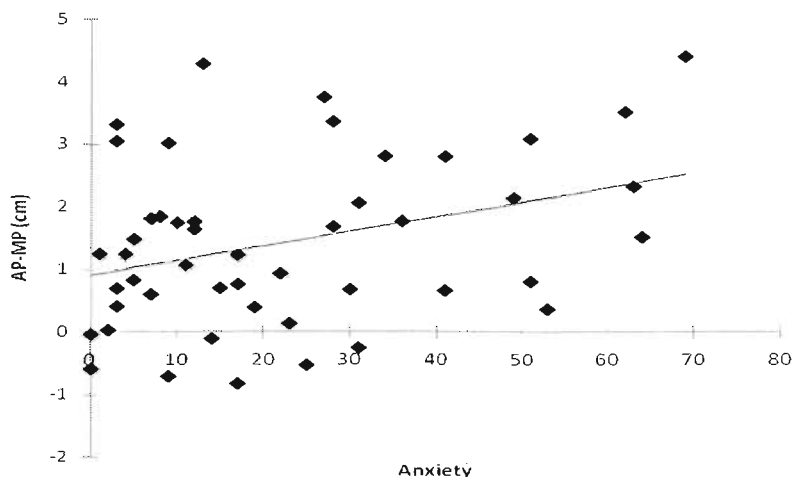


Figure 7. The relationship between the change in perceived anxiety and the change in AP-COP MP. Note that a large change in perceived anxiety is associated with a large shift in mean position away from the edge of the platform.

4.3.5 Relationship between Postural Control and Cognitive Measures

The relationship between postural control and cognitive measures can be seen in Table 8. There was a significant relationship between the change in AP-COP MP and the change in CMP ($r = 0.448$, $p = 0.001$), MSC ($r = 0.378$, $p = 0.008$), and external focus ($r = 0.373$, $p = 0.009$). Leaning further away from the edge of the platform was associated with a greater increase in the conscious control of movement, concern for movement, and attention focused external to the pressure exerted by the feet onto the platform. The relationship between AP-COP MP and CMP and MSC can be seen in Figure 8 and 9, respectively.

	AP-COP MP	AP-COP RMS	AP-COP MPF	PA	PV
CMP	0.448**	-0.181	0.111	-0.039	0.002
MSC	0.378**	-0.076	0.194	-0.057	0.177
Internal Focus	0.253	-0.149	0.161	-0.203	-0.134
External Focus	0.373**	-0.066	-0.045	-0.058	-0.083

Table 8. Relationship between postural control measures and cognitive strategies.

Correlations between difference scores (HIGH – LOW) for variables. * Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

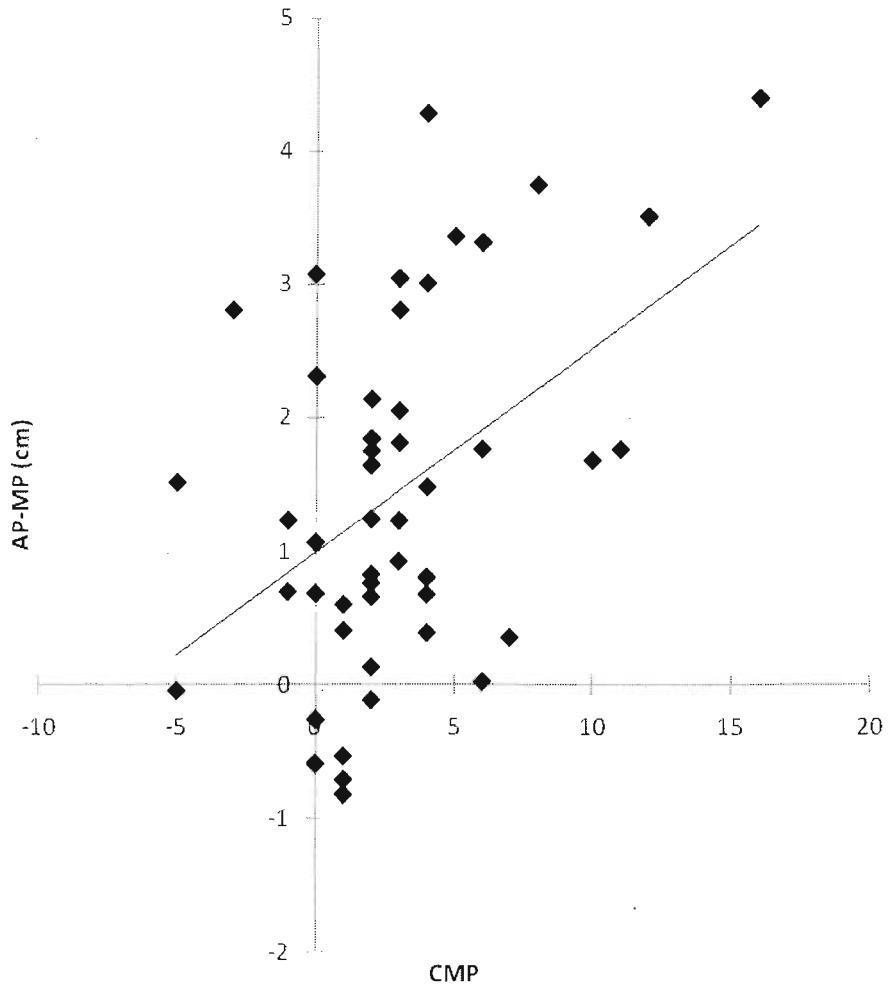


Figure 8. The relationship between the change in CMP and the change in AP-COP MP. Note that a larger change in the amount of conscious control is associated with a larger shift away from the edge of the platform.

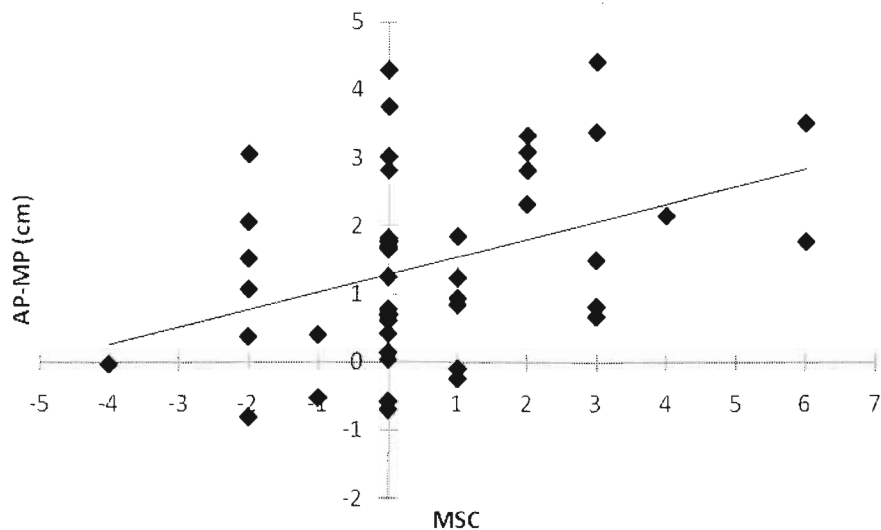


Figure 9. The relationship between the change in MSC and the change in AP-COP MP. Note that a larger worry or concern for movement is related to a larger shift away from the edge of the platform.

4.3.6 Relationship between Psychological and Physiological Measures and Cognitive Measures

Table 9 shows the relationships between the psychological and physiological and cognitive measures. The change in MSC was significantly related to the change in balance confidence ($r = -0.302$, $p = 0.037$), perceived anxiety ($r = 0.407$, $p = 0.004$), and perceived stability ($r = -0.399$, $p = 0.005$). A large increase in the concern for movement was related to greater feelings of less confidence, more anxiety, and less stability. The change in internal focus was significantly associated with fear of falling ($r = 0.452$, $p = 0.001$), perceived anxiety ($r = 0.507$, $p < 0.0001$), and perceived stability ($r = -0.437$, $p = 0.002$). A larger amount of attention directed internally on the pressure exerted under the feet was associated with a larger increase in fear of falling, increase in perceived anxiety,

and decrease in perceived stability. The relationship between perceived anxiety and CMP and MSC can be seen in Figure 10 and Figure 11, respectively.

	CMP	MSC	Internal Focus	External Focus
Balance Confidence	-0.166	-0.302*	-0.228	-0.062
Fear of Falling	0.188	0.252	0.452**	0.178
Perceived Anxiety	0.284	0.407**	0.507**	0.185
Perceived Stability	-0.245	-0.399**	-0.437**	-0.123
Electrodermal Activity	0.082	0.031	0.179	-0.057

Table 9. Relationship between psychological and physiological measures and cognitive strategies. Correlations between difference scores (HIGH – LOW) for variables. * Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

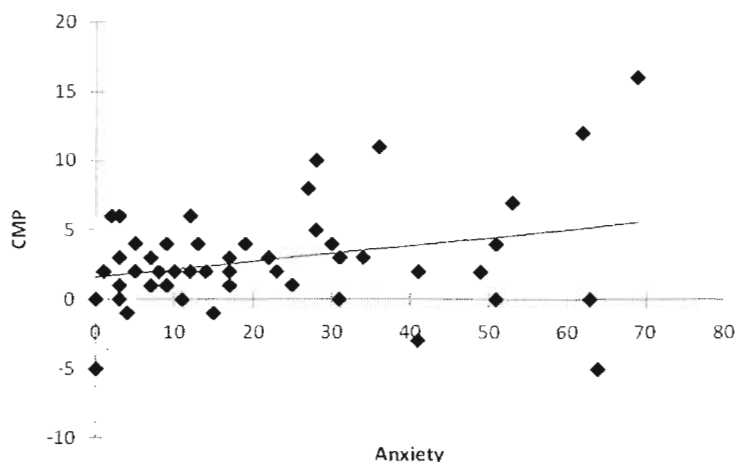


Figure 10. The relationship between the change in perceived anxiety and the change in conscious motor processing. Note that a larger increase in perceived anxiety is related to a greater conscious control of movement.

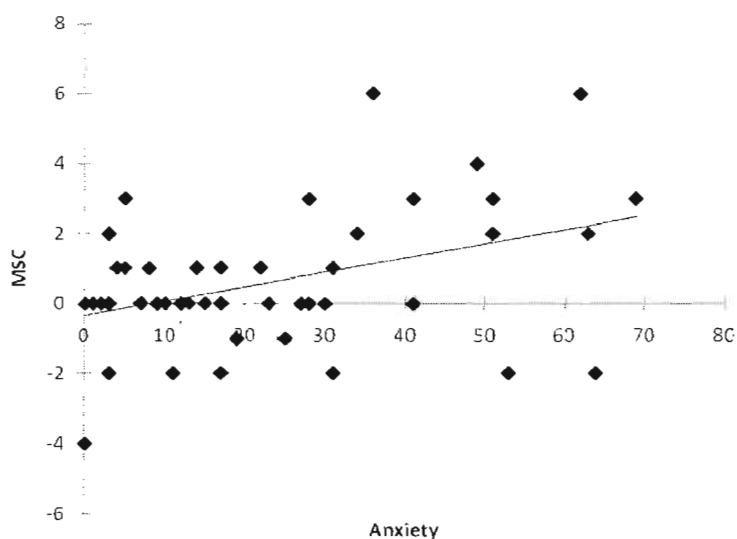


Figure 11. The relationship between the change in perceived anxiety and the change in conscious motor processing. Note that a larger increase perceived anxiety is associated with a increase in the worry or concern for movement.

4.4 Mediator Analysis

Only AP-COP MP was related to any of the cognitive strategies and perceived anxiety showed significant relationships with AP-COP MP as well as the cognitive strategies. Based on these findings it was thought that the change in perceived anxiety may have caused a shift in cognitive strategies to a more conscious mode of control which was then responsible for the shift in AP-COP MP away from the edge of the platform. Three separate single mediator model analyses were performed with each of the cognitive variables (CMP, MSC, and external focus) acting as the mediating variable. The direct effect with anxiety predicting AP-COP MP was significant ($F(1,46) = 5.89$, $p = 0.019$; $R^2 = 0.113$) (Figure 12a). When CMP was used as the mediating variable, the indirect effect was significant ($F(2,45) = 7.45$, $p = 0.002$; $R^2 = 0.249$) as was the causal effect between anxiety and CMP ($F(1,46) = 4.04$, $p = 0.05$; $R^2 = 0.081$) (Figure 12b). Similarly, with MSC acting as the mediating variable, the indirect effect ($F(2,45) = 5.03$, $p = 0.011$; $R^2 = 0.183$) and causal effects ($F(1,46) = 9.15$, $p = 0.004$, $R^2 = 0.166$) were significant as well (Figure 12c). As a mediator, external focus produced a significant indirect effect ($F(2,45) = 6.11$, $p = 0.004$, $R^2 = 0.214$) but anxiety did not have a significant causal effect with external focus ($F(1,46) = 1.63$, $p = 0.208$; $R^2 = 0.034$) (Figure 12d). As CMP and MSC were the only two possible mediators which had both significant indirect and causal effects, further calculations were performed for each of these possibilities to determine if statistical significance was reached. When determining the mediated effect (ME), by dividing the estimate of the mediated effect by the standard error of the estimated mediated effect, both CMP (ME = 1.66, $p = 0.103$) and MSC (ME = 1.63, $p = 0.109$) had a trend for but failed to reach significance as they were less than

1.96 (see Appendix I for calculations).

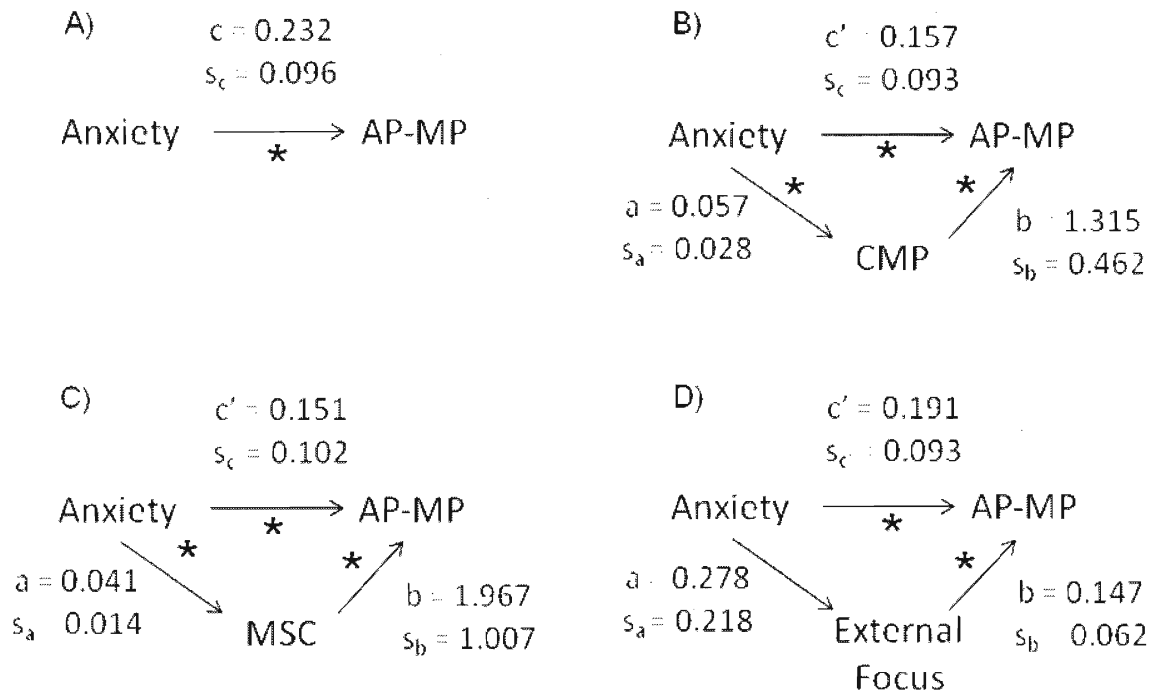


Figure 12. Graphical representation of mediation analyses. A) Direct effect with perceived anxiety predicting AP-COP MP. Indirect and causal effect for B) conscious motor processing, C) movement self consciousness, and D) external focus. a , b , c , and c' represent unstandardized coefficients. s_a , s_b , s_c , and $s_{c'}$ represent standard error of unstandardized coefficients. * indicates that a path was significant at $p < 0.05$.

CHAPTER FIVE - DISCUSSION

5.1 *Effects of Postural Threat*

The main purpose of this thesis was to determine the influence of postural threat on cognitive strategies used to maintain upright stance. The results of this thesis showed that cognitive strategies were altered when threatened. There was more conscious control of posture and more concern or worry about posture as well as an increase in the amount of attention focused to internal and external sources when standing on an elevated surface. Although this is the first study to assess cognitive strategies, research has suggested that the presence of a postural threat may induce a more conscious control of posture (Brown et al., 2002b; Gage et al. 2003). Research has suggested that changes in context, for example performing under pressure inducing situations, can modify emotions resulting in a shift to conscious control of movement leading to changes in motor performance (Baumeister 1984, Pijpers et al., 2005). It has also been suggested that postural anxiety may lead to an increase in movement reinvestment (Wong et al., 2008). These authors suggested that elderly fallers would be more anxious concerning falling compared to elderly non-fallers and thus more likely to reinvest in their movements.

This thesis replicated several of the findings of previous studies related to postural threat effects on postural control (Carpenter et al., 1999; Carpenter et al., 2001a; Adkin et al., 2000; Brown et al., 2002; Brown et al., 2006; Laufer et al., 2006; Carpenter et al., 2006; Hauck et al., 2007). Changes in postural control in response to a threat to posture included an increase in frequency of postural adjustments and leaning back away from the edge of the platform. These changes were accompanied by changes in psychological

measures, including feeling less confident, more fearful of falling, and less stable when threatened. There were also increases in actual and perceived indicators of anxiety when threatened. These observations have been consistently demonstrated in numerous studies (Adkin et al., 2002; Simeonov et al., 2003; Carpenter et al., 2004; Carpenter et al., 2006; Hauck et al., 2007; Davis et al., 2008). Thus, in the present thesis, a threat to posture, which generated changes in affect and postural control, also modified cognition.

This thesis provides the first evidence that postural threat can influence trunk sway measures as pitch velocity significantly increased when standing under conditions of postural threat. Although this was the first thesis to measure trunk sway, other studies have assessed changes to the COM when faced with a postural threat (Brown & Frank, 1997; Carpenter et al., 2001a; Brown et al., 2006). Carpenter et al. (2001a) showed that when faced with a postural threat during upright stance the COM was shifted away from the platform edge, however the amplitude and frequency of the COM's displacement did not differ. Brown et al. (2006) also observed the posterior shift of the COM as well as reduced amplitude and decreased frequency of displacements. As trunk sway measurements were referenced to the initial trunk position, the lean of the trunk was not an attainable measure in this thesis.

5.2 *Relationships between Measures*

5.2.1 *Relationships between Postural Control Measures*

This thesis found an inverse relationship between amplitude and frequency of postural adjustments as participants' decreased amplitude and increased frequency of postural adjustments when faced with a postural threat. This is consistent with the

stiffening strategy proposed by Winter (1995). A relationship was also found between amplitude of postural adjustments and trunk angle in the AP direction. This finding is also consistent with the inverted pendulum model of upright stance as the COP and COM have been found to be related (Gage et al., 2004).

5.2.2 Relationships between Psychological and Physiological Measures

The change in perceptions of balance confidence, fear of falling, anxiety, and stability were all related to each other. The changes between all psychological measures were related to changes in physiological arousal, except for perceived stability. This thesis replicates the finding of Carpenter et al. (2004) and Davis et al. (2009) who also found significant relationships between perceived anxiety and physiological arousal. However, Davis et al. (2009) did not find a relationship between physiological arousal and balance confidence or fear of falling. This may be attributed to procedural differences as Davis et al. (2009) had participants stand for multiple trials at multiple surface heights and as such the physiological response may have been attenuated over time while the psychological response was not. It has been shown that individuals with generalized anxiety disorder display a mismatch between objective and subjective measures of physiological states (Hoehn-Saric & McLeod, 2000). The authors suggested that expectation of physiological responses may have exaggerated the perceptions of anxiety. In the case of Davis et al. (2009), it is possible that the physiological response diminished over repeated exposures to postural threat but the experience of increased physiological arousal on the first trial may have influenced the expectations and perceptions of anxiety on subsequent trials.

5.2.3 Relationships between Cognitive Measures

This thesis found significant associations between the changes in conscious motor processing and movement self consciousness as well as internal and external focus. There was a lack of a relationship between movement self consciousness and internal and external focus. It is possible that internal and external focus represent the specific ways in which individuals consciously control their movements.

5.2.4 Relationship between Postural Control and Psychological, Physiological and Cognitive Measures

This thesis also investigated the relationship between changes in postural control and changes in psychological, physiological, and cognitive strategies in response to changes in postural threat. Significant associations between changes in postural control measures and psychological and cognitive measures were observed. This thesis showed that there was a relationship between the change in mean position of the COP and psychological measures, including perceived stability and perceived anxiety, and cognitive measures, including conscious motor processing, movement self-consciousness, and an external focus of attention. Leaning further backward away from the edge of the platform was related to feeling more anxious and less stable and cognition as participants reported greater conscious control of posture, more worry or concern related to posture, and focusing more externally when threatened. This thesis was able to replicate previous findings of an inverse relationship between frequency of postural adjustments and balance confidence (Hauck et al., 2007). A new finding was that pitch angle was related to balance confidence as well as perceived anxiety.

The observation of only a significant relationship between leaning away from the platform edge and cognitive strategies is interesting. Changes in amplitude and frequency of postural adjustments were not related to changes in cognitive strategies. For this task, leaning away from the edge of the platform can be considered a useful strategy to provide for an increased range of movement to ensure safety (Carpenter et al., 1999, Carpenter et al., 2001a, Brown & Frank, 1997). Thus, in this case, conscious control of movement may be viewed as positive. It is possible that changes in cognition can selectively influence some aspects of postural control (e.g., leaning) whereas other aspects may be unaffected by these changes (e.g., amplitude and frequency). The effects of postural threat on anticipatory postural control have revealed that specific aspects of these strategies were not modified in the presence of postural threat. For example, when rising to the toes, only the magnitude of muscle activity but not the relative timing of this activity was altered in response to postural threat (Adkin et al., 2002).

The results of this thesis suggest that shifting the position of the body away from the direction of the postural threat may reflect a cognitive strategy to ensure safety in this situation due to the inability to employ a stepping strategy when standing on an elevated platform. Previous studies have demonstrated that the changes in postural control and affect are most pronounced when standing at the edge of an elevated platform (Carpenter et al., 1999; Adkin et al., 2002; Brown et al., 2006). Research has shown that viewing unpleasant images results in a shift in body position away from the location of the threatening picture (Hillman, Rosengren, & Smith, 2004). This shift is thought to reflect a defensive mechanism in which the individual attempts to withdraw from the threat. Other work has shown that increased physiological arousal is associated with a forward lean

during upright stance, a change thought to facilitate gait initiation reflecting a situation-specific flight response (Maki & McIlroy, 1996). Thus, shifts in body position during stance may be context dependent. This is consistent with the cognitive appraisal framework as a perception of threat leads to a coping process where the individual attempts to reduce or eliminate the anticipated harm (Lazarus & Opton, 1966). The lack of a relationship between amplitude and frequency measures and movement reinvestment may also suggest that these changes in response to postural threat are mediated by the neurological influences of fear and anxiety networks within the central nervous system (Davis, 1992; Balaban & Thayer, 2001; Balaban, 2002). Alterations of neural connections due to the experience of fear may be responsible for the changes in balance control. It has been shown that the amygdala, which is responsible for the expression of fear, has connections with structures responsible for postural control such as the vestibular system (Davis, 1992).

Other studies have found relationships between fear of falling (Davis et al., 2009) and perceived stability in association with postural control. Davis and colleagues (2009) found that as fear of falling increased there was an increase in amplitude and frequency of postural adjustments in the AP direction. This thesis found no such relationship and may be attributed to procedural differences. Davis et al. (2009) had presented participants with four different heights (0m, 0.8m., 1.6m, 3.2m) presented in ascending order and performed three trials at each height, one for each visual condition (eyes open, eyes closed, and peripheral vision occluded). In this thesis participants only performed a single trial at ground level and then a single trial at a surface height of 3.2m above ground level. Hauck et al. (2007) found a relationship between amplitude of postural adjustments and

perceived stability while Simeonov et al. (2003) found a relationship with frequency of sway and sway velocity. This thesis showed that perceived stability was related to mean position in the AP direction. These mixed results highlight the need for future research in this area.

Interestingly, a relationship was not found between the change in attention focus measures and the change in postural measures of amplitude and frequency of postural adjustments as had been shown by previous research (Vuillerme & Nafati, 2007; Wulf, 2007). Previous research showed an increase in amplitude and decrease in frequency of COP displacement when instructed to focus internally compared to external and control focus instructions. However, these studies instructed participants to devote all of their attention to a specific source and in some studies this was confirmed through a manipulation check (Vuillerme & Nafati, 2007). In this thesis, the context was altered through changes in postural threat and participants' natural cognitive strategies were assessed. Participants reported focusing on both internal and external sources which may have confounded the effectiveness of either strategy. Future studies should assess the effects of specific attention focus instructions to internal and external sources under conditions of postural threat. The lack of a relationship between attention focus and amplitude and frequency of postural adjustments may also be due to the difficulty of the task as Landers and colleagues (2005) found that the effectiveness of attention focus instructions was influenced by task difficulty. More difficult tasks showed the typical effects for decreased amplitude and increased frequency of postural adjustments, indicative of more automatic motor control while simple tasks such as upright stance did not. More difficult tasks such as standing on one leg, which has been shown to be

impaired by postural threat (Hauck et al., 2008), may more easily show the effects of different attention focus.

5.2.5 Relationships between Psychological and Physiological Measures and Cognitive Measures

This thesis found that only movement self consciousness and internal focus were related to the psychological and physiological measures. These findings indicate that increased anxiety and decreased perceived stability are related to increased worry or concern for movement and an internal focus of attention while decreased balance confidence is associated with increased worry for movement and increased fear of falling is associated with an increase in the amount of attention directed internally. This provides evidence to suggest that the psychological measures are related to a more conscious mode of control as has been suggested by Baumeister (1984) and Pijper et al. (2005).

5.3 The Role of Cognitive Measures as a Mediating Variable

The second purpose of this thesis was to determine if alterations in cognitive strategies could explain the relationship between psychological measures and postural control when faced with a postural threat. It was hypothesized that psychological measures would lead to more conscious control of posture which would in turn alter postural control. Examination of the associations between variables revealed a possible relationship between perceived anxiety and mean position with cognitive variables acting as a mediator. Analysis of the direct, indirect and causal effects revealed that conscious motor processing and movement self consciousness may be possible mediators to explain the relationship between perceived anxiety and mean position; however further statistical

analyses failed to reach statistical significance. It is possible that in addition to the cognitive strategies measured in this thesis there are others that may prove more useful as a mediator, such as alterations in visual fixation strategies. Also, measurement error of the mediating variables can be especially harmful as this may attenuate possible mediating effects (MacKinnon, 2008). Although the original Movement Specific Reinvestment Scale's conscious motor processing and movement self consciousness subscales have demonstrated acceptable test-retest ($r = 0.76$ and 0.67 , respectively) and internal reliability ($r = 0.71$ and 0.78 , respectively), the reliability or validity of the modified Movement Specific Reinvestment Scale have yet to be determined.

5.4 *Limitations and Future Directions*

There are a number of limitations due to the nature of the attention focus questionnaires. With the other balance perception measures there is an objective measure (i.e., EDA, COP measures) that can be related to a subjective measure (ie., fear, anxiety, perceived stability). However, with the attention focus measures there is not a corresponding objective measure. This is especially concerning when considering the fact that it has been suggested that people are not always capable of being aware of and accurately reporting their own cognitions (Schooler, 2002). Also, even though theoretically it seems that it is fear or anxiety that changes cognitive strategies and subsequently postural control this may not be true. It may be possible that a change in postural control may cause a change in psychological variables and subsequently alters cognition or that cognition changes which subsequently alters postural control and psychological measures. This is important as mediation analysis assumes that there is a

temporal relationship between the variables with the independent variable occurring before the mediator and the mediator before the dependent variable (MacKinnon, 2008). This again highlights the need for an objective measure of cognition to determine the temporal changes over a trial in relation to other objective measure of balance and balance perceptions. It is also possible that the attention focus questionnaires may have primed participants to direct their attention to certain sources that they would not have naturally. If such priming effects did occur they would exist for both trials as participants performed a practice trial with questionnaires before the low and high height trials. It has yet to be determined if the effects seen with this postural threat paradigm would be generalizable to a fear of falling experienced by older adults in everyday situations or if they are specific to the task and surface height constraints of the experiment.

It is also possible that the attention focus questionnaire developed for this thesis may not have probed all the strategies that participants may have used to control their balance. It is possible that focusing on the visual target may represent a cognitive strategy used by participants to maintain balance. Research has shown that the characteristics of a visual target, such as distance, can alter balance control (Stroffregen, Smart, Bardy, Pagulayan, 1999). The authors suggest that individuals can minimize movement when standing by fixating on a visual target as a way of reducing movement on the environment and therefore head movement. Such a strategy would be considered an external focus of attention according to the attention focus literature by Wulf (2007). A post-trial interview may provide insight into the strategies that participants naturally adopt while standing under conditions of elevated threat to aid the development of questionnaires to quantify attention focus strategies.

This thesis used difference scores between the high and low postural threats to examine possible relationships between the changes in dependent variables. The use of difference scores in statistical analysis has yet to be conclusively determined. The use of difference score have been criticized for their unreliability, regression towards the mean, and susceptibility to distortion due to ceiling and floor effects (Judd & Kenny, 1981). However, others have argued that these criticisms may be unfounded and that difference scores are appropriate to use (Allison, 1990). Similar studies have used difference scores to examine the relationships between the changes in dependent variables and found significant relationships (Hauck et al., 2007; Davis et al., 2009).

The development of tools for objective measures of attention focus would aid in the study of cognition and also aid in the development of reliable questionnaires. It is possible that electroencephalography which measures cortical activity may be used as a measure of attention focus through changes in conscious control of posture (Slobounov, Hallett, Stanhope, & Shibasaki, 2005; Slobounov, Hallett, Cao, & Newell, 2008).

5.5 *Implications*

This thesis showed that postural threat alters cognitive strategies and that this change was associated with only one component of standing postural control strategies, leaning opposite to the direction of the postural threat. This specific change in postural control can be viewed as beneficial to performance as options for stepping to maintain upright stance are constrained. However, depending on the type of postural task, conscious control of movement may lead to changes in postural control that are not beneficial and future research should explore this possibility.

The change in cognitive strategies, to a more conscious form of control, confirms findings of Brown et al. (2002) and Gage et al. (2003) in their investigation of the influence of postural threat on attentional resources, such as reaction time and dual task performance. These authors suggested that the decrease in reaction time and worse performance on a dual task when standing at an increased surface height may have been due to a shift in attention to the postural task. This has important implications for everyday life. If a person is fearful or anxious and consciously controlling their balance in addition to the possibility of impaired control they may also have less attention resources that could be directed elsewhere such as the environment or to secondary tasks (Huxham, Goldie, & Patla, 2001) which could increase the risk of falls.

5.6 *Conclusion*

This thesis was the first to investigate the influence of postural threat on subjective measures of cognition and its possible role as a mediator between psychological and postural control measures. This finding of increased conscious control is important as it might impair control of more difficult tasks and result in decreased attentional resources that could be directed to more important sources, such as the environment. This research shows that cognition, affect, and postural control are influenced by postural threat. These results are important to show that multiple factors, including cognition, can be affected by manipulations of postural threat. Each of these factors should be considered when developing intervention strategies to assist individuals performing postural tasks under pressure-inducing situations. Future studies should

attempt to determine the causal variable responsible for increased movement
reinvestment when faced with a postural threat.

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APPENDIX A - ETHICS CLEARANCE

FROM: Michelle McGinn, Chair
Research Ethics Board (REB)

TO: Allan ADKIN, Physical Education & Kinesiology
Jennifer Huffman

FILE: 08-271 - ADKIN/HUFFMAN
Faculty Research

DATE: March 10, 2009

The Brock University Research Ethics Board has received the research proposal:

Central and Peripheral Mechanisms Controlling Human Balance Control

Initial screening of your proposal has been completed. Your proposal has been submitted for an **Expedited Review**.

If a reviewer of a proposal submitted for expedited review decides that a full review is warranted, that proposal will be reviewed at the next REB meeting. We will be in touch by Email when the reviewers have made their recommendations (approximately 15-20 working days).

Thank you for submitting your proposal.

Please remember that no research with Human Participants shall commence prior to receiving clearance from this committee.

MM/an

Research Ethics Office
Brock University
Office of Research Services, MC D250A
500 Glenridge Avenue, St. Catharines, ON L2S 3A1
Phone 905-688-5550 ext. 3035
Fax 905-688-0748
Email: reb@brocku.ca
http://www.brocku.ca/researchservices/Ethics_Safety/Humans/Index.php

APPENDIX B – BALANCE CONFIDENCE QUESTIONNAIRE

APPENDIX C – FEAR OF FALLING QUESTIONNAIRE

Using the following scale, please rate how fearful of falling you felt when performing the balance task:

0.....10.....20.....30.....40.....50.....60.....70.....80.....90.....100
I did not feel I felt moderately I feel completely
fearful at all fearful fearful

APPENDIX D – PERCEIVED ANXIETY QUESTIONNAIRE

Please answer the following questions about how you honestly feel just after standing at this height using the following scale:

1	2	3	4	5	6	7	8	9
I don't feel at all			I feel this moderately			I feel this extremely		

1. I felt nervous when standing at this height

1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---

2. I had lapses of concentration when standing at this height

1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---

3. I had self doubts when standing at this height

1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---

4. I felt myself tense and shaking when standing at this height

1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---

5. I was concerned about being unable to concentrate when standing at this height

1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---

6. I was concerned about doing the balance task correctly when standing at this height

1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---

7. My body was tense when standing at this height

1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---

8. I had difficulty focusing on what I had to do when standing at this height

1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---

Please answer the following questions about how you honestly feel just after standing at this height using the following scale:

1	2	3	4	5	6	7	8	9
I don't feel				I feel this				I feel this
at all				moderately				extremely

9. I was worried about my personal safety when standing at this height

1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---

10. I felt my stomach sinking when standing at this height

1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---

11. While trying to balance at this height, I didn't pay attention to the point on the wall all of the time

1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---

12. My heart was racing when standing at this height

1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---

13. Thoughts of falling interfered with my concentration when standing at this height

1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---

14. I was concerned that others would be disappointed with my balance performance at this height

1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---

15. I found myself hyperventilating when standing at this height

1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---

16. I found myself thinking about things not related to doing the balance task when standing at this height

1	2	3	4	5	6	7	8	9
---	---	---	---	---	---	---	---	---

APPENDIX E – PERCEIVED STABILITY QUESITONNAIRE

Using the following scale, please rate how stable you felt when performing the balance task:

0.....10.....20.....30.....40.....50.....60.....70.....80.....90.....100
I did not feel I felt moderately I felt completely
stable at all stable stable

APPENDIX F – ORIGINAL MOVEMENT SPECIFIC REINVESTMENT SCALE

The Movement Specific Reinvestment Scale

©Masters, Eves, & Maxwell (2005)

Name: _____ Date: ____ Age: ____ Hand: L/F

Directions: Below are a number of statements about your movements. The possible answers go from 'strongly agree' to 'strongly disagree'. There are no right or wrong answers so circle the answer that best describes how you feel for each question.

1. I rarely forget the times when my movements have failed me, however slight the failure.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree
----------------------	------------------------	--------------------	-----------------	---------------------	-------------------

2. I'm always trying to figure out why my actions failed.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree
----------------------	------------------------	--------------------	-----------------	---------------------	-------------------

3. I reflect about my movement a lot.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree
----------------------	------------------------	--------------------	-----------------	---------------------	-------------------

4. I am always trying to think about my movements when I carry them out.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree
----------------------	------------------------	--------------------	-----------------	---------------------	-------------------

5. I'm self-conscious about the way I look when I am moving.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree
----------------------	------------------------	--------------------	-----------------	---------------------	-------------------

6. I sometimes have the feeling that I'm watching myself alone.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree
----------------------	------------------------	--------------------	-----------------	---------------------	-------------------

7. I'm aware of the way my mind and body works when I am carrying out a movement.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree
----------------------	------------------------	--------------------	-----------------	---------------------	-------------------

8. I'm concerned about my style of moving.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree
----------------------	------------------------	--------------------	-----------------	---------------------	-------------------

9. If I see my reflection in a shop window, I will examine my movements.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree
----------------------	------------------------	--------------------	-----------------	---------------------	-------------------

10. I am concerned about what people think about me when I am moving.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree
----------------------	------------------------	--------------------	-----------------	---------------------	-------------------

APPENDIX G – MODIFIED MOVEMENT SPECIFIC REINVESTMENT SCALE

Please answer the following questions about how you honestly feel just after standing at this height using the following scale:

1. I was trying to figure out why my actions failed when standing at this height.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree
----------------------	------------------------	--------------------	-----------------	---------------------	-------------------

2. I reflected about my movement a lot standing at this height

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree
----------------------	------------------------	--------------------	-----------------	---------------------	-------------------

3. I was always trying to think about my movements when I carried them out standing at this height.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree
----------------------	------------------------	--------------------	-----------------	---------------------	-------------------

4. I was self-conscious about the way I looked when I was standing at this height.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree
----------------------	------------------------	--------------------	-----------------	---------------------	-------------------

5. I was aware of the way my mind and body worked when I was standing at this height.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree
----------------------	------------------------	--------------------	-----------------	---------------------	-------------------

6. I was concerned about my style of moving when standing at this height.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree
----------------------	------------------------	--------------------	-----------------	---------------------	-------------------

7. I was concerned about what people thought about me when I was standing at this height.

strongly disagree	moderately disagree	weakly disagree	weakly agree	moderately agree	strongly agree
----------------------	------------------------	--------------------	-----------------	---------------------	-------------------

APPENDIX H – ATTENTION FOCUS QUESTIONNAIRE

1. During the balance task, how often did you think about each of the following?

a. controlling the movement of your body (e.g., your feet, your legs, your trunk, etc.)

0.....10.....20.....30.....40.....50.....60.....70.....80.....90.....100
 Rarely Sometimes Extremely

b. controlling the pressure that you were exerting on the platform under your feet

0.....10.....20.....30.....40.....50.....60.....70.....80.....90.....100
 Rarely Sometimes Extremely

APPENDIX I – MEDIATION ANALYSES CALCULATIONS

Mediated Effect with CMP acting as mediator variable

$$\begin{aligned} \text{ME} &= (c - c') / \sqrt{(b^2 s_a^2 + a^2 s_b^2)} \\ &= (0.232 - 0.157) / \sqrt{[(1.315)^2(0.028)^2 + (0.057)^2(0.462)^2]} \\ &= 1.66 \end{aligned}$$

Mediated Effect with MSC acting as mediator variable

$$\begin{aligned} \text{ME} &= (c - c') / \sqrt{(b^2 s_a^2 + a^2 s_b^2)} \\ &= (0.232 - 0.151) / \sqrt{[(1.967)^2(0.014)^2 + (0.041)^2(1.007)^2]} \\ &= 1.63 \end{aligned}$$