Personality traits and individual differences predict changes in postural control under conditions of height-induced postural threat

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ABSTRACT

This thesis explored whether individual characteristics could predict changes in postural control in young adults under conditions of height-induced postural threat. Eighty-two young adults completed questionnaires to assess trait anxiety, trait movement reinvestment, physical risk-taking, and previous experience with height-related activities. Tests of static (quiet standing) and anticipatory (rise to toes) postural control were completed under conditions of low and high postural threat manipulated through changes in surface height. Individual characteristics were able to significantly predict changes in static, but not anticipatory postural control. Trait movement reinvestment and physical risk-taking were the most influential predictors. Evidence was provided that changes in fear and physiological arousal mediated the relationship between physical risk-taking and changes in static postural control. These results suggest that individual characteristics shape the postural strategy employed under threatening conditions and may be important for clinicians to consider during balance assessment and treatment protocols.

Keywords: Personality, postural control, emotions, risk-taking, movement reinvestment

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CHAPTER ONE: LITERATURE REVIEW

Postural control is a complex motor skill involving the interaction of multiple sensorimotor processes to maintain whole body stability (Rothwell, 1995; Maki & McIlroy, 1996; Horak, 2006). This process is further influenced by a dynamic interaction between task, individual, and environmental factors. For instance, an individual with reduced cutaneous sensation in his/her feet may be able to compensate for this sensory deficit by relying more heavily on visual and vestibular sensory information. However, if this same individual is required to balance in a dimly lit environment, he/she may be less stable and at a greater risk of falling (Horak, 2006). To gain a comprehensive understanding of the situations in which certain individuals may be at risk of falling, research has attempted to systematically explore different physiological and psychological factors contributing to one's ability to maintain whole body postural control. Recently, effort has been invested in understanding how emotions, such as fear and anxiety, influence postural control.

1.1 Emotional influence on postural control

The relationship between emotion and postural control has been highlighted using different experimental models. For instance, individuals diagnosed with pathological anxiety disorders (i.e., panic attack disorder, agoraphobia) consistently demonstrate postural instability compared to healthy controls under conditions in which sensory information is either removed (Perna et al., 2001) or misleading/disorienting (Jacob, Joseph, Furman, & Turner, 1997; Redfern, Furman, & Jacob, 2007). However, co-morbidity with vestibular dysfunction is common amongst those with anxiety disorders and is thought to primarily contribute to these differences in postural control (Jacob et al., 1997; Redfern et al., 2007). Other research has shown that sub-clinical levels of state anxiety in non-pathologically anxious individuals are related to changes in postural control (Ohno, Wada, Saitoh, Sunaga, & Nagai, 2004; Wada, Sunaga, & Nagai, 2001). Bolmont and colleagues measured changes in state anxiety and postural control in healthy young adults using the Sensory Organization Test over a 12-day period and found state anxiety negatively affected postural control (Bolmont, Gangloff, Vouriot, & Perrin, 2002). Collectively, these studies provide evidence for a link between chronic and transient elevations in anxiety and postural control.

Other research has shown that more specific forms of anxiety, such as fear of falling, are also related to changes in postural control (Yardley, 2004). This has been shown in older adults and neurologically impaired populations (i.e., Parkinson's disease). Older adults with a self-reported fear of falling have shown larger amplitude postural adjustments during quiet standing (Maki, Holliday, and Topper, 1991) as well as more cautious spatial and temporal gait characteristics (Donoghue, Cronin, Savva, O'Regan, & Kenny, 2013; Maki, 1997; Rochat et al., 2010) compared to those not afraid of falling. Similarly, individuals with Parkinson's disease reporting greater fear of falling have also shown poorer postural control on a variety of clinical stance tests (Adkin, Frank, & Jog, 2003). A limitation of this research is that it is difficult to distinguish the actual effects of fear on postural control from other physiological, psychological, and cognitive confounds associated with aging (Horak & Shupert, 1989; Lord, Clark, & Webster, 1991) and disease progression (Adkin et al., 2003).

1.2 Postural threat model

1.2.1 Height-induced postural threat

To explore how specific emotions influence postural control independent of possible confounds such as vestibular dysfunction and/or physiological changes associated with aging and pathology, research has examined changes in postural control in healthy individuals when presented with anxiety-inducing stimuli. One approach commonly used has involved elevating the height of the surface on which individuals stand (Adkin, Frank, Carpenter, & Peysar, 2000; 2002; Brown & Frank, 1997; Brown, Polych, & Doan, 2006; Carpenter, Frank, & Silcher, 1999; Carpenter, Frank, Silcher, & Peysar, 2001; Carpenter, Frank, Adkin, Paton, & Allum, 2004; Carpenter, Adkin, Brawley, & Frank, 2006; Cleworth, Horslen, & Carpenter, 2012; Davis, Campbell, Adkin, & Carpenter, 2009; Hauck, Carpenter, & Frank, 2008; Huffman, Horslen, Carpenter, Adkin, 2009; Laufer, Barak, & Chemel, 2006; Yiou, Deroche, & Woodman, 2011). It has been shown that when standing at the edge of an elevated platform (height-induced postural threat), healthy individuals consistently exhibit greater physiological arousal and report feeling less confident and stable, and more anxious and fearful of falling (Adkin et al., 2002; Brown et al., 2006; Carpenter et al., 2006; Cleworth et al., 2012; Davis et al., 2009; Hauck et al., 2008; Huffman et al., 2009). In addition, concomitant changes in static (Adkin et al., 2000; Brown et al., 2006; Carpenter et al., 1999; 2001; 2006; Cleworth et al., 2012; Davis et al., 2009; Hauck et al., 2008; Huffman et al., 2009), anticipatory (Adkin et al., 2002; Yiou et al., 2011), and reactive (Brown & Frank, 1997; Carpenter et al., 2004) postural control, and gait (Brown, Doan, McKenzie, & Cooper, 2006; Gage, Sleik, Polych, McKenzie, & Brown, 2003) are observed, with individuals often employing more conservative strategies under these threatening conditions.

To quantify height-induced changes in postural control, researchers have calculated centre of pressure (COP) or centre of mass (COM) under conditions of low and high postural threat. The COM is the location around which the body's total mass is equally distributed (Winter, 1995). During standing postural control, the COM is controlled within the base of support by the dynamic distribution of forces exerted by the feet onto the ground (Winter, Prince, Frank, Powell, & Zabjek, 1996). The COP reflects the weighted average of these ground reaction forces. Thus, the COP is the variable responsible for controlling the position of the COM within the base of support in order to maintain upright stability (Winter, 1995). From both COP and COM signals, summary measures have been calculated to characterize changes in postural control in response to height-induced postural threat.

1.2.2 Effect of height-induced postural threat on postural control

1.2.2.1 Static postural control

When standing quietly at heights up to 1.6m above the ground, research has frequently shown that individuals adopt a postural strategy characterized by increased frequency of smaller amplitude COP adjustments and a posterior shift in the mean position of COP away from the platform edge (Adkin et al., 2000; Brown et al., 2006; Carpenter et al., 1999; 2001; 2006; Hauck et al., 2008; Laufer et al., 2006). Similar changes have been observed when COM is calculated in addition to COP (Brown et al., 2006; Carpenter et al., 2001). While the majority of research has examined these changes in postural control in young adults, older adults (Carpenter et al., 2006; Brown et al., 2006; Laufer et al., 2006) and individuals with Parkinson's disease (Pasman, Murnaghan, Bloem, & Carpenter, 2011) have been shown to employ similar strategies under conditions of height-induced postural threat. These changes in postural control reflect a cautious strategy, as individuals attempt to withdraw from the direction of the postural threat and more tightly regulate the COM within the base of support to limit the possibility of falling. By modelling the body as an inverted pendulum (Winter, Patla, Prince, Ishac, & Gielo-Perczak, 1998), Carpenter et al. (2001) estimated a stiffness constant based on the difference between COP and COM signals under conditions of low and high postural threat. This stiffness constant was found to be significantly greater in the anterior-posterior (A-P) direction under conditions of threat, providing evidence this postural strategy is achieved through increases in ankle joint stiffness (Carpenter et al., 2001).

While this stiffness strategy has been frequently observed when standing at surface heights up to 1.6m above the ground, the strategy employed appears more variable in terms of the amplitude of postural adjustments when standing at extreme surface heights (i.e., greater than 3m above the ground). When standing at the edge of a rooftop 10.22m above the ground, individuals showed increased amplitude of postural adjustments compared to when standing at ground level (Nakahara, Takemori, & Tsuroka, 2000). However, because participants stood outdoors, environmental factors such as wind may have contributed to this change in postural control. Nonetheless, other studies conducted in controlled laboratory settings have also shown disparate results (Cleworth et al., 2012; Davis et al., 2009; Huffman et al., 2009). When standing 3.2m above the ground, amplitude of postural adjustments have been shown to decrease (Cleworth et al., 2012; Davis et al., 2009), increase (Davis et al., 2009), or not change at all (Huffman et al., 2009). Davis et al. (2009) found that the postural strategy employed when standing 3.2m above the ground depended on how fearful individuals perceived themselves to be. Individuals classified as ‘non-fearful’ demonstrated a typical stiffness strategy characterized by increased frequency and decreased amplitude of postural adjustments, while those classified as ‘fearful’ demonstrated a strategy characterized by increased frequency and increased amplitude of postural adjustments. It was suggested that because fear and anxiety are distinct emotional constructs that operate through different neuroanatomical substrates (Davis, 1998), differences in postural control strategy may have resulted from some individuals experiencing a robust fear response while others simply became more anxious (Davis et al., 2009). However, other research has failed to show that changes in amplitude of postural adjustments are correlated with changes in perception of fear and anxiety (Hauck et al., 2008; Huffman et al., 2009), raising question to this speculation.

1.2.2.2 Anticipatory postural control

Postural threat has also been shown to modify anticipatory postural control (Adkin et al., 2002; Yiou et al., 2011). Anticipatory postural adjustments (APAs) precede voluntary movement either to facilitate movement initiation by destabilizing the COM in the direction of the planned movement or to stabilize the COM before an otherwise destabilizing movement. For example, when rising onto toes, a net ankle dorsiflexor torque causes the COP to move backwards while propelling the COM forwards; this reflects the anticipatory component of the movement. Ankle plantarflexor activation is then needed to stop the COM once in its new position over the toes; this reflects the voluntary movement component and involves rising onto toes. Adkin et al. (2002) showed the peak amplitude and velocity of the APA and voluntary movement component of the rise to toes were significantly reduced under conditions of high (1.6m above the ground at the platform edge) compared to low (0.4m above ground away from the platform edge) postural threat. This reflects a cautious strategy, as individuals are less willing to destabilize their COM as far and as fast in the direction of the postural threat, limiting the likelihood of falling over the platform edge. However, this resulted in more unsuccessful attempts to rise onto toes under threatening conditions because the amplitude of the APA was not sufficient to propel the COM far enough forwards to execute the rise onto toes. Thus, while employing this strategy reduces the likelihood of incurring an injurious fall, it may compromise the performance of certain voluntary movements.

1.3 Other postural threat models

While the surface height model provides an effective means to examine the relationship between emotion and postural control, other approaches have been employed. One method has involved presenting individuals with pictures known to elicit different emotional responses (Azevedo et al., 2005; Facchinetti, Imbiriba, Azevedo, Vargas, & Volchan, 2006; Horslen & Carpenter, 2011; Stins & Beek, 2007). Emotion can be mapped according its valence (how pleasant or unpleasant an experience is) and arousal (intensity of the reaction to a stimulus; Watson, Clark, & Tellegen, 1988). Thus, the pictures used in this paradigm vary in terms of their arousal and valence to examine how postural control is affected by specific emotions. When presented with highly arousing unpleasant images relative to less arousing, neutral, and pleasant images, individuals have employed a stiffness strategy similar to that observed when standing at heights up to 1.6m above the ground (Azevedo et al., 2005; Facchinetti et al., 2006).

Postural leaning has also been reported, but the direction has been inconsistent across studies (Hillman, Rosengren, & Smith, 2004; Stins & Beek, 2007) while others have not demonstrated leaning in either direction (Azevedo et al., 2005; Facchinetti et al., 2006). While these studies suggest that emotion exerts an independent effect on postural control, they have not attempted to examine the independent effects of arousal and valence. Horslen and Carpenter (2011) showed that when arousal and valence are manipulated separately, changes in postural control are only related to changes in arousal induced by the pictures. Although the only significant change observed in postural control across the arousal conditions was an increase in the frequency of postural adjustments, these findings suggest that arousal may play an important role mediating the relationship between fear and postural control (Horslen & Carpenter, 2011).

Research has also used social evaluative threats to examine the effect of anxiety on postural control (Geh, Beauchamp, Crocker, & Carpenter, 2011). This has been done by having individuals perform different postural tasks while being observed and evaluated by an 'expert'. This manipulation has been shown to increase state anxiety and fear in both young and older adults relative to when performing the same postural tasks without being evaluated. Performance on different postural tasks has been shown to be more affected in older adults compared to young adults under these conditions. When being evaluated, older adults have demonstrated increased amplitude and frequency of postural adjustments during eyes closed standing and reduced one-leg standing duration (Geh et al., 2011). It is possible that because postural control is a greater concern for older adults, the possibility of being evaluated negatively by an expert is more threatening than it is for young adults.

1.4 State-related changes associated with postural threat

1.4.1 Psychological and physiological changes

Research has identified a number of state-related psychological and physiological changes associated with postural threat. Individuals consistently exhibit elevated physiological arousal (commonly indexed by recording electrodermal activity (EDA)) and report lower balance confidence and perceptions of stability and greater perceptions of anxiety and fear of falling when standing under conditions of high compared to low postural threat (Adkin et al., 2002; Brown et al., 2006; Cleworth et al., 2012; Davis et al., 2009; Geh et al., 2011; Hauck et al., 2008; Huffman et al., 2009). These changes have been shown to be related to changes in postural control. For instance, balance confidence has been negatively associated with changes in the frequency of postural adjustments during standing (Hauck et al., 2008; Huffman et al., 2009). Perceptions of stability have been negatively associated with changes in amplitude (Hauck et al., 2008) and frequency of postural adjustments (Simeonov, Hsiao, Dotson, & Ammons, 2003), such that individuals report feeling less stable when they employ a stiffness strategy. Lastly, state anxiety has been associated with leaning further away from the platform edge (Huffman et al., 2009).

1.4.2 Changes in sensory gain

Recent work has suggested that changes in postural control when threatened may be related to changes in sensory gain. Research has shown facilitation of the soleus tendon-tap reflex under conditions of height-induced postural threat (Davis et al., 2011) without concomitant increases in the soleus Hoffman reflex (Horslen, Murnaghan, Inglis, Chua, & Carpenter, 2013). These findings provide evidence there is an increase in muscle spindle sensitivity under conditions of height-induced postural threat. Given that individuals often limit the amplitude of postural adjustments under these conditions, increased muscle spindle sensitivity may serve to facilitate proprioceptive input to the central nervous system despite smaller movements about the ankle joint. There is also emerging evidence suggesting postural threat alters the processing of vestibular information (Horslen et al., in press). Research has reported increases in the coupling and gain of ground reaction forces in response to stochastic vestibular stimulation when standing under conditions of height-induced postural threat, suggesting there is heightened gain of vestibular reflexes (Horslen et al., in press). Collectively, these studies suggest balance-relevant sensory inputs are adjusted under threatening conditions to augment feedback of one's current postural state, likely contributing to automatic changes in postural control observed under these conditions (Horslen et al., 2013).

1.4.3 Cortical changes

There is evidence of altered cortical responsiveness under conditions of height-induced postural threat. Research has shown that when responding to a series of unexpected postural perturbations under conditions of high compared to low postural threat, there is increased peak-to-peak amplitude of the N1 cortical response (Adkin, Campbell, Chua, & Carpenter, 2008; Sibley, Mochizuki, Frank, & McIlroy, 2010). The N1 cortical response is a strong negative potential that occurs shortly after the onset of a perturbation and it is thought to reflect an index of error detection between expected and actual postural states (Adkin et al., 2008). Increased excitability of this response has been suggested to result from either increased early processing of sensory information or shifting attention towards one's current postural state (Adkin et al., 2008). In either case, these studies suggest that cortical contribution to postural control is modified during states of elevated fear and anxiety.

1.4.4 Cognitive changes

Cognitive changes have also been reported when provided with a threat to posture. Gage et al. (2003) found that when walking on an elevated narrow beam, both young and older adults had slower probed reaction times relative to when performing the same task at ground level on an unconstrained walkway. In this dual-task paradigm, a slower reaction time is indicative of a greater cognitive demand associated with the primary task. Similar cognitive changes have been observed during standing. Older adults demonstrated significantly poorer performance on the Brook's Spatial Letter Task when standing on an elevated platform compared to when standing at ground level (Brown, Sleik, Polych, & Gage, 2002). Taken together, these studies suggest that when balance is threatened, individuals modify their cognitive strategy and allocate more attention towards certain aspects of the postural task. However, it is unclear how attention is reallocated. As suggested by the authors, individuals may direct more attention towards the internal mechanics of postural control in an effort to ensure successful performance and avoid falling under more threatening conditions (Brown et al., 2002; Gage et al., 2003). This claim is supported by research that has shown young adults self-report directing more attention towards the control and perception of their movement when standing under threatening conditions (Huffman et al., 2009). On the other hand, individuals may become preoccupied with the possibility of falling, thus distracting attentional resources and making it more difficult to dual-task (Eysenck, Derakshan, Santos, and Calvo, 2007).

1.5 Limitation to Current Research

The postural threat model has been instrumental in improving our understanding of the relationship between specific emotions, such as fear and anxiety, and postural control. Using this model, research has been able to identify characteristic changes in postural control associated with fear and anxiety as well as a number of state-related changes that may be underlying this relationship. However, limited research has considered how characteristics of the individual might contribute to this relationship. As there is evidence of inter-individual variability in terms of the postural control strategy adopted when standing under conditions of height-induced postural threat (Davis et al., 2009), it is reasonable that personality traits and other individual differences may predispose individuals to be more or less vulnerable to the effects of these threatening stimuli.

1.6 Individual characteristics may influence postural control

Personality traits are stable internal factors that are consistent across situations and vary between individuals (Allport, 1966; Tett & Guterman, 2000). These traits interact with environmental factors to influence how individuals appraise a situation and subsequently behave, with traits more relevant to the environmental context exerting a greater influence (Kenrick & Funder, 1988; Tett & Guterman, 2000). In addition to personality traits, individual differences in perceptions, beliefs, and past experiences have also been shown to influence behaviour (Anshel, Robertson, & Caputi, 1997; Lazarus, 1993; Lazarus & Opton, 1966; Nicholson, Soane, Fenton-O'Creevy, & Willman, 2005; Wilken, Smith, Tola, & Mann, 2000). While these individual differences are still consistent across situations, they are distinct from personality traits as they are less stable over time and are more modifiable through intervention and life events (Lazarus, 1993; Nicholson et al., 2005). For the purpose of this thesis, personality traits and individual differences will be collectively referred to as ‘individual characteristics’.

While a range of individual characteristics influence how an individual behaves across different situations, a smaller subset of situation relevant characteristics may play a more influential role when confronted with a particular threat to posture (Tett & Guterman, 2000). For the present thesis, altering the surface height on which individuals stand was used to explore how individual characteristics contribute to changes in postural control during threatening postural tasks. Based on existing literature and the nature of this postural threat, personality traits including trait anxiety and movement reinvestment, and individual differences in physical risk-taking and experience with height-related activities were considered relevant for explaining behaviour under these conditions.

1.6.1 Trait anxiety

Trait anxiety reflects an individual’s tendency to experience anxiety reactions in response to external stressors (Spielberger, Gorssuch, Lushene, Vagg, & Jacobs, 1983). Thus, this trait may predispose individuals to experience greater perceptions of anxiety when presented with a postural threat. For example, studies have shown that, despite low and high trait anxious individuals often showing similar changes in physiological arousal in response to physical (e.g., threat of electrical stimulation), cognitive (e.g., mental arithmetic), and social (e.g., public speaking) stressors, high trait anxious individuals consistently self-report greater increases in state anxiety (Arena & Hobbs, 1995; Baggett, Saab, & Carver, 1996; Gonzalez-Bono, Moya-Albiol, Salvador, Carrillo, & Gomez-Amor, 2002; Noteboom, Barnholt, & Enoka, 2001; Steptoe & Vogele, 1992; Willmann, Langlet, Hainaut, & Bolmont, 2012). Furthermore, trait anxiety has been shown to be a significant predictor of fear of falling in older adults (Lawrence et al., 1998; Tinetti, Richman, and Powell, 1990).

Postural control has also been found to be differentially affected by state anxiety depending on an individual's level of trait anxiety (Hainaut, Caillet, Lestienne, & Bolmont, 2011). Hainaut et al. (2011) had low and moderate trait anxious participants perform trials of quiet standing with eyes open and closed before and after completing an anxiety-inducing cognitive task (Stroop Colour-Word Test). When standing with eyes open, individuals with low and moderate levels of trait anxiety showed equal increases in amplitude and velocity of postural adjustments following completion of the anxiety-inducing cognitive task. However, when standing with eyes closed, only low trait anxious individuals demonstrated these same changes in postural control after completing the cognitive task. Individuals with moderate levels of trait anxiety showed no changes in postural control under these conditions. However, examination of baseline postural control during eyes closed quiet standing revealed that moderately anxious individuals had greater amplitude and velocity postural sway compared to their less anxious counterparts. It was suggested that because trait anxious individuals are more dependent on visual information to maintain balance (Jacob, Furman, Durrant, & Turner, 1996; Yardley, Britton, Lear, Bird, & Luxon, 1995), removing visual information might have overridden the effect of the cognitive stressor in moderately anxious individuals. Individuals with low levels of trait anxiety were thought to be less reliant on vision, and were consequently more affected by increases in state anxiety, which has been shown to affect one's ability to use vestibular and somatosensory information (Bolmont et al., 2002; Wada et al., 2001). These findings suggest that the weighting of sensory modalities involved in postural control is differentially affected by state anxiety depending on an individual's level of trait anxiety (Hainaut et al., 2011).

Taken together, these findings suggest that individuals with higher levels of trait anxiety may not only respond more fearfully when standing under conditions of increased postural threat, they may also employ strategies less conducive to maintaining postural control in this particular context. For instance, when standing under conditions of height-induced postural threat, there may be fewer visual cues available to monitor self-motion (Brandt, Arnold, Bles, & Kapetyn, 1980). Thus, preferential processing of visual information and greater susceptibility to increases in state anxiety may lead to greater instability in trait anxious individuals.

1.6.2 Movement reinvestment

Movement reinvestment is a personality trait that reflects individuals' propensity to direct attention to the control/perception of their movement. It is composed of two sub-traits; conscious motor processing (CMP-T) and movement self-consciousness (MSC-T). CMP-T reflects an individual's tendency to consciously monitor/control their movement, while MSC-T reflects an individual's concern over their movement style/appearance (Masters & Maxwell, 2008). It is theorized individuals higher in these traits are more likely to attempt to consciously attend to their movement under anxiety-inducing conditions (Masters & Maxwell, 2008). This change in cognitive strategy is thought to be inefficient, particularly when performing well-learned movements, as conscious intervention may disrupt movement automaticity leading to poorer motor performance. Support for this claim has been provided by research showing that individuals classified as high reinvesters demonstrate poorer motor performance under anxiety-inducing conditions across a variety of skilled motor tasks (Chell, Graydon, Crowley, & Child, 2003; Kinrade, Jackson, Ashford, & Bishop, 2010; Malhotra, Poolton, Wilson, Ngo, & Masters, 2012; Masters & Maxwall, 2008; Masters, Polman, & Hammond, 1993). Given that standing at the edge of an elevated surface is known to be anxiety inducing, it is possible that individuals higher in either movement reinvestment sub-trait are prone to this cognitive strategy when threatened. Research has already shown that individuals reinvest more attention in the control/perception of their movement under conditions of height-induced threat and this change in cognitive strategy is associated with leaning away from the platform edge (Huffman et al., 2009). However, this research only examined state-related changes in movement reinvestment.

1.6.3 Physical risk-taking

Given the perceived risk associated with the increased consequences of falling when standing under conditions of height-induced threat, individuals' risk-taking propensity may influence their appraisal of the situation and subsequent behaviour. Risk-takers are often more self-assured and may experience greater excitement as opposed to fear when confronted with potentially dangerous situations (Salassa & Zapala, 2009). For example, older adults who are more extroverted – a personality trait linked to one's willingness to take risks – are less likely to be fearful of falling than those who are less extroverted (Kloseck, Hobson, Crilly, Vandervoort, & Ward-Griffin, 2007). Thus, when faced with a threatening postural task, risk-takers may perceive less fear and anxiety and limit any changes in postural control. Risk-taking has also been consistently shown to be a domain specific characteristic. For example, an individual may be willing to take physical risks, but not financial or ethical risks (Blais & Weber, 2006; Hanoch, Johnson, & Wilke, 2006; Weber, Blais, & Betz, 2002). Thus, only certain types of risk-taking may influence behaviour during threatening postural tasks. Given the physical threat associated with falling, one's willingness to take physical risks may best predict behaviour under these conditions.

There is also emerging evidence that risk-taking is task-specific within the same domain. O'Brien and Ahmed (2013) assessed the direction and degree of risk-sensitivity (i.e., willingness to take risk) using two different movement tasks. Participants completed an arm-reaching movement and a full body lean to move a cursor towards the edge of a virtual cliff. Participants received points for getting closer to the cliff, but lost points if they went over the edge. It was shown that while the direction of risk-sensitivity was consistent across participants (i.e., consistently risk-seeking or risk-averse during both tasks), the degree of risk-sensitivity varied considerably (i.e., highly risk-seeking on one task but only slightly on the other). This finding suggests that while one's preference to take or avoid risk is relatively consistent across different movement types, the extent of the risk taken can vary. Thus, individuals may be more or less willing to take risk during different postural tasks under threatening conditions.

1.6.4 Previous experience with height

Experience with a particular situation or stressor can also influence the stress response and subsequent behaviour of an individual (Anshel et al., 1997; Lazarus, 1993; Lazarus & Opton, 1966; Wilken et al., 2000). Of particular relevance is one's experience with recreational or occupational activities that involve exposure to height. Construction workers with more experience working on scaffolding have shown significantly smaller increases in physiological arousal when performing a manual task under conditions of high (3.3m above ground) compared to low (1.7m above ground) postural threat relative to their less experienced counterparts (Min, Kim, & Parnianpour, 2012). In addition, while both groups showed increased amplitude and velocity of postural sway under threatening conditions, less experienced individuals showed significantly larger increases in the medial-lateral direction (Min et al., 2012). These results suggest that individuals with more experience working at height are more comfortable under these conditions, limiting the influence of this threat on postural control. Similar relationships may also be expected in individuals who frequently engage in recreational activities at heights such as rock climbing or mountaineering.

CHAPTER TWO: RATIONALE, PURPOSE, AND HYPOTHESES

2.1 Rationale

It is well established that specific emotions (i.e., fear and anxiety) influence postural control. Differences in postural control have been observed between individuals with and without pathological anxiety disorders (Jacob et al., 1997; Perna et al., 2001; Redfern et al., 2007) as well as between older adults with and without a fear of falling (Maki, 1997; Maki et al., 1991; Rochat et al., 2010). To explore how these emotions influence postural control, researchers have experimentally manipulated fear and anxiety in healthy individuals using methods such as increasing the height of the surface on which they stand (height-induced postural threat; Adkin et al., 2000; 2002; Brown et al., 2006; Carpenter et al., 1999; 2001; 2004; 2006; Davis et al., 2009; Hauck et al., 2008; Huffman et al., 2009; Yiou et al., 2011) or presenting them pictures known to elicit negative emotional responses (Azevedo et al., 2005; Horslen & Carpenter, 2011). While this research has been instrumental in identifying characteristic changes in static (Adkin et al., 2000; Brown et al., 2006; Carpenter et al., 2001; 2006; Davis et al., 2009; Hauck et al., 2008; Huffman et al., 2009), anticipatory (Adkin et al., 2002; Yiou et al., 2011), and reactive (Brown & Frank, 1997; Carpenter et al., 2004) postural control associated with fear and anxiety, limited research has considered how characteristics of the individual contribute to these changes (Alpers & Adolph, 2008; Min et al., 2012). As there is evidence of inter-individual variability in terms of the postural control strategy adopted when standing under conditions of height-induced postural threat (Davis et al., 2009), it is reasonable that personality traits and other individual differences may predispose individuals to be more or less vulnerable to the effects of these threatening stimuli.

Personality traits are stable internal factors that are consistent across situations and vary between individuals (Allport, 1966; Tett & Guterman, 2000). These traits interact with environmental factors to influence how individuals appraise a situation and subsequently behave, with traits more relevant to the environmental context exerting a greater influence (Kenrick & Funder, 1988; Tett & Guterman, 2000). Other individual differences in perceptions, beliefs, and past experiences have also been shown to influence behaviour in a similar manner to personality traits (Anshel et al., 1997; Lazarus, 1993; Lazarus & Opton, 1966; Nicholson et al., 2005; Min et al., 2012; Wilken et al., 2000). While a range of individual characteristics influence how an individual behaves across different situations, a smaller subset of situation relevant characteristics may play a more influential role when confronted with a threat to posture. In the present thesis, altering the surface height on which individuals stand was used to explore how individual characteristics contribute to changes in postural control during threatening postural tasks. Based on existing literature and the nature of this postural threat, personality traits including trait anxiety and movement reinvestment, and individual differences in physical risk-taking and experience with height-related activities were considered relevant for explaining behaviour under conditions of height-induced postural threat.

2.2 Purpose

1) Determine if the selected individual characteristics could predict changes in postural control in young adults under conditions of height-induced postural threat. This was explored by having young adults perform static (quiet standing) and anticipatory (rising to toes) postural tasks under conditions of low and high postural threat. These tasks were selected because they test different types of postural control and have been

shown to be influenced by height-induced postural threat in healthy young adults (Adkin et al., 2000; 2002; Brown et al., 2006; Carpenter et al., 1999; 2001; 2006; Cleworth et al., 2012; Davis et al., 2009; Hauck et al., 2008; Huffman et al., 2009).

2) If any relationships were observed between individual characteristics and changes in postural control, a secondary aim of this study was to identify potential mechanisms through which these individual characteristics operate to influence postural control. Previous work has shown that postural threat lowers individuals' balance confidence, increases their perceptions of anxiety and fear of falling, elevates physiological arousal, and increases their tendency to direct attention towards the control/perception of movement (Adkin et al., 2002; Carpenter et al., 2006; Cleworth et al., 2012; Davis et al., 2009; Hauck et al., 2008; Huffman et al., 2009). Because these state psychological, physiological, and cognitive changes have been associated with changes in postural control and may be influenced by the individual characteristics being examined, they were considered as potential mediators underlying any relationships observed between the individual characteristics and changes in postural control.

2.3 Hypotheses

1) A linear combination of individual characteristics would be able to explain height-induced changes in postural control for both postural tasks. Given the exploratory nature of this thesis, no hypotheses regarding the relative strength of each individual characteristic were made. However, the direction of effect of each individual characteristic on changes in postural control was hypothesized. For quiet standing, greater increases in the frequency and amplitude of postural adjustments were hypothesized to be related to greater trait anxiety (Hainaut et al., 2011; Willmann et al.,

2012), lower physical risk-taking, and less experience with height-related activities (Min et al., 2012), but not either element of trait movement reinvestment (Huffman et al., 2009). Leaning further away from the platform edge was hypothesized to be related to greater trait anxiety and both elements of trait movement reinvestment (Huffman et al., 2009), lower physical risk-taking and less experience with height-related activities (Min et al., 2012). For rise to toes, greater decreases in peak amplitude and velocity of the APA were hypothesized to be related to greater levels of trait anxiety, CMP-T and MSC-T, lower physical risk-taking, and less experience with height.

2) Changes in EDA, balance confidence, and perceptions of fear and anxiety were expected to mediate any relationships between trait anxiety (Willmann et al., 2012), physical risk-taking (Salassa & Zapala, 2009), and previous experience with height-related activities (Min et al., 2012) and changes in postural control. State-related changes in movement reinvestment were expected to mediate any relationships between CMP-T and MSC-T and changes in postural control (Masters & Maxwell, 2008).

CHAPTER 3: METHODS

3.1 Participants

Ninety-four healthy young adults volunteered to participate in this thesis (50 males; mean age in years ± standard deviation = 23.96 ±4.05). Participants were excluded if they reported an extreme fear of heights or any neurological, vestibular, or orthopaedic condition that could influence postural control.

3.2 Procedure

All experimental procedures were reviewed and given ethical clearance by the University of British Columbia and Brock University research ethics boards (Appendix A and B). Each participant provided written informed consent prior to the start of testing. First, participants completed a randomly presented series of questionnaires to assess specific individual characteristics. These individual characteristics were trait anxiety, trait movement reinvestment, physical risk-taking, and previous experience with height-related activities.

Trait anxiety was assessed using the trait form of the State-Trait Anxiety Inventory (Spielberger et al., 1983; Appendix C). This 20-item questionnaire, in which items are rated on a 4-point Likert scale, has shown good test-retest reliability and internal consistency in college aged individuals (Spielberger et al., 1983). Higher scores on this questionnaire reflect greater trait anxiety.

Trait movement reinvestment was assessed using the Movement Specific Reinvestment Scale (MSRS; Masters, Eves, & Maxwell, 2005; Appendix D). This 10-item questionnaire, in which items are rated on a 6-point Likert scale, contains two 5-item subscales to assess CMP-T and MSC-T. Both subscales have been shown to have good test-retest reliability and internal consistency (Masters et al., 2005). Higher scores reflect greater CMP-T and MSC-T, respectively.

Physical risk-taking was assessed using the risk-taking form of the short-form Domain Specific Risk-Taking scale (DOSPERT; Blais & Weber, 2006; Appendix E). This 30-item questionnaire, in which items are rated on a 7-point Likert scale, is used to evaluate an individual's willingness to engage in various risky behaviours across five content domains (ethical, social, health and safety, financial, and recreational). Due to the nature of the threat imposed in the current thesis and the domain-specific nature of risk-taking (Blais & Weber, 2006; Hanoch et al., 2006), only the six items related to the recreational domain were examined. When only examining this domain, the DOSPERT has shown good internal consistency (Blais & Weber, 2006). Higher scores on this questionnaire reflect a greater willingness to engage in recreational activities that present a physical risk.

Experience with height-related activities was assessed using a single item questionnaire in a manner similar to that used by Alpers and Adolph (2008) (Appendix F). Participants were asked to report on a 9-point Likert scale how often they engage in recreational and/or occupational activities that involve exposure to a height-related situation (e.g., rock climbing, platform diving, working on scaffolding, etc.). Higher scores reflect more experience with height-related activities.

After completing this series of questionnaires, participants were asked to stand on a force plate (#K00407, Bertec, USA) positioned at the edge of a 2.13m x 1.52m hydraulic lift (M419-207B10H01D, Penta-lift, Canada) and perform a quiet standing and rise to toes task under two levels of postural threat. Postural threat was manipulated by changing the height of the platform on which the participants stood. For the low threat condition, the platform was positioned at its lowest possible height (0.8m above ground level). At this height specifically, an additional support surface (0.61m x1.52m) was positioned in front of, and flush with, the edge of the platform to create a continuous support surface in front of the subject. Previous work has shown that standing at elevations up to 0.8m does not modify postural control if standing away from the edge (Carpenter et al., 2001). For the high threat condition, the platform was positioned 3.2m above the ground for quiet standing and 1.6m above the ground for rise to toes to account for differences in postural task difficulty.

For quiet standing, participants were instructed to stand as still as possible for 60s during each threat condition. For rise to toes, participants were instructed to rise onto their toes as quickly as possible following a verbal cue from the experimenter and to hold that position for approximately 3s. The rise to toes task consisted of a series of five successful rises onto toes under each threat condition, with any unsuccessful attempts repeated. For both postural tasks, participants stood with a stance width equal to the length of their foot. Foot position was kept consistent across all trials by tracing the borders of the participants' feet onto the force plate. Participants visually fixated on a target positioned at eye level 3.87m away from the platform. Practice trials for both postural tasks were performed with the platform positioned 0.8m above the ground in order to familiarize participants with the tasks and diminish possible first trial effects (Adkin et al., 2000). To control for possible order effects, the postural task and level of postural threat were presented in a randomized order. For all trials, participants wore a harness which was secured to the ceiling to prevent any falls, yet provided no cutaneous sensation/support that could aid in the postural task.

3.3 Dependent measures

Prior to each postural task, participants' rated their confidence to maintain balance and avoid a fall on a scale ranging from 0% (not at all confident) to 100% (completely confident) (Appendix G). Following each postural task, perceptions of fear of falling, anxiety, and state conscious motor processing (CMP-S) and movement self-consciousness (MSC-S) were reported. Fear of falling was reported on a scale ranging from 0% (not at all fearful) to 100% (completely fearful) (Appendix H). Anxiety was reported on a 16-item questionnaire adapted from the Sport Anxiety Scale (Smith, Smoll, & Schutz, 1990) which assessed worry (4-items), somatic (6-items), and concentration (6-items) elements of anxiety (Adkin et al., 2002; Carpenter et al., 2006; Appendix I). Items were rated on a 9-point Likert scale and an anxiety score was calculated by summing the scores of the worry and somatic anxiety items (Huffman et al., 2009). The aforementioned questionnaires have been shown to be valid and reliable measures when used under similar testing conditions (Hauck, 2011). CMP-S and MSC-S were reported on a modified version of the MSRS containing seven reworded items (CMP-S: 4 items; MSC-S: 3 items) from the original trait version (Huffman et al., 2009; Appendix J). Measures of CMP-S and MSC-S have been used to estimate state-related changes in conscious control/monitoring of movement and self-consciousness related to movement style/appearance, respectively, and have shown good internal consistency (Huffman et al., 2009).

To estimate changes in physiological arousal, electrodermal activity (EDA) was recorded from two Ag/AgCl electrodes placed on the thenar and hypothenar eminences of the non-dominant hand (Model 2502SA, CED, UK) and sampled at 1kHz (Power 1401, CED, UK). For quiet standing, mean EDA was calculated offline over the 60s period of standing. For rise to toes, mean EDA was calculated offline over 1s intervals prior to the onset of movement for each successful rise to toes. Average EDA was calculated from the five successful rise to toes completed at each threat condition. Due to technical problems, EDA was not available for three participants during quiet standing and five participants during rise to toes.

Ground reaction forces and moments of forces were sampled at 1kHz from the force plate and were used to calculate centre of pressure (COP) in only the A-P direction (Adkin et al., 2000; Carpenter et al., 1999). For quiet standing, force and moment of force signals were low-pass filtered offline using a dual-pass second order Butterworth filter with a cut-off frequency of 5 Hz before calculating COP. COP mean position (MP), root mean square (RMS), and mean power frequency (MPF) were then calculated (Carpenter et al., 1999; Davis et al., 2009). MP-COP reflects the average location of the COP referenced to the ankle joint over the 60s trial and indicates how far an individual leaned away from the edge of the platform. RMS-COP and MPF-COP were calculated after subtracting the MP-COP from the COP signal to provide a measure of amplitude and frequency of postural adjustments, respectively.

For rise to toes, COP in the A-P direction was calculated from the raw force and moment of force signals and low-pass filtered offline using a dual-pass second order Butterworth filter with a cut-off frequency of 5 Hz (Adkin et al., 2002). Analysis focused on the peak amplitude and velocity of the anticipatory postural adjustment (APA) as these measures have been shown to be modified by height-induced postural threat (Adkin et al., 2002). The peak backward displacement of the COP served as a point of reference from which both COP summary measures were calculated. A mean baseline of COP was calculated over a 500ms period prior to each rise to toes. The peak amplitude of the APA was calculated as the difference between the mean baseline COP and peak backwards COP displacement. To determine peak velocity of the APA, the COP profile was first differentiated. Peak APA velocity was then identified as the maximum value of the COP velocity profile occurring within a 500ms window prior to the peak backward displacement of the COP. APA peak amplitude and velocity for the five successful rise to toes completed were averaged within each threat condition. Due to technical problems, COP data was not available for two participants during quiet standing and three participants during the rise to toes.

3.4 Statistical analysis

3.4.1 Descriptive statistics

Descriptive statistics were calculated for all individual characteristics (Table 1), as well as for postural control and state psychological, physiological, and cognitive measures under low and high threat conditions for both quiet standing and rise to toes.

3.4.2 Postural threat effects

To examine the effect of postural threat (low vs high), one-way within-subject repeated-measures multivariate analyses of variance (MANOVAs) were conducted for three sets of dependent variables for the quiet standing and rise to toes tasks independently (total of 6 MANOVAs). Dependent measures for postural control included

MP-COP, MPF-COP, and RMS-COP for quiet standing and APA peak amplitude and velocity for rise to toes. Dependent measures for psychological and physiological state included balance confidence, anxiety, fear of falling, and EDA. Dependent measures for cognitive state included CMP-S and MSC-S. For any significant MANOVA effects, follow-up univariate ANOVAs were conducted to determine which measures were significantly different between low and high threat conditions.

3.4.3 Predicting changes in postural control from individual characteristics

To determine if individual characteristics predicted variance in changes in postural control when threatened, five standard multiple linear regressions were conducted. The five individual characteristics were included as the predictor variables and the postural control difference scores for both quiet standing and rise to toes tasks were included as the outcome variables. Difference scores were calculated for each postural control measure by subtracting values between the high and low threat conditions (Davis et al., 2009; Huffman et al., 2009). For all aforementioned analyses, alpha was set at 0.05 to indicate statistical significance.

Table 1: Descriptive statistics for individual characteristics

	Mean	SD	Min	Max
TANX	35.33	7.56	22.00	59.00
CMP-T	19.27	4.55	9.00	28.00
MSC-T	15.04	4.84	5.00	29.00
RRT	24.66	8.33	10.00	41.00
HT	4.04	1.93	1.00	9.00

Note: TANX=state-trait anxiety inventory (scale range: 20-80); CMP-T=conscious motor processing scale (scale range: 5-30); MSC-T=movement self-consciousness scale (scale range: 5-30); RRT=domain specific risk-taking scale (scale range: 6-42); HT=experience with height questionnaire (scale range: 1-9)

3.4.4 Mediation Analyses

Multiple mediation analyses were conducted to identify state-related changes that individual characteristics potentially operate through to influence height-induced changes in postural control. These analyses test whether the influence a predictor variable (X) has on an outcome variable (Y) is transmitted through one or more mediating variables (M) (Hayes, 2013). This is done by testing whether or not the cross-product of the regression coefficients between X-M_i and M_i-Y (the indirect effect: *ab*) is statistically different from zero independent of the relationship between X-Y (the direct effect: *c'*) and other indirect effects considered in the same analysis (Hayes, 2013). The cross-products of these coefficients are rarely normally distributed; thus, inferential tests which assume normality are not recommended (Hayes, 2013). Mediation analyses in the present thesis were tested using a non-parametric bias-corrected bootstrap cross-product test (Preacher & Hayes, 2008). For this test, 10,000 identically sized samples are randomly created through resampling with replacement from the original sample. The cross-products of each indirect effect are calculated in each sample to create a sampling distribution. If there is no zero value within a 95% confidence interval of this distribution, there is a significant indirect or mediation effect (Hayes, 2013).

In the case of the present thesis, individual characteristics were the predictor variables (X), difference scores for psychological, physiological, and cognitive state measures were the mediating variables (M), and changes in postural control were the outcome variables (Y). As the aim of this statistical approach was to explore potential state-related changes through which individual characteristics operate to influence postural control, multiple mediation analyses were only planned for cases in which an individual characteristic was identified as a significant independent predictor of a change in postural control based on the results of the multiple linear regression analyses. As multiple linear regression analyses account for shared variance across all predictor variables, the individual characteristics not examined in each mediation analysis were included as covariates (Hayes, 2013).

For all analyses, total and specific indirect effects as well as direct effects were examined. Each specific indirect effect reflects how much Y is estimated to change for each unit change in X indirectly through a specific mediator while holding variance due to other mediators constant. The total indirect effect reflects the sum effect of all specific indirect effects. The direct effect reflects the relationship between the predictor and outcome variable after accounting for the effect of each mediator. All effects are reported in their unstandardized form.

CHAPTER 4: RESULTS

4.1 Data screening and statistical assumptions

4.1.1 Outliers

Twelve of the 94 participants who volunteered were not included in the final statistical analysis due to extraneous factors including physical illness/impairment that could have confounded results or any self-reported difficulty understanding questionnaires/instructions due to a language barrier. Thus, the total sample size was reduced to 82 participants (44 males; mean age in years ± standard deviation = 23.95 ±4.08).

All variables were screened for univariate outliers. This included each of the individual characteristics, as well as low threat, high threat, and difference score values for all psychological, physiological, and cognitive state measures, and postural control measures. To check for univariate outliers, data for these variables were converted to standardized z-scores. A univariate outlier was identified as having a z-score greater or less than ±3.29. If a variable fit this criteria, it was replaced by a value ±3 standard deviations of the mean in the direction it was previously outlying. After replacements were made for each variable, data were screened again and any new cases identified as outliers were replaced using the same method (Tabachnick & Fidell, 2007). This procedure was repeated until no new outliers emerged.

4.1.2 Normality

Normality was assessed for all variables. This included each of the individual characteristics, as well as low threat, high threat, and difference score values for all psychological, physiological, and cognitive state measures, and postural control measures. Normality was determined by examining the skewness and kurtosis statistics for each variable with significance set at $p<0.001$. Significance was determined by converting each skewness and kurtosis statistic to a standardized z-score by dividing each value by its own standard error. Any values greater or less than ±3.29 were considered significantly skewed or kurtotic (Field, 2009). Tables 2, 3, and 4 display skewness and kurtosis statistics for all variables examined. While a number of variables were considered significantly non-normal, examination of the skewness statistics and frequency distribution plots suggested these variables were only minimally skewed and kurtotic in most cases (Field, 2009). In addition, all values were thought to reflect participants' true perceptions and behaviour. Thus, while the assumption of normality was violated for some variables, transformations were not considered necessary.

Table 2: Skewness and kurtosis statistics for individual characteristics

	Skewness	Kurtosis
TANX	1.148*	1.715
CMP-T	-.285	-.521
MSC-T	.226	-.036
PRT	.063	-.868
HT	.724	.126

Note: TANX=state-trait anxiety inventory; CMP-T=conscious motor processing scale; MSC-T=movement self-consciousness scale; RRT=domain specific risk-taking scale; HT=experience with height questionnaire

* indicates significant skewness or kurtosis with $p<0.001$

Table 3: Skewness and kurtosis statistics for quiet standing postural control and state psychological, physiological, and cognitive measures

	Low threat		High threat		Difference	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
MP-COP	-.175	.589	-.219	-.182	-.142	-.410
MPF-COP	.956*	1.182	1.087*	.802	1.246*	1.719
RMS-COP	.766	-.062	1.011*	1.085	-.117	.211
Confidence	-1.614*	.903	-1.080*	1.148	-1.057*	.856
FOF	2.209*	3.641*	.414	-1.203	.416	-1.195
Perceived anxiety	2.017*	3.208*	.809	-.316	.845	-.388
EDA	1.090*	2.005*	1.347*	1.520	1.312*	1.773*
CMP-S	.167	-.596	-.390	-.421	-.083	.205
MSC-S	.902	.085	.688	-.516	.172	2.287*

Note: MP-COP=mean position of centre of pressure; MPF-COP=mean power frequency of COP; RMS-COP=root mean square of COP; FOF=perceived fear of falling; EDA=electrodermal activity; CMP-S=state conscious motor processing; MSC-S=state movement self-consciousness

* indicates significant skewness or kurtosis with $p<0.001$

Table 4: Skewness and kurtosis statistics for rise to toes postural control and state psychological, physiological, and cognitive measures

	LOW		HIGH		Difference	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
AMP	.138	-.695	.433	-.197	-.325	-.240
VEL	.726	.236	.798	.252	-.063	1.068
Confidence	-.814	.098	-.574	.035	-1.196*	1.221
FOF	1.475*	1.585	.313	-.731	.573	-.331
Perceived anxiety	1.048*	.384	.439	-.229	.895	.496
EDA	1.281*	1.626	1.070*	.608	1.050*	1.349
CMP-S	-.687	-.209	-1.047*	1.113	-.062	.360
MSC-S	.191	-1.213	.209	-1.006	.033	1.035

Note: AMP=peak amplitude of anticipatory postural adjustment; VEL=peak velocity of the anticipatory postural adjustment; FOF=perceived fear of falling; EDA=electrodermal activity; CMP-S=state conscious motor processing; MSC-S=movement self-consciousness

* indicates significant skewness or kurtosis with $p<0.001$

4.1.3 Assumptions of regression

4.1.3.1 Multicollinearity

Multicollinearity was checked by conducting bivariate correlations between the individual characteristics (Table 5), between the difference scores for state psychological, physiological, and cognitive measures for quiet standing (Table 6) and rise to toes (Table 7), and between all postural control measures (Table 8). Any variables sharing a bivariate correlation greater than 0.8 were considered multicollinear (Field, 2009). None of the individual characteristics or postural control measures exceeded this threshold. However, changes in perceptions of fear of falling and anxiety for both quiet standing and rise to toes were considered multicollinear (r=0.876, r=0.856, respectively), thus only one of these two variables was included in further analyses. Previous work has shown that the multi-item questionnaire used to assess perceived anxiety is less reliable than the single item questionnaire used to assess fear of falling (Hauck, 2011). Thus, perceived anxiety was not included in further analyses.

Table 5: Bivariate correlations between individual characteristics

	2	3	4	5
1) TANX	-.079	.324**	-.227*	-.154
2) CMP-T	-	.292**	.195	.100
3) MSC-T		-	.090	0.014
4) PRT			-	.477**
5) HT				-

Note: TANX=state-trait anxiety inventory; CMP-T=conscious motor processing scale; MSC-T=movement self-consciousness scale; RRT=domain specific risk-taking scale; HT=experience with height questionnaire

*$p<0.05$; **$p<0.01$

Table 6: Bivariate correlations between state-related changes in psychological, physiological, and cognitive measures during quiet standing

	2	3	4	5	6
1) Confidence	-.539**	-.521**	-.247*	-.071	-.036
2) Perceived anxiety	-	.876**	.473**	.241*	.094
3) FOF		-	.492**	.216	.036
4) EDA			-	.094	.184
5) CMP-S				-	.319**
6) MSC-S					-

Note: FOF=perceived fear of falling; EDA=electrodermal activity; CMP-S=state conscious motor processing; MSC-S=state movement self-consciousness

*p<0.05; **p<0.01

Table 7: Bivariate correlations between state-related changes in psychological, physiological, and cognitive measures during rise to toes

	2	3	4	5	6
1) Confidence	-.349**	-.363**	.019	-.010	-.091
2) Perceived anxiety	-	.856**	.057	.087	.324**
3) FOF		-	.078	-.086	.227*
4) EDA			-	-.006	.089
5) CMP-S				-	.472**
6) MSC-S					-

Note: FOF=perceived fear of falling; EDA=electrodermal activity; CMP-S=state conscious motor processing; MSC-S=state movement self-consciousness

*p<0.05; **p<0.01

Table 8: Bivariate correlations between changes in postural control measures

	2	3	4	5
1) MP-COP	.365**	-.027	-.267*	-.307**
2) MPF-COP	-	-.247*	-.239*	-.198
3) RMS-COP		-	-.040	.042
4) AMP			-	.775**
5) VEL				-

Note: MP-COP=mean position of centre of pressure; MPF-COP=mean power frequency of COP; RMS-COP=root mean square of COP; AMP=peak amplitude of the anticipatory postural adjustment; VEL=peak velocity of the anticipatory postural adjustment

*p<0.05; **p<0.01

4.1.3.2 Linearity and absence of bivariate outliers

The assumption of linearity and absence of bivariate outliers was checked by visually inspecting bivariate scatterplots between all individual characteristics and postural control difference scores as well as between all difference scores for state psychological, physiological, and cognitive measure and postural control measures (Field, 2009). No non-linear relationships or bivariate outliers were identified.

4.1.3.3 Absence of multivariate outliers

Data were screened for multivariate outliers. These are cases that have an unusual combination of scores on two or more variables. Multivariate outliers were identified by calculating Mahalanobis distances for each case. These values were compared to a critical value based on the chi square value with degrees of freedom equal to the number of predictor variables included in each multiple linear regression analysis (n=5) with significance set at p<0.001. Any case with a Mahalnobis distance greater than 20.515 was considered a multivariate outlier (Tabachnick & Fidell, 2007). Based on this criterion, no multivariate outliers were identified.

4.1.3.4 Independence of errors

The assumption of independence of errors was checked using the Durbin-Watson test. The Durbin-Watson test statistic for each analysis did not fall outside of an acceptable range (i.e., all within 1.5-2.5), indicating this assumption was met (Field, 2009).

4.1.3.5 Homoscedasticity of residuals

The assumption of homoscedasticity of residuals was tested by visually inspecting the scatterplot between the standardized predicted and standardized residual values for all multiple linear regression analyses. Residual values appeared to be equally distributed above and below the line of best fit across each level of the predicted variable, indicating this assumption was met (Field, 2009).

4.2 Postural threat effects

MANOVAs for quiet standing revealed significant main effects of postural threat for postural control measures ($F_{(3,77)} = 45.096$, $p<0.001$), state psychological and physiological measures ($F_{(4,75)} = 37.104$, $p<0.001$), and state cognitive measures ($F_{(2,80)} = 6.528$, $p=0.002$). As revealed by univariate ANOVAs, when standing at the high compared to low threat condition, MP-COP shifted further away from the platform edge ($p<0.001$), MPF-COP increased ($p<0.001$), and RMS-COP decreased ($p=0.009$). In addition, participants reported less balance confidence ($p<0.001$), more anxiety ($p<0.001$), greater fear of falling ($p<0.001$) and had elevated EDA ($p<0.001$) when standing at the high compared to low threat condition. Participants also reported greater CMP-S ($p=0.001$) but no significant change in MSC-S ($p=0.513$) when standing at the high compared to low threat condition.

MANOVAs for rise to toes revealed significant main effects of postural threat for postural control measures ($F_{(2,77)}$ = 47.243, p<0.001), state psychological and physiological measures ($F_{(4,73)}$ = 61.014, p<0.001), and state cognitive measures ($F_{(2,80)}$ = 4.901, p=0.010). As revealed by univariate ANOVAs, when rising to toes at the high compared to low threat condition, there was a decrease in both APA peak amplitude (p<0.001) and velocity (p<0.001). In addition, participants reported less balance confidence (p<0.001), more anxiety (p<0.001), greater fear of falling (p<0.001) and had elevated EDA (p<0.001) when rising to toes at the high compared to low threat condition. Participants also reported greater CMP-S (p=0.003) and MSC-S (p=0.033) when rising to toes at the high compared to low threat condition. Mean and standard deviation values for all dependent measures under low and high threat conditions are presented in Table 9.

Table 9: Mean and standard deviation values for low and high postural threat values

	Quiet standing	
Dependent measure	Low	High
MP-COP (mm)	37.01 (14.05)	24.72 (13.49)**
MPF-COP (Hz)	0.20 (0.09)	0.30 (0.16)**
RMS-COP (mm)	4.47 (1.68)	3.99 (1.31)*
Confidence (%)	97.97 (4.13)	78.35 (19.51)**
Fear of falling (%)	1.77 (4.34)	38.54 (32.28)**
Perceived anxiety (sum)	12.66 (4.18)	30.66 (17.13)**
EDA (μS)	23.49 (9.01)	32.33 (14.53)**
CMP-S (sum)	12.87 (4.75)	14.76 (4.38)*
MSC-S (sum)	6.49 (3.68)	6.68 (3.39)
	Rise to toes	
AMP (mm)	43.75 (14.63)	34.99 (14.73)**
VEL (mm/s)	241.13 (106.39)	196.12 (97.49)**
Confidence (%)	86.17 (13.23)	69.68 (20.32)**
Fear of falling (%)	10.56 (14.37)	42.73 (27.64)**
Perceived anxiety (sum)	19.351 (8.36)	34.792 (15.70)**
EDA (μS)	27.454 (10.64)	32.543 (13.01)**
CMP-S (sum)	17.09 (4.34)	18.56 (3.86)*
MSC-S (sum)	8.37 (4.01)	9.05 (4.22)*

Note: MP-COP=mean position of centre of pressure; MPF-COP=mean power frequency of COP; RMS-COP=root mean square of COP; EDA=electrodermal activity; CMP-S=state conscious motor processing; MSC-S=state movement self-consciousness; AMP=amplitude of anticipatory postural adjustments; VEL=peak velocity of anticipatory postural adjustment

*$p<0.05$; **$p<0.001$

4.3 Predicting changes in postural control from individual characteristics

Standard multiple linear regressions revealed that a linear combination of individual characteristics significantly accounted for variance in the changes in MP-COP (R^2=.201, $F_{(5,74)}$=3.717, p=0.005), MPF-COP (R^2=.162, $F_{(5,74)}$=2.858, p=0.021), and RMS-COP (R^2=.162, $F_{(5,74)}$=2.869, p=0.020) between the high and low threat conditions. Leaning further away from the platform edge at the high threat condition was significantly associated with lower physical risk taking (β= -.303, p=0.016) and higher CMP-T scores (β=.299, p=0.010). Greater increases in MPF-COP at the high threat condition were significantly associated with lower physical risk-taking scores (β= -.335, p=0.009). Changes in RMS-COP were significantly associated with physical risk-taking (β= .263, p=0.040), CMP-T (β= .249, p=0.035), and MSC-T scores (β= -.264, p=0.032), with higher physical risk-taking and CMP-T associated with increases in RMS-COP and higher MSC-T associated with decreases in RMS-COP.

A linear combination of individual characteristics did not account for a significant amount of variance for changes in APA peak amplitude (R^2=.038, $F_{(5,73)}$=0.571, p=0.722) or velocity (R^2=.119, $F_{(5,73)}$=1.980, p=0.092) between the high and low threat conditions. Results for all multiple linear regression analyses are summarized in Table 10.

Table 10: Multiple linear regressions for postural control measures

	Quiet standing								
	MP-COP			MPF-COP			RMS-COP		
	β	B	SE	β	B	SE	β	B	SE
TANX	-.108	-0137	0.144	-.129	-0.003	0.003	.092	0.020	0.025
CMP-T	.299*	0.627	0.237	.179	0.007	0.004	.249*	0.088	0.041
MSC-T	-.149	-0.295	0.232	-.086	-0.003	0.004	-.264*	-0.088	0.040
PRT	-.303*	-0.347	0.140	-.335*	-0.007	0.003	.263*	0.051	0.024
HT	-.154	-0.762	0.587	-.112	-0.010	0.010	-.167	-0.139	0.101
	R^2=0.201*			R^2=.162*			R^2=.162*		
	Rise to toes								
	AMP			VEL					
	β	B	SE	β	B	SE			
TANX	.034	0.036	0.133	.141	1.041	0.890		-	
CMP-T	-.082	-0.144	0.219	-.223	-2.735	1.467		-	
MSC-T	-.070	-0.115	0.214	-.169	-1.952	1.434		-	
PRT	.075	0.072	0.130	.116	0.779	0.868		-	
HT	.121	0.498	0.542	.093	2.674	3.629		-	
	R^2=0.038			R^2=.119				-	

Note: TANX=state-trait anxiety inventory; CMP-T=conscious motor processing scale; MSC-T=movement self-consciousness scale; PRT=domain specific risk-taking scale; HT=experience with height questionnaire; MP-COP=mean position of centre of pressure; MPF-COP=mean power frequency of COP; RMS-COP=root mean square of COP; AMP=peak amplitude of anticipatory postural adjustment; VEL=peak velocity of anticipatory postural adjustment; β=standardized beta weight; B=unstandardized beta weight; SE=standard error of unstandardized beta-weight

*p<0.05; **p<0.01

4.4 Mediation analyses

Based on the results of the multiple linear regression analyses, six multiple mediation analyses were conducted for the quiet standing task, while none were conducted for the rise to toes task.

The lower (LL) and upper (UL) limits of a bias-corrected bootstrap confidence interval revealed a significant total indirect effect of physical risk-taking on changes in MP-COP (*ab*=-0.2260; LL=-0.3938, UL=-0.0750). Specific indirect effects revealed changes in fear of falling (*ab*=-0.1254; LL=-2948, UL=-0.0178) and EDA (*ab*=-0.1026; LL=-0.2335, UL=-0.0245) were the only significant independent mediators of this relationship. Furthermore, while a significant overall relationship between physical risk-taking and changes in MP-COP was observed (*c*=-0.3417; LL=-0.6273; UL=-0.0562), this was non-significant after accounting for the influence of each of the mediators examined (*c'*=-0.1157; LL=-0.4044; UL=0.1730) (Figure 1). A significant total indirect effect of physical risk-taking on changes in MPF-COP was also found (*ab*=-0.0028; LL=-0.0065, UL=-0.0002). While specific indirect effects did not reveal any significant independent mediators of this relationship, examination of the unstandardized *ab* coefficients suggests that fear of falling and EDA contribute the most to the total indirect effect (*ab*=-0.0015 and *ab*=-0.0010, respectively), albeit non-significantly (Hayes, 2013). In addition, while a significant overall relationship between physical risk-taking and changes in MPF-COP was observed (*c*=-0.0070; LL=-0.0121; UL=-0.0020), this was non-significant after accounting for the influence each of the mediators examined (*c'*=-0.0043; LL=-0.0094; UL=0.0009) (Figure 2). None of the remaining multiple mediation analyses examined revealed significant mediation effects (Table 11).

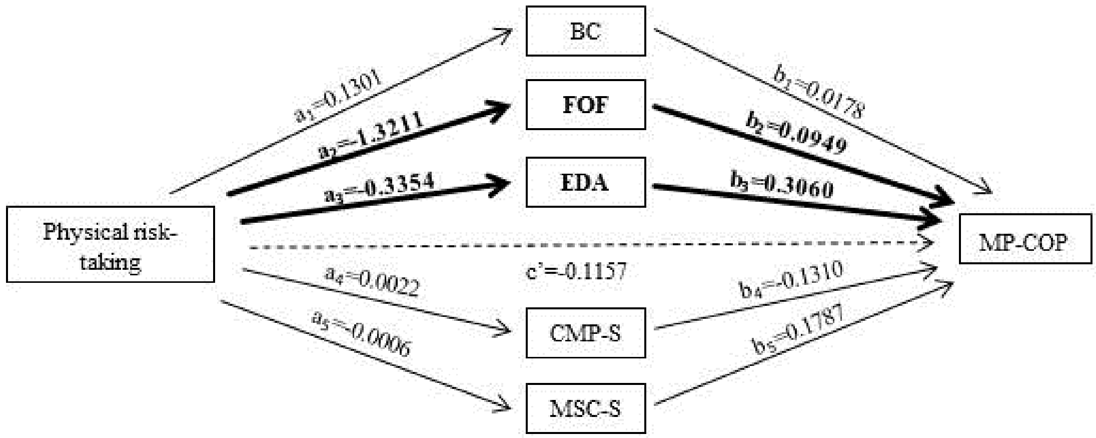

Figure 1. Multiple mediation analysis between physical risk-taking and changes in mean position of centre of pressure (MP-COP). The effect of physical risk-taking on changes in MP-COP was significantly mediated by changes in fear of falling (FOF) and electrodermal activity (EDA).

Note: a_i and b_i=unstandardized regression coefficients between the predictor and mediating variables and between the mediating variables and the outcome variable, respectively; c'=unstandardized direct effect; BC=balance confidence; CMP-S=state conscious motor processing; MSC-S=state movement self-consciousness

Significant specific indirect effects are highlighted in bold

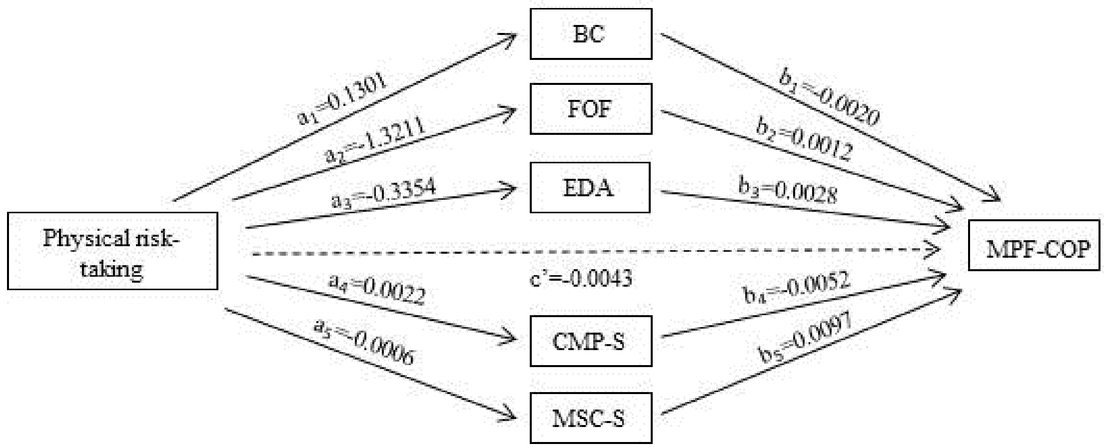

Figure 2. Multiple mediation analysis between physical risk-taking and changes in mean power frequency of centre of pressure (MPF-COP). The effect of physical risk-taking on changes in MPF-COP was significantly mediated by a combination of psychological, physiological, and cognitive state changes, but no specific indirect effects reached significance.

Note: a_i and b_i=unstandardized regression coefficients between the predictor and mediating variables and between the mediating variables and the outcome variable, respectively; c'=unstandardized direct effect; BC=balance confidence; CMP-S=state conscious motor processing; MSC-S=state movement self-consciousness

Significant specific indirect effects are highlighted in bold

Table 11: Total and specific indirect effects for multiple mediation analyses

Physical risk-taking to mean position of centre of pressure				
			BC 95% CI	
	Effect	SE	LL	UL
CON	0.0023	0.0810	-0.0248	0.0605
FOF	**-0.1254**	**0.0714**	**-0.2948**	**-0.0178**
EDA	**-0.1026**	**0.0512**	**-0.2335**	**-0.0245**
CMP-S	-0.0003	0.0182	-0.0444	0.0352
MSC-S	-0.0001	0.0207	-0.0403	0.0480
Total	**-0.2260**	**0.0810**	**-0.3938**	**-0.0750**
Physical risk-taking to mean power frequency of centre of pressure				
CON	-0.0003	0.0006	-0.0023	0.0006
FOF	-0.0015	0.0013	-0.0050	0.0003
EDA	-0.0010	0.0010	-0.0031	0.0011
CMP-S	0.0000	0.0005	-0.0013	0.0009
MSC-S	0.0000	0.0004	-0.0009	0.0007
Total	**-0.0028**	**0.0016**	**-0.0065**	**-0.0002**
Physical risk-taking to root mean square of centre of pressure				
CON	-0.0018	0.0050	-0.0201	0.0038
FOF	0.0116	0.0125	-0.0065	0.0449
EDA	-0.0040	0.0096	-0.0275	0.0121
CMP-S	0.0001	0.0043	-0.0078	0.0097
MSC-S	0.0000	0.0038	-0.0075	0.0091
Total	0.0059	0.0132	-0.0192	0.0341
Trait conscious motor processing to mean position of centre of pressure				
CON	-0.0013	0.0360	-0.0880	0.0677
FOF	0.0645	0.0936	-0.0944	0.2967
EDA	0.0837	0.0812	-0.0285	0.3032
CMP-S	0.0145	0.0423	-0.0290	0.1727
MSC-S	0.0025	0.0421	-0.0612	0.1279
Total	0.1640	0.1359	-0.0969	0.4408
Trait conscious motor processing to root mean square centre of pressure				
CON	0.0010	0.0100	-0.0151	0.0280
FOF	-0.0060	0.0129	-0.0531	0.0068
EDA	0.0033	0.0094	-0.0075	0.0375
CMP-S	-0.0044	0.0088	-0.0367	0.0044
MSC-S	-0.0013	0.0074	-0.0232	0.0096
Total	-0.0073	0.0184	-0.0423	0.0297
Trait movement self-consciousness to root mean square centre of pressure				
CON	0.0016	0.0095	-0.0115	0.0317
FOF	-0.0002	0.0088	-0.0226	0.0160
EDA	-0.0012	0.0070	-0.0254	0.0069
CMP-S	-0.0046	0.0088	-0.0376	0.0039
MSC-S	0.0129	0.0141	-0.0042	0.0571
Total	0.0084	0.0181	-0.0282	0.0452

Note: CON=balance confidence; FOF=perceived fear of falling; EDA=electrodermal activity; CMP-S=state conscious motor processing; MSC-S=state movement self-consciousness; BC 95% CI=bias-corrected bootstrapped 95% confidence intervals; LL=lower limit of confidence interval; UL=upper limit of confidence interval

Significant indirect effects highlighted in bold

CHAPTER 5 - DISCUSSION

This thesis replicates previous work investigating the effects of height-induced postural threat on emotions, cognitions, and postural control. Postural threat lowered balance confidence, increased anxiety, fear of falling, and reinvestment in movement, elevated physiological arousal (Adkin et al., 2002; Carpenter et al., 2006; Cleworth et al., 2012; Davis et al., 2009; Hauck et al., 2008; Huffman et al., 2009), and modified quiet standing (Adkin et al., 2000; Carpenter et al., 2001; 2006; Hauck et al., 2008) and anticipatory postural control (Adkin et al., 2002; Yiou et al., 2011). This thesis extends understanding of the contribution of individual characteristics in explaining changes in postural control under conditions of height-induced postural threat. Select individual characteristics were able to significantly predict height-induced changes in quiet standing, but not anticipatory postural control, suggesting certain types of postural control may be more susceptible to modification through these characteristics.

5.1 Individual characteristics influence changes in quiet standing postural control

Of the individual characteristics examined, physical risk-taking and both elements of trait movement reinvestment were identified as significant independent predictors of changes in quiet standing. Individuals reporting less willingness to take physical risks were more likely to adopt a cautious postural control strategy when standing under conditions of height-induced postural threat. This strategy was characterized by a more pronounced lean away from the platform edge, greater increases in frequency of postural adjustments, and decreased amplitude of these adjustments. Previous reports have demonstrated individuals adopt this strategy under conditions of height-induced postural threat, as they attempt to withdraw from the direction of the threat and stiffen control of posture to limit the possibility of falling (Adkin et al., 2000; Brown et al., 2006; Carpenter et al., 1999; 2001; 2006; Cleworth et al., 2012; Hauck et al., 2008). Given the perceived risk associated with an increased consequence of falling during the high postural threat condition, it is reasonable that those less willing to take physical risks would adopt this strategy to a greater extent. Mediation analyses revealed the relationship between physical risk taking and changes in leaning was mediated through changes in perceptions of fear of falling and physiological arousal. These same state-related changes also appeared to be the strongest, albeit non-significant, independent mediators underlying the significant indirect relationship between physical risk-taking and changes in frequency of postural adjustments. Taken together, this suggests perceptions of fear of falling and physiological arousal are important state-related changes underlying the relationship between physical risk-taking and changes in quiet standing.

The relationship between changes in amplitude of postural adjustments and physical risk-taking was not significantly mediated by any of the state-related changes considered in the mediation analyses. Previous work has shown that changes in amplitude of postural adjustments are not consistently related to changes in psychological, physiological, and cognitive state measures when exposed to a height-induced postural threat (Hauck et al., 2008; Huffman et al., 2009). Thus, it is likely that one’s willingness to take physical risks either influences changes in this aspect of quiet standing directly or through other state-related changes not considered in this thesis.

When standing under conditions of high compared to low postural threat, individuals who have a greater tendency to consciously control their movement (CMP-T) were more likely to lean further away from the platform edge and sway at larger amplitudes, while those more self-conscious of their movement appearance (MSC-T) were more likely to sway at smaller amplitudes. According to the theory of reinvestment (Masters & Maxwell, 2008), individuals scoring higher on either subscale of the MSRS have a greater tendency to reinvest attention toward the control/perception of their movement, particularly under anxiety-inducing conditions, leading to modifications in behaviour. However, no significant indirect effects between either of these reinvestment subscales and changes in postural control were observed, indicating the relationships between these traits and changes in postural control were not mediated through further reinvestment in the control/perception of movement. Limited research has systematically confirmed theoretical claims that individuals higher in either of these traits reinvest attention in their movement to a greater extent under anxiety-inducing conditions compared to those lower in these traits (Maxwell, Masters, & Poolton, 2006). However, individuals classified as high reinvesters have been shown to direct more attention to their movement in the absence of anxiety (Maxwell, Masters, & Eves, 2000; Zhu, Poolton, Wilson, Maxwell, & Masters, 2011). It is possible that other psychological and cognitive changes associated with the postural threat (e.g., increases in overall cognitive load) interfere with these individuals' natural tendency to direct attention to the control/perception of their movement, contributing to changes in postural control (Eysenck et al., 2007). However, because state-related changes in overall attention were not measured in the present thesis, it is unclear how attention is reallocated and if this is different depending on one's tendency to direct attention to their movement.

It is interesting that changes in amplitude of postural adjustments were influenced in opposite directions by trait conscious motor processing and movement self-consciousness. While most research has considered movement reinvestment a unidimensional trait (Chell et al., 2003; Kinrade et al., 2010; Malhotra et al., 2012; Masters et al., 1993; Maxwell et al., 2006), other work has shown skilled motor performance is influenced differently depending on whether an individual has a greater tendency to consciously control their movement or is highly self-conscious of their movement appearance (Malhotra et al., in press). Furthermore, when comparing elderly fallers and non-fallers, Wong and colleagues found while both elements of trait movement reinvestment were higher in elderly fallers, only a tendency to consciously control movement significantly predicted faller/non-faller status (Wong, Masters, Maxwell, & Abernethy, 2008). Therefore, it is clear that these traits influence behaviour in unique ways and should be considered as distinct traits when attempting to predict postural control in different situations.

It should be noted that trait anxiety and experience with height-related activities were not identified as significant independent predictors of changes in quiet standing. Although trait anxious individuals have been shown to perceive greater state anxiety in response to different stressors (Arena & Hobbs, 1995; Baggett et al., 1996; Gonzalez-Bono et al., 2002; Noteboom et al., 2001; Steptoe & Vogele, 1992; Willmann et al., 2012), exposure to a height-induced threat may not be relevant to this trait. As a consequence, trait anxious individuals may perceive this situation to be equally threatening in comparison to less anxious individuals. In addition, while the trait anxiety scores fell within a typical range for this cohort, those scoring the highest were less anxious than individuals who have been classified as either ‘moderate’ or ‘high’ trait anxious by previous investigators who have shown a relationship between trait anxiety and postural control (Hainaut et al., 2011; Kogan, Lidor, Bart, Bar-Haim, & Mintz, 2008). Thus, it is possible that individuals' trait anxiety levels in the present thesis were not high enough to influence postural control under conditions of postural threat. Experience with height-related activities may not have been identified as a significant independent predictor of changes in postural control due to its fairly high shared variance with physical risk-taking (r=0.477). This association is not surprising, as individuals more prone to taking physical risks are more likely to have participated in potentially dangerous height-related activities in the past (Salassa & Zapala, 2009). It is possible that experience with height-related activities is related to changes in postural control, but after controlling for shared associations with other individual characteristics, it does not explain unique variance in any of the measures considered.

5.2 Individual characteristics do not predict changes in anticipatory postural control

A combination of individual characteristics did not predict height-induced changes in anticipatory postural control. Although contrary to our hypothesis, the overall difference in the height of the platform from low to high threat conditions may have contributed to this finding. The difference in platform height for the rise to toes task was only 0.8m, while the difference for the quiet standing task was 2.8m. Although this modification was made to account for differences in task difficulty, the high threat condition for rise to toes task may have been relatively less threatening than it was for the quiet standing task and insufficient to elicit strong individual variability (Monson, Hesley, & Chernick, 1982). However, it is also possible the individual characteristics examined in the present thesis simply do not predict changes in anticipatory postural control.

5.3 Cognitive changes associated with postural threat

While the primary objective of this thesis was not to explore changes in cognitive strategy associated with postural threat, only one other study to date has directly examined this. Huffman et al. (2009) showed that individuals report reinvesting greater attention in the control of their movement and are more concerned about their movement appearance when standing quietly under conditions of height-induced postural threat. While the present thesis replicated these findings for the rise to toes task, individuals only reported directing more attention to the control of their movement during quiet standing, but were not any more concerned about their movement appearance. Methodological differences between this study and that of Huffman and colleagues may account for this discrepancy. For instance, participants in the present thesis performed a quiet standing and rise to toes task under low and high threat conditions, while those in the study by Huffman and colleagues only performed a quiet standing task. In addition, the order of task and threat conditions in the present thesis were randomized as opposed to being presented in an ascending order (i.e., low to high). Thus, the addition of the rise to toes task and possible order effects may have contributed to these disparate findings. Nonetheless, this highlights the need for further research to examine the specific cognitive changes associated with postural threat during different postural tasks.

5.4 Limitations and future directions

Multiple linear regression analyses are very sensitive to the combination of independent variables entered into the analysis (Tabachnick & Fidell, 2007). It is possible individual characteristics identified as significant independent predictors could appear more or less important with the addition or removal of other individual characteristics.

Nonetheless, this thesis was able to provide initial insight into several characteristics that appear relevant for predicting behaviour during threatening postural tasks.

The relationships observed in this thesis are only generalizable to young adults when presented with a height-induced postural threat. Different individual characteristics may account more or less strongly for variance in changes in postural control in older adults or neurologically impaired populations (e.g., Parkinson's disease) when exposed to a similar threat. In addition, the individual characteristics contributing to changes in postural control may also be different depending on the type of postural threat (e.g., threat of unexpected perturbation; Shaw, Stefanyk, Frank, Jog, & Adkin, 2012). Another limitation of this thesis is the breadth of individual characteristics considered. Although these accounted for a moderate amount of variance in changes in quiet standing, other individual characteristics not considered could contribute to the unexplained variance, particularly for more dynamic postural control tasks, such as rising onto toes. Given the above limitations, future research should systematically investigate whether similar and different subsets of characteristics can predict changes in postural control under different threatening conditions in different populations (e.g., older adult, neurologically impaired individuals, etc.). This research would provide insight into which individual characteristics are the most important and versatile for predicting threat-induced changes in postural control over a range of situations.

This thesis calculated difference scores for all postural control measures and included these as the dependent variables in multiple linear regression analyses. In addition, difference scores were calculated for all state psychological, physiological, and cognitive variables and included as potential mediating variables in the multiple mediation analyses. Many have criticized difference scores because of the long held belief they are unreliable measures of change (Cronbach & Furby, 1970; Judd & Kenny, 1981). However, others have suggested differences scores are an appropriate measure of change and are highly reliable in many statistical designs including regression analyses (Allison, 1990). Others have suggested difference scores are particularly reliable when assessing physiological variables (i.e., COP and EDA) as well as when pre- and post-test variables have unequal variances, as is the case for psychological variables assessed under low and high conditions of threat such as balance confidence and perceptions of fear of falling and anxiety (Overall & Woodward, 1982; Zimmerman & Williams, 1982; Dimitrov & Rumrill, 2003).

While mediation analyses were able to identify state-related changes underlying the relationship between physical risk-taking and changes in quiet standing, no mediators underlying the relationships between either element of trait movement reinvestment and changes in quiet standing were observed. Based on the theory of reinvestment (Masters & Maxwell, 2008), it was expected that individuals higher in these traits would reinvest more attention in the control/perception of their movement under threatening conditions, leading to altered postural control. However, this was not shown to be the case. It has been shown that these traits predispose individuals to direct more attention to their movement under normal conditions (Maxwell et al., 2000; Zhu et al., 2011). It is possible that other psychological and cognitive changes associated the postural threat (e.g., increases in overall cognitive load) may have interfered with one's natural tendency to employ this cognitive strategy, contributing to changes in postural control. To address this speculation, future research should assess where individuals allocate their attention under threatening and non-threatening conditions using qualitative methods such as open-ended questionnaires or post-trial interviews.

5.5 Implications

To date, insufficient research examining the relationship between emotion and postural control has considered the influence of personal factors. In most cases, samples are treated as either homogenous or dichotomous groups (e.g., fearful vs. non-fearful), while ignoring that each individual brings with them a unique set of characteristics that shape how they appraise a situation and subsequently behave. The present thesis provides initial insight into a subset of individual characteristics that can influence the postural strategy employed under threatening conditions. This finding has practical implications for clinicians and rehabilitation specialists, as it opens up a new dimension to consider when assessing fall risk and designing interventions to address postural control problems. For instance, individual characteristics identified as significant predictors of threat-induced changes in postural control may have the potential to be used by clinicians as context-specific predictors of instability. In addition, despite individual characteristics (including specific personality traits) being relatively stable over time, these have been shown to be amendable by cognitive and behavioural therapies (Beck, Freeman, & Davis, 2004). Thus, it may be prudent for interventions to address individual characteristics in addition to other psychological and physiological factors contributing to postural control problems in patient populations at risk of falling.

5.6 Conclusions

This thesis provides evidence that individual characteristics, including specific personality traits and individual differences, shape the postural control strategy employed under conditions of height-induced postural threat. In particular, individual differences in one's willingness to take physical risk and trait movement reinvestment were identified as the most influential characteristics. This thesis also provides initial insight into state-related changes mediating the relationship between these individual characteristics and changes in postural control. Systematically examining individual characteristics contributing to variability in postural control in response to different conditions of threat and identifying the mechanisms through which these characteristics operate has the potential to assist clinicians in identifying individuals at risk of falling and designing interventions.

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APPENDIX A – BROCK UNIVERSITY ETHICS CLEARANCE

Brock University
Research Ethics Office
Tel: 905-600-5550 ext. 3035
Email: reb@brocku.ca

Bioscience Research Ethics Board

Certificate of Ethics Clearance for Human Participant Research

DATE: 6/20/2013

PRINCIPAL INVESTIGATOR: ADKIN, Allan Kinesiology

FILE: 12-303 - ADKIN

TYPE: Masters Thesis/Project STUDENT: Martin Zaback
SUPERVISOR: Allan Adkin

TITLE: Effects of Postural Threat on Postural Control: Influence of Personality Traits

ETHICS CLEARANCE GRANTED

Type of Clearance: NEW Expiry Date: 6/30/2014

The Brock University Bioscience Research Ethics Board has reviewed the above named research proposal and considers the procedures, as described by the applicant, to conform to the University's ethical standards and the Tri-Council Policy Statement. Clearance granted from 6/20/2013 to 6/30/2014.

The Tri-Council Policy Statement requires that ongoing research be monitored by, at a minimum, an annual report. Should your project extend beyond the expiry date, you are required to submit a Renewal form before 6/30/2014. Continued clearance is contingent on timely submission of reports.

To comply with the Tri-Council Policy Statement, you must also submit a final report upon completion of your project. All report forms can be found on the Research Ethics web page at http://www.brocku.ca/research/policies-and-forms/research-forms.

In addition, throughout your research, you must report promptly to the REB:

a) Changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
b) All adverse and/or unanticipated experiences or events that may have real or potential unfavourable implications for participants;
c) New information that may adversely affect the safety of the participants or the conduct of the study;
d) Any changes in your source of funding or new funding to a previously unfunded project.

We wish you success with your research.

Approved:

Brian Roy, Chair
Bioscience Research Ethics Board

Note: Brock University is accountable for the research carried out in its own jurisdiction or under its auspices and may refuse certain research even though the REB has found it ethically acceptable.

If research participants are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and clearance of those facilities or institutions are obtained and filed with the REB prior to the initiation of research at that site.

APPENDIX B – UNIVERSITY OF BRITISH COLUMBIA ETHICS CLEARANCE

The University of British Columbia
Office of Research (Services) Ethics
Clinical Research Ethics Board – Room 210, 828 West 10th Avenue, Vancouver, BC V5Z 1L8

ETHICS CERTIFICATE OF FULL BOARD APPROVAL: RENEWAL WITH AMENDMENTS TO THE STUDY

PRINCIPAL INVESTIGATOR:	DEPARTMENT:	UBC CREB NUMBER:
Mark G Carpenter	UBC/Education/School of Kinesiology	H06-70316

INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT:

Institution	Site
UBC	Vancouver (excludes UBC Hospital)

Other locations where the research will be conducted:
N/A

CO-INVESTIGATOR(S):
Bastiaan Bloem
J.Timothy Inglis
Justin R. Davis
Allan Adkin
Adam Campbell
Taylor Cleworth
Romeo Chua
Eduardo N. Naranjo
Jean-Sébastien Blouin
Brian C. Horslen

SPONSORING AGENCIES:
- Natural Sciences and Engineering Research Council of Canada (NSERC) - "Central and peripheral mechanisms contributing to human balance control"

PROJECT TITLE:
Central and peripheral mechanisms contributing to human balance control

The current UBC CREB approval for this study expires: June 11, 2014

AMENDMENTS BELOW REVIEWED AT REB FULL BOARD MEETING DATE:
June 11, 2013

AMENDMENT(S):

AMENDMENT APPROVAL DATE:
June 17, 2013

Document Name	Version	Date
Protocol:		
Amended Research Protocol -may 2013	Version 7	May 23, 2013
Consent Forms:		
Consent form-substudy2-ExpGroup3-revised	Version 11	June 13, 2013
Consent form-substudy3-ExpGroup2-revised	Version 9	May 23, 2013
Questionnaire, Questionnaire Cover Letter, Tests:		
Previous experience questionnaire	Version 1	June 13, 2013
Domain Specific Risk Taking Scale	Version 1	June 13, 2013
State version of the Movement Specific Reinvestment Scale	Version 1	June 13, 2013
Attention Focus Quesitonnaire	Version 1	June 13, 2013

CERTIFICATION:
In respect of clinical trials:
1. The membership of this Research Ethics Board complies with the membership requirements for Research Ethics Boards defined in Division 5 of the Food and Drug Regulations.
2. The Research Ethics Board carries out its functions in a manner consistent with Good Clinical Practices.
3. This Research Ethics Board has reviewed and approved the clinical trial protocol and informed consent form for the trial which is to be conducted by the qualified investigator named above at the specified clinical trial site. This approval and the views of this Research Ethics Board have been documented in writing.

The UBC Clinical Research Ethics Board has reviewed the documentation for the above named project. The research study, as presented in the documentation, was found to be acceptable on ethical grounds for research involving human subjects and was approved for renewal by the UBC Clinical Research Ethics Board.

Approval of the Clinical Research Ethics Board by one of:

Dr. Peter Loewen, Chair
Dr. Stephen Hoption Cann, Associate Chair

APPENDIX C – TRAIT FORM OF THE STATE TRAIT ANXIETY INVENTORY

Directions: A number of statements which people have used to describe themselves are given below. Read each statement and then place the appropriate number to the right of the statement to indicate how you *generally* feel.

1= Almost Never
2= Sometimes
3= Often
4= Almost Always

1. I feel pleasant ______
2. I feel nervous and restless ______
3. I feel satisfied with myself ______
4. I wish I could be as happy as others seem to be ______
5. I feel like a failure ______
6. I feel rested ______
7. I am “calm, cool, and collected” ______
8. I feel that difficulties are piling up such that I cannot overcome them ______
9. I worry too much over something that really doesn’t matter ______
10. I am happy. ______
11. I have disturbing thoughts. ______
12. I lack self-confidence. ______
13. I feel secure. ______
14. I make decisions easily. ______
15. I feel inadequate. ______
16. I am content. ______
17. Some unimportant thought runs through my mind and bothers me. ______
18. I take disappointments so keenly that I can’t put them out of my mind. ______
19. I am a steady person. ______
20. I get in a state of tension or turmoil as I think over my recent concerns and failures. ______

APPENDIX D – TRAIT VERSION OF THE MOVEMENT SPECIFIC REINVESTMENT SCALE

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 E – RISK TAKING FORM OF THE DOMAIN SPECIFIC RISK-TAKING SCALE

For each of the following statements, please indicate the likelihood that you would engage in the described activity or behaviour if you were to find yourself in that situation. Provide a rating from *"Extremely Unlikely"* to *"Extremely Likely"* using the following scale:

1	2	3	4	5	6	7
extremely unlikely	moderately unlikely	somewhat unlikely	not sure	somewhat likely	moderately likely	extremely likely

1. Admitting that your tastes are different from those of a friend _____
2. Going camping in the wilderness _____
3. Betting a day's income at the horse _____
4. Investing 10% of your annual income in a moderate growth mutual fund _____
5. Drinking heavily at a social event _____
6. Taking some questionable deduction on your income tax return _____
7. Disagreeing with an authority figure on a major issue _____
8. Betting a day's income at a high-stake poker game _____
9. Having an affair with a married man/woman _____
10. Passing off somebody else's work as your own _____
11. Going down a ski run that is beyond your ability _____
12. Investing 5% of your annual income in a very speculative stock _____
13. Going whitewater rafting at high water in the spring _____
14. Betting a day's income on the outcome of a sporting event _____
15. Engaging in unprotected sex _____
16. Revealing a friend's secret to someone else _____
17. Driving a car without wearing a seatbelt _____
18. Investing 10% of your annual income in a new business venture _____
19. Taking a skydiving class _____
20. Riding a motorcycle without a helmet _____
21. Choosing a career that you truly enjoy over a more secure one _____
22. Speaking your mind about an unpopular issue in a meeting at work _____

23. Sunbathing without sunscreen _____

24. Bungee jumping off a tall bridge _____

25. Piloting a small plane _____

26. Walking home alone at night in a unsafe area of town _____

27. Moving to a city far away from a your extended family _____

28. Starting a new career in your mid-thirties _____

29. Leaving your young children alone at home while running an errand _____

30. Not returning a wallet you found that contains $200 _____

APPENDIX F – PREVIOUS EXPERIENCE AT HEIGHT QUESTIONNAIRE

Individuals engage in a number of activities that involve being elevated or suspended various distances above ground level for both recreational and occupational purposes. Such activities include, but are not limited to: rock climbing, platform diving, working on scaffolding, sky diving, cleaning windows of skyscraper, paragliding, working on rooftops...

Using the scale below, please indicate how often you engage in activities that involve being exposed to heights.

1	2	3	4	5	6	7	8	9
never	very rarely	rarely	not often	somewhat often	moderately often	often	very often	everyday

APPENDIX G – BALANCE CONFIDENCE QUESTIONNAIRE

Subject Code: _______ Surface Height: _______

1. Please use the following scale to rate how confident you are that you can maintain your balance and avoid a fall during the balance task:

0……10……20……30……40……50……60……70……80…..90……100

I do not feel confident at all	**I feel moderately confident**	**I feel completely confident**

0 10 20 30 40 50 60 70 80 90 100

APPENDIX H – PERCEIVED FEAR OF FALLING QUESTIONNAIRE

Subject Code:__________________ Surface Height:____________

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

0……10……20……30……40……50……60……70……80…..90……100

I did not feel fearful at all	**I felt moderately fearful**	**I felt completely fearful**

0 10 20 30 40 50 60 70 80 90 100

APPENDIX I – PERCEIVED ANXIETY QUESTIONNAIRE

Subject Code:_________________ Surface Height:___________

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

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 J – STATE VERSION OF THE MOVEMENT SPECIFIC REINVESTMENT SCALE

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 was always trying to figure out why my actions failed **<u>during this task at this height</u>**.

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

2. I reflected about my movement a lot **<u>during this task at this height</u>**.

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

3. I was always trying to think about my movements when I carry them out **<u>during this task at this height</u>**.

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

4. I was self-conscious about the way I looked **<u>during this task at this height</u>**.

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

5. I was aware of the way my mind and body worked **<u>during this task at this height</u>**.

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

6. I was concerned about my style of moving **<u>during this task at this height</u>**.

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

7. I was concerned about what people thought about me **<u>during this task at this height</u>**.

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