Understanding the Influence of Fear of Falling on Clinical Balance Control - Efforts in Fall Prediction and Prevention

by

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AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Introduction: A review of the literature shows that standard clinical balance measures do not adequately predict fall risk in community-dwelling older individuals. There is significant evidence demonstrating the interactions of fear, anxiety, and confidence with the control of standing posture. Little is known however about the nature of this relationship under more challenging balance conditions, particularly in the elderly. The primary purpose of this work was to evaluate the relationship between fear of falling, clinical balance measures and fall-risk.

Methods: Three studies were conducted evaluating the effects of postural threat (manipulated by support surface elevation) and/or cognitive loading (working memory secondary task) on clinical balance performance and task-specific psychological measures. Predictive and construct validity as well as test-retest reliability was evaluated for measures used to assess fear of falling and related psychological constructs .

Results: Postural threat resulted in reduced balance confidence and perceived stability as well as increased state anxiety and fear of falling. These changes were significantly correlated to decrements in performance of clinical balance tasks. Neither standard clinical scales of balance and mobility nor generalized psychological measures, alone or in combination, could predict falls in community-dwelling elderly. However, combined scores on selected challenging clinical balance tasks could significantly predict falls. Furthermore, improved predictive precision resulted from having these tasks performed under combined postural threat and cognitive loading. Finally, the inclusion of task-specific psychological measures resulted in further improvements to predictive precision. Psychological measures demonstrated fair to excellent test-retest reliability in both healthy young and independent-living older individuals.

Conclusions: Clinical balance tasks performed under more challenging conditions likely better reflect everyday experiences in which a fall is likely to occur. Incorporating easy-to-administer task-specific psychological evaluations and self-reported health estimates with clinical balance assessments might improve the likelihood of correctly identifying community-dwelling individuals at risk for falls. Improved estimates of fall-risk may lead to a reduction in the number of falls experienced in this population, thereby reducing the significant burden of fall-related hospitalizations, treatments and rehabilitation on the individual, families and health care system.

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Dedication

This body of work is dedicated to my family.

To my parents for always believing in me and pushing me to achieve. To dad for sharing mom, and to mom for the countless hours of babysitting - without these sacrifices, completion of this work would not have been possible.

To my brothers for accepting their nerdy, eternal-student sister. Special thanks to Aaron and Waylan for helping me with on-campus dealings over the years.

To Kera, my pride and joy. Without your smiling face and laughing eyes, the process and all the accompanying challenges would simply have been too much – thank you for getting mommy through the tough times by just being your incredibly adorable self.

To Kyla, our wonderful new addition. Thank you for being a patient baby and for sharing me with academia. You deserved much more from me in your first year of life, but I promise to make it up to you in the years to come!

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Chapter 1

Falls in the Elderly: Costs, Risk Factors and Causes
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1.1 Falls in the Elderly

Falls in the elderly continue to be a concern for researchers and health care professionals alike. Statistics from the Canadian Institute of Health Information (CIHI) show that in 2002, injuries accounted for nearly 10% of the hospital admissions in individuals over the age of 65. Unintended falls accounted for 84% of those injury-related admissions, with the proportion of injuries related to falls increasing with advancing age (figures 1 and 2) [1].

Figure 1.1: 2002 Injury-related hospital admissions in individuals over 65 in Canada

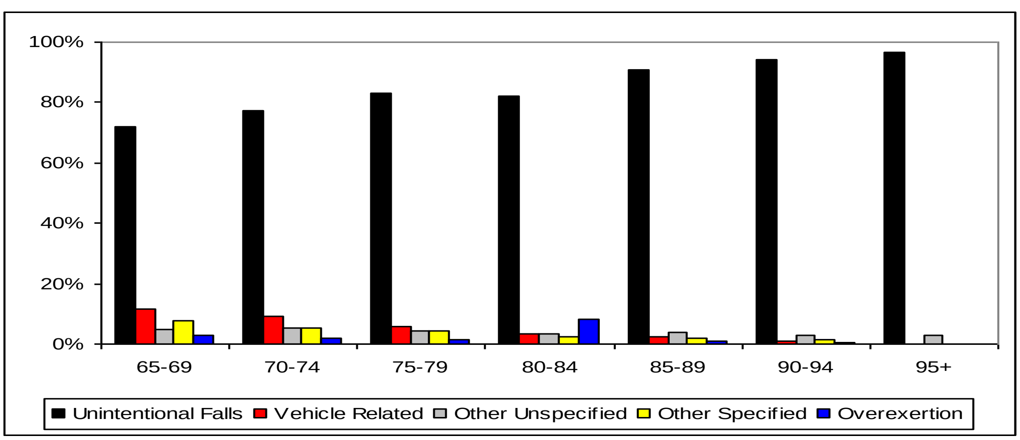

Figure 1.2: 2002 Injury-related hospital admissions in individuals over 65 in Canada by age

The burden of falls in the elderly on the individual, family members, hired caregivers, and healthcare system is also significantly problematic. SMARTRISK is a non-profit organization dedicated to injury prevention and is partnered with the public health agency of Canada, provincial health agencies as well as injury research organizations. SMARTRISK and CIHI estimate that falls in the elderly account for 1/3 of the in-hospital deaths among those admitted for injuries, 40% of the fall-related hospitalizations are a result of a hip fracture, and 7% of hip fractures result in death[1,2]. For those individuals discharged from hospital care, loss of mobility and the resultant changes to activities of daily living can lead to a decline in physical function and independent living. Experiencing a fall can also lead to fear of falling (FOF) and that fear of falling can result in a fall – This bi-directional relationship results in a harmful "spiralling risk of falls, fear of falling, and functional decline"[3]. In 1995, falls in the elderly lead to $980 million in direct health care costs in Canada, and $390 million in Ontario alone. It was estimated that a 20% reduction of hospitalizations due to falls could save $138 million annually nationwide[2]. The 2009 report published by the same organization showed that falls in the elderly in 2004 lead to 2.0 billion dollars in direct health care costs in Canada, 42% of the total injury-related costs. Accounting for a liberal inflation rate of 3% per annum, the 1995 statistics would have suggested that the direct health care costs for treatment of falls in 2004 would have been 1.28 billion dollars. Given the discrepancy between the projected and actual 2004 costs, the burden on the health care system is growing at an alarming rate.

Given the steady increase in number of falls [4] and the growing costs incurred as a result, a significant amount of research has been conducted aimed at understanding the causes of and risk factors associated with falls in the elderly. Important individual risk factors for falls relating to the aging process include muscle weakness, balance/gait/visual deficits, limited mobility, cognitive impairment, impaired functional status (due to chronic disease), and postural hypotension [5,6]. Other risk factors include exposure to hazardous environments, risk-taking behaviours, and use of psychotropic medications [4]. Horak (2006) highlighted the important resources required for postural stability including biomechanical constraints, movement strategies, sensory strategies, orientation in space, control of dynamics, and cognitive processing. It was suggested that disorders affecting any of these resources might be the cause of increased falls in the elderly [7]. There is no mention in this model however, of the psychological factors that may result in changes to postural stability via their influence on the neurophysiological mechanisms controlling balance. Psychological factors related to changes in postural control include increased anxiety, reduced balance confidence, and a generalized fear of falling[8-19].

1.2 The Influence of Psychological Factors on Postural Control

1.2.1 Anxiety, Confidence and Fear of Falling: Influence on Postural Performance

Anxiety can be divided into two categories: trait and state[20]. The distinction shows that trait anxiety is a general tendency towards worry or anxiety, assessed by asking questions such as "are you often worried", while state anxiety can vary from minute to minute and task to task and is assessed by asking questions such as "are you worried about your performance now" [21]. Clinical observations dating back to the middle of the 20th century y have shown interesting correlations between balance control and anxiety measures such that patients with diagnosed psychological disorders (e.g. panic disorder and agoraphobia) also demonstrate balance system dysfunction (e.g. vestibular abnormalities and postural instability), and an unusually high number of adult patients undergoing specialized treatment for balance disorders (e.g. vertigo and peripheral vestibulopathy) are also diagnosed with trait anxiety disorders [10]. Furthermore, examining balance control in children diagnosed with general and separation anxiety found that these children demonstrated more balance mistakes (e.g. use of external supports to regain balance) and slower performance on timed tasks, as compared to control children[22]. Studies using animals genetically and pharmacologically prepared for differing levels of anxiety related behaviours[12] show that mice with both high and low levels of trait anxiety demonstrate degraded balance control compared to control mice as measured by number of falls from a beam. Postural strategies also differed between these mice such that high trait anxiety mice exhibited a crouching behaviour keeping their trunks and tails low and close to the beam, while the behaviour of low trait anxiety mice was closer to that of control mice.

A number of studies employing healthy young and elderly adults have shown that postural threat and state anxiety can also affect standing postural control[14,23-27]. At high levels of postural threat with eyes open, participants report feeling more anxious and also demonstrate a tighter control of postural sway through increases in mean power frequency and decreases in the variability of area and range of center of pressure movements. This relationship is scaled such that low levels of postural threat show only small changes to balance measures, medium levels of postural threat show greater changes in balance measures, and the highest level of postural threat shows the largest modifications to balance measures. Research has also found that changes to mood states, particularly anxiety, were significantly and negatively correlated to standing postural control, as measured by sensory organization tests and latencies of balance recovery following perturbation[11]. Furthermore, increased anxiety induced by postural threat results in changes to reactive postural control, specifically affecting long-latency reflexes between 120-220ms. It was suggested that increased anxiety resulted in changes to the gain of postural responses[28]. It is therefore apparent, that trait and state anxiety can affect postural control measures.

Reductions in balance confidence also relate to changes in measures of balance control[14-16]. In both young and elderly individuals, postural threat resulted in concomitant reductions in balance confidence and mean center of pressure position[14]. Hatch and colleagues (2003) found a significant and strong correlation between balance scores (Berg Balance Scale and Timed-Up-and-Go) and confidence ratings (Activities-Specific Balance Confidence scale or ABC) in community-dwelling elderly individuals[16]. Tsang and Hui-Chan (2005) found that ratings of confidence, as measured by the ABC, in older adults were significantly and negatively correlated to body sway angles during performance of one-leg stance tests[15].

Fear of falling (FOF) also affects measures of postural control[17-19]. Maki, Holliday, and Topper (1991) found that fear of falling related to poorer performance of spontaneous-sway tests and one-leg stance tests[19]. Binda and colleagues (2003) found that elderly individuals who reported a fear of falling showed reductions in their limits of stability by reduced centre of pressure excursions and poorer weight shifting abilities[17]. Fear of falling in these individuals was also correlated to decreases in balance confidence. Rosen, Sunnerhagen, and Kreuter (2005) found that stroke patients who reported a fear of falling demonstrated degradations in standing balance performance[18].

1.2.2 Neurophysiological Correlates of Psychological Measures and Balance Control

As previously delineated, balance and psychological disorders frequently occur concomitantly. Following the notion that these must be inherently linked to result in such comorbidity, it has been proposed that specific neural circuitry is shared by vestibular, autonomic and emotional processing systems [8] and ongoing research is improving our understanding of the connectivity[29-33]. With the advent of improved anatomical tracing tools, a great deal of information has been gleaned about the possible neural substrates linking balance control and psychological measures associated with fear and avoidance responses. Three integrated neural circuits have been identified – The parabrachial nucleus network, the coeruleo-vestibular network, and the serotonergic network.

The parabrachial nucleus network consists of the parabrachial nucleus, located in the brainstem, and its reciprocal connections with the amygdala, limbic cortex and hypothalamus, structures thought to be involved in avoidance conditioning, anxiety, and conditioned fear. The parabrachial nucleus receives input from vestibular and solitary nuclei, both of which also affect reflexes (postural/visual stabilization and parasympathetic/sympathetic autonomic, respectively) and send ascending neurons to the cortex.

The Coeruleo-Vestibular network illustrates another set of neural connections between psychological/behavioural centers and those controlling balance and posture. The locus coeruleus, located in the pons, receives input from the parabrachial nucleus network, amygdala, limbic structures, prefrontal cortex and central vestibular processing pathways, and in turn sends output to the lateral vestibular nucleus (LVN) of the brainstem and structures of the aforementioned parabrachial nucleus network. The LVN nucleus affects postural control through the vestibulo-spinal tract and also affects vestibulo-occular reflexes important for gaze stabilization during movement.

The third network linking psychological factors and balance control is known as the serotonergic network. The serotonergic raphe nuclei of the brainstem receive information from the locus coeruleus (arousal), solitary nucleus (vagal afferents relaying information about the state of internal organs such as heart rate and blood pressure), vestibular nuclei (postural control) and hypothalamus (contextual anxiety and emotion). The raphe nuclei project in turn to the amygdala (danger detection and conditioned learning), hypothalamus, limbic cortex, spinal cord (pain processing and thermoregulation), and vestibular nuclei.

The parabrachial network can therefore be viewed as the gateway for ascending visceral and vestibular information to the amygdala, hypothalamus, basal forebrain, and cortical regions. The coeruleo-vestibular network is thought to modulate vestibular related motor performance with changes in alertness, vigilance and arousal; and the serotonergic "projections from the raphe nuclei are likely to coactivate major structures in the vestibulo-parabrachial pathways"[9].

1.3 Purpose

Evidently, there is an abundance of behavioural and neurophysiological evidence demonstrating the interactions of psychological measures and balance control. Much of the research to date in human participants however has been correlational or observational in nature. The vast majority of those studies that have attempted to empirically evaluate this relationship, by manipulating levels of fear, anxiety and/or arousal through postural threat, have been restricted to measures of standing balance control and as a result little is known about the nature of the associations between psychological measures and balance control under more challenging balance conditions, particularly in elderly populations. Furthermore, little attention has been devoted to incorporating this knowledge into fall risk assessment, prevention and rehabilitation programs.

Three studies were conducted with the global purpose of better understanding the influence of fear of falling, and related psychological measures, on clinical measures of balance control in young and elderly individuals. The first study evaluated this relationship in 31 healthy young individuals. The second study is reported in two parts: 1) the influence of postural threat and cognitive loading on clinical balance performance in community-dwelling older adults and 2) fall prediction in this same group. Given the indisputable multifactorial nature of causes in falls and fall-risk, various models incorporating clinical balance, psychological and comorbidity scores were evaluated for their ability to predict falls in healthy community-dwelling elderly individuals. A third study was conducted on a separate sample of community-dwelling elderly adults and was focused on evaluating the reliability and validity of psychological measures related to fear of falling. A significant driving force in the design of the studies was clinical utility with an interest in knowledge transfer from laboratory to clinical settings.

Chapter 2

Study 1: Task Specific Measures of Balance Efficacy, Anxiety, and Stability and Their Relationship to Clinical Balance Performance*

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2.1 Introduction

Despite the prevalence of fear of falling, coupled with low balance confidence in older adults[1] and patient populations[2-4], there has been little focus on the impact of such psychological factors on postural control. The majority of research examining the effects of fear and anxiety on balance behavior has been restricted to posturographic measures[5-10], which are not commonly used in clinical settings, in addition to being poorly correlated with patient performance during clinical balance assessments[11-12]. Therefore, it is of value to examine how psychological measures affect performance on tests used in clinical balance assessments; in particular, functional reach and one-leg stance tests, which have shown strong intrarater and interrater reliability[13-15] and potential for predicting falls in elderly patients[16-17].

Fear of falling has commonly been assessed using scales such as the Activities-Specific Balance Confidence scale (ABC)[18]. However, there is evidence that psychological measures relating to gait and balance are task-specific[19], and that self-efficacy and anxiety are separate constructs[20], suggesting that independent evaluation tools for confidence, anxiety, and stability are necessary. Task-specific tools that probe self-efficacy and perceived anxiety have been developed, which are sensitive to changes in postural threat and related to concomitant changes in postural control.[6] However, the reliability of these task-specific measures remains unknown.

In this study, a height-induced postural threat was used to gain insight into the relationship between balance and psychological factors. The use of healthy young adults as participants was the result of minimizing potential confounds related to the aging process. The study's objectives were threefold (1) to determine the effects of postural threat on balance control during quiet stance, functional reach, and one-leg stance tasks; (2) to explore the predictive validity of task-specific questionnaires; and (3) to determine the reliability of these questionnaires over three repeated sessions.

2.2 Methods

2.2.1 Subjects

The subjects were: thirty-one healthy young adults, composed of 18 females (mean ± S.D.: age = 19.94 ± 1.51 years, height = 1.66 ± 0.07 m, mass = 62.06 ± 8.65 kg) and 13 males (mean ± S.D.: age 20.23 ± 1.64 years, height = 1.78 ± 0.08 m, mass = 76.12 ± 12.39 kg) all of whom were volunteer participants. All participants were required to provide written, informed consent in relation to experimental procedures approved by the University of Waterloo's Office of Human Research (OHR # 8509).

2.2.2 Procedure

Participants stood on a portable force platform (AMTI model SMF-4A, 46.4 x 50.3 x 20.0 cm), which was placed on a hydraulic lift (Pentalift model 7P482.5, 20.0 cm high when fully lowered). During each trial, participants stood with their toes aligned to the anterior edge of the force plate, which was aligned to the anterior edge of the hydraulic lift, in order to maintain consistency across tasks and trials, and to ensure a perceived postural threat. A custom wooden surround was positioned around the remaining three sides of the force plate to create a level support surface (122.0 x 122.0 x 20.0 cm), in the event that participants would need to take a step for balance recovery. Two levels of postural threat were utilized in this study: the "low" threat condition (40 cm above ground level) and the “high” threat condition (140 cm above ground level). It is acknowledged that the “low” threat condition was not equivalent to a “no” threat condition, although it was the lowest possible manipulation of threat given the combined height of the lift and force platform.

There exists the possibility that factors such as confidence and anxiety are affected by gender[9]. As such, our participants were first stratified by gender in order to control for this potential confound. Within gender blocks, participants were randomly assigned to begin trials in either the “high” or “low” condition.

Each participant was outfitted with a safety harness, for the completion of six balancing tasks (three balance tasks at two levels of postural threat). The first task, Quiet Stance (QS), required that participants stand with two feet on the force platform, arms at their sides, and eyes open for a period of 60 s. Participants were directed to focus on a target at eye level, located 6 m away. The second task, maximal reach (MR), was a modification of the Functional Reach test. Participants were asked to stand on two feet, arms at their sides with open eyes for approximately 5 s, to then reach out, as far as possible, with the right arm, and to remain static in the reach position for approximately 5 s, and finally to return to upright stance for the remainder of the trial. Data were collected for 30 s. For the third task, one-leg stance (OL), participants were directed to stand on two feet, arms at their sides with eyes open for approximately 5 s, to then lift the right foot from the force platform and balance on the left leg for as long as possible or to a maximum of 30 s. Although there may have been an effect of lower limb dominance, it was decided that all participants were to stand on the left leg in order to maintain consistency between and within participants across tasks and sessions. Data were collected for 35 s. At each level of postural threat balance tasks were performed in the order of QS, MR, and OL. This data collection procedure was repeated, for each participant, in two further testing sessions, for a total of three sessions each.

2.2.3 Data Collection and Analysis

Ground reaction and moment of force signals were collected from the force platform with a sampling frequency of 60 Hz from which center of pressure (COP) measures were calculated. Changes in the anterior-posterior (AP) direction and medial-lateral (ML) directions for all QS trials were examined, and low-pass filtered with a cut-off frequency of 5 Hz using a dual-pass second-order Butterworth filter. The mean-power-frequency (MPF) and root-mean-square (RMS) were calculated after the bias, or mean position (MP), was calculated and removed from the filtered COP signal.

For MR trials, maximum anterior displacement of the COP was calculated (max-reach). For OL trials, a 'zero' reference point was assigned where COP had been shifted significantly and remained so for a minimum of 1500 ms. The dependent variable (duration of one-leg stance) was calculated from this point until the COP had shifted back to the baseline or, alternatively, until the end of the trial. In other words, the duration of the one-leg stance was calculated as the total time from when the right foot was lifted from the force platform until it was put back onto or touched the platform. Accordingly, there was an attempt to bridge the gap between research and rehabilitation methods by using both established laboratory measures (COP measures derived from force plate data) and clinical measures (duration of one-leg stance and maximal/functional reach).

For each of the six balancing tasks, participants reported on their perceived balance efficacy, stability, and anxiety measures[6]. Prior to the series of balance tasks, participants were asked to complete two balance-efficacy questionnaires addressing two issues: the first was overall confidence (task-specific balance efficacy or TSBE); the second was contributors to overall confidence, i.e., four measures of coping efficacy evaluating the participants' ability to avoid a fall (AF), maintain concentration (MC), overcome worry (OW), and reduce anxiety (RA).

Following the completion of each individual balance task, perceived anxiety ratings were obtained using a 16-item, 9-point scale. The total anxiety score was calculated by summing the ratings for each of the 16 questions, determining state anxiety (SA) for each task at each level of postural threat. Perceived stability ratings (S) were obtained upon the completion of the series of balancing tasks, for which participants rated perceived stability for each individual task. See Supplementary Data for additional questionnaire detail.

An estimate of physiological anxiety (PA) was obtained through measurement of galvanic skin response (GSR)[21]. The skin resistance signal was collected with a sampling frequency of 60 Hz and low-pass filtered at 5 Hz using a dual-pass second order Butterworth filter. Mean conductance values (μMhos) were calculated for each balance task at each level of postural threat.

Multivariate repeated measures analyses of variance (MANOVA) were performed to examine the within-subject effects of postural threat ("high" vs. "low") on measures of postural control (AP and ML RMS, MPF, and MP) during quiet stance (α=0.05). Additionally, univariate repeated measures analyses of variance (ANOVA) were performed to determine the within-subject effect of postural threat on the measures of max-reach during MR and duration of OL ($\alpha=0.05$). MANOVAs were also performed to examine the within-subject effects of postural threat ("high" vs. "low") and task (QS, MR, and OL) on perceived balance efficacy (task-specific balance efficacy and four coping-efficacy measures), ratings of stability, and measures of anxiety (SA and PA) ($\alpha=0.05$). Significant main effects were further examined through within-subject univariate ANOVA ($\alpha=0.05$) and post-hoc tests with Bonferroni corrections. The above-mentioned statistics were performed on results from the first testing session only, in order to control for the potential confounds of learning and testing procedure familiarization.

Percentage differences between the "high" and "low" threats were calculated for both postural and psychological measures. Correlation analyses were then performed to examine the relationships between postural and psychological measures (two-tailed Pearson values). Intraclass correlation coefficients were calculated from mean squares developed in the repeated measures ANOVAs (2-way fixed effects model) to determine test-retest reliability for each dependent measure in each balance task, across three-repeated observations[22]. Moderate reliability was considered to range from 0.50-0.79, while strong reliability ranged from 0.80-1.0.

2.3 Results

2.3.1 Postural Changes

MANOVAs for postural measures during the quiet stance revealed a significant main effect of postural threat (Wilks'=0.56, $F_{(6,25)}$=3.28, p=0.02). Univariate ANOVAs revealed significant effects for COP measures of AP-RMS, AP-MPF, and AP-MP: ($F_{(1,30)}$=13.66, p=0.001), ($F_{(1,30)}$=6.03, p=0.02), and ($F_{(1,30)}$=5.86, p=0.02), respectively. As shown in Figure 2.1A, the AP-MPF was significantly increased (18.26%) in the high compared to the low threat, while the AP-RMS and AP-MP were both significantly reduced (21.01% and 5.38%, respectively) during the "high" compared to the "low" threat. No significant effect of postural threat was found for the medial-lateral measures of postural control during quiet stance.

A significant effect of postural threat was also found on max-reach during MR and on duration of OL ($F_{(1,29)}$=63.84, p<0.0001 and $F_{(1,30)}$=4.06, p=0.05, respectively). As shown in Figure 2.1B, max-reach was significantly reduced (10.40%) in the "high" compared to the "low" threat. Similarly, Figure 2.1C shows that the duration of OL was significantly reduced (11.98%) in the "high" compared to the "low" threat.

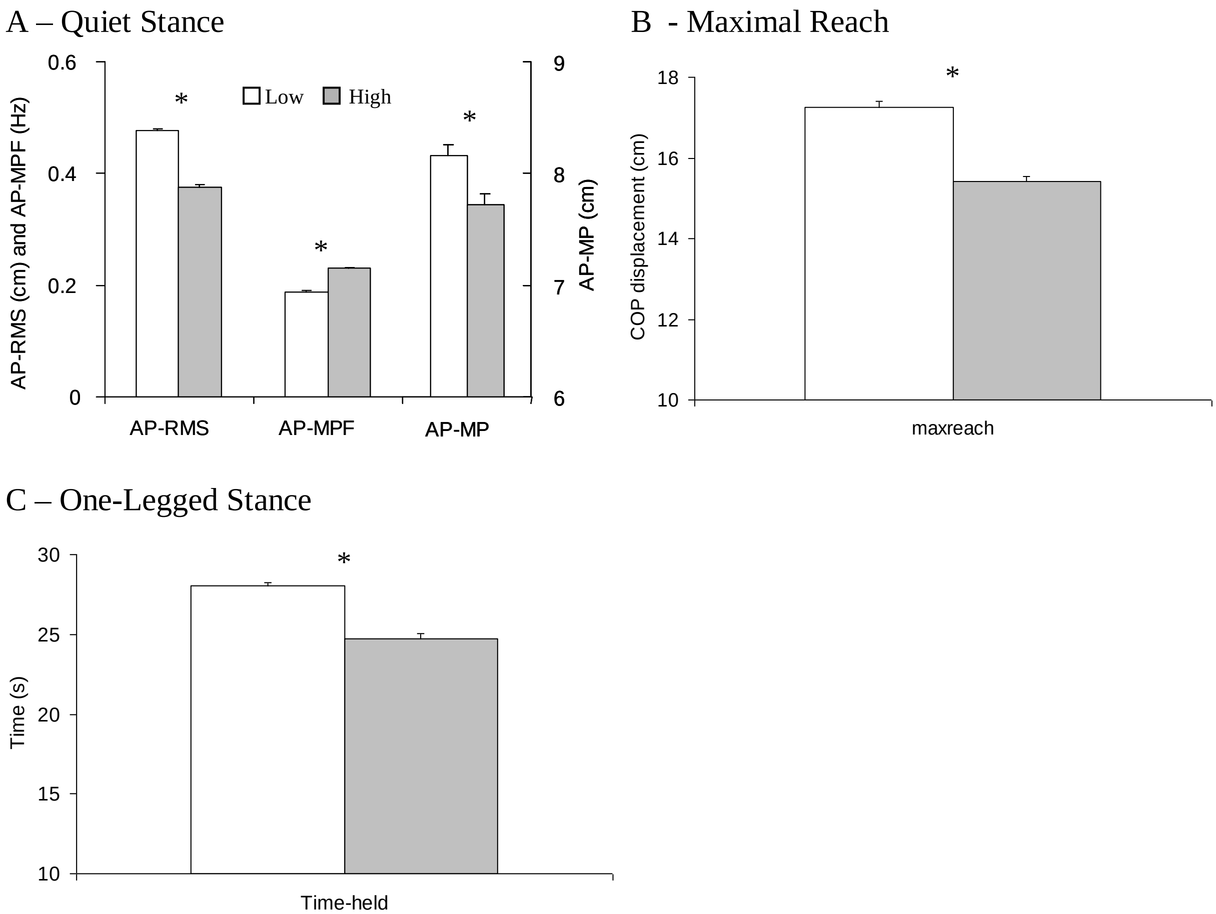

Figure 2.1: Main effect of postural threat on measures of postural control *significant difference.

2.3.2 Psychological Changes

MANOVAs for measures of balance efficacy revealed significant main effects of postural threat (Wilks'=0.23, $F(5,24)=18.87$, $p<0.0001$) and task (Wilks'=0.22, $F(10,104)=11.87$, $p<0.0001$). Univariate ANOVAs revealed significant effects of postural threat for the measures of overall confidence (task-specific-balance efficacy, $F(1,27)=51.10$, $p<0.0001$), as well as each of the four measures of coping efficacy contributing to overall confidence: AF ($F(1,27)=28.03$, $p<0.0001$), MC ($F(1,27)=25.07$, $p<0.0001$), OW ($F(1,27)=39.55$, $p<0.0001$), and RA ($F(1,27)=42.921$, $p<0.0001$). As illustrated in Figure 2.2A, all measures of balance efficacy were found to be significantly reduced in the "high" compared to the "low" threat condition. Univariate ANOVAs also revealed a significant main effect of task difficulty for the measures of overall confidence (task-specific balance efficacy, $F(2,54)=44.21$, $p<0.0001$), as well as each of the four measures of coping efficacy contributing to overall confidence: AF ($F(2,54)=50.15$, $p<0.0001$), MC ($F(2,54)=41.97$, $p<0.0001$), OW ($F(2,54)=33.80$, $p<0.0001$), and RA ($F(2,54)=52.19$, $p<0.0001$). As shown in Figure 2.2B, balance efficacy decreased with increasing task difficulty: all efficacy measures were significantly reduced during the performance of OL compared to QS and MR, and reduced during MR compared to QS.

Ratings of perceived stability were significantly influenced by main effects of postural threat ($F(1,27)=18.13$, $p<0.0001$) and task ($F(2,54)=43.78$, $p<0.0001$). The main effect of postural threat suggests that, independent of task, participants felt more stable (14.06%) in the "low" threat compared to the "high" threat condition (rightmost bar on Figure 2.2A). Furthermore, ratings of stability and task difficulty were inversely related: participants reported feeling more stable during QS as compared to MR and more stable during MR than OL (Figure 2.2B).

MANOVAs for state and physiological anxiety revealed significant effects of postural threat (Wilks'=0.51, $F(2,27)=13.25$, $p<0.0001$) and task (Wilks'=0.41, $F(4,110)=15.40$, $p<0.0001$). Univariate ANOVAs revealed significant effects of postural threat on both state and physiological anxiety ($F(1,28)=10.28$, $p<0.0001$ and $F(1,28)=23.85$, $p<0.0001$, respectively). As illustrated in Figure 2.3A, both state and physiological anxiety were significantly increased during the "high" compared to the "low" threat condition (23.11% and 12.09%, respectively). Univariate ANOVAs also revealed significant effects of task on both state and physiological anxiety ($F(2,56)=13.08$, $p<0.0001$ and $F(2,56)=25.14$, $p<0.0001$, respectively). As shown in

Figure 2.3B, state anxiety was significantly increased during OL compared to both MR and QS, while physiological anxiety was higher during both OL and MR compared to QS.

A – Postural threat B – Task

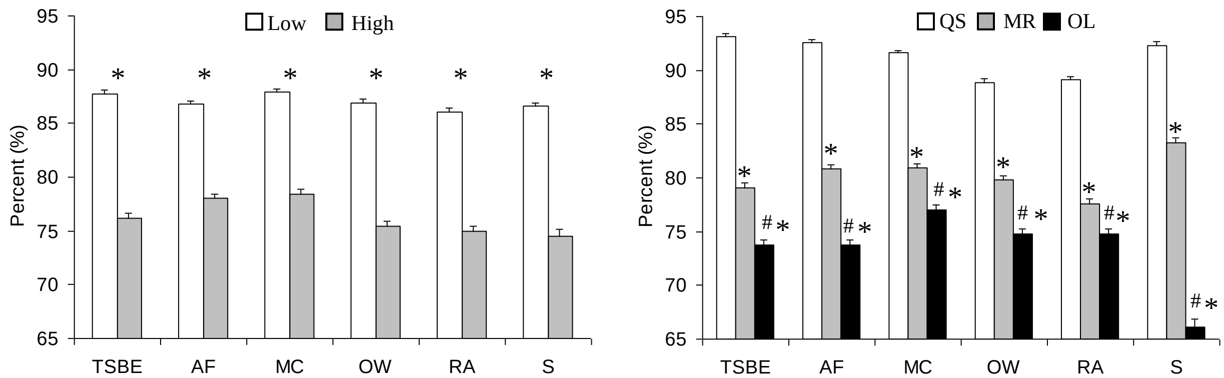

Figure 2.2: Main effects of postural threat and task on psychological measures (A) *significant difference (B) *significantly different from QS, #significantly different from MR.

A – Postural threat B – Task

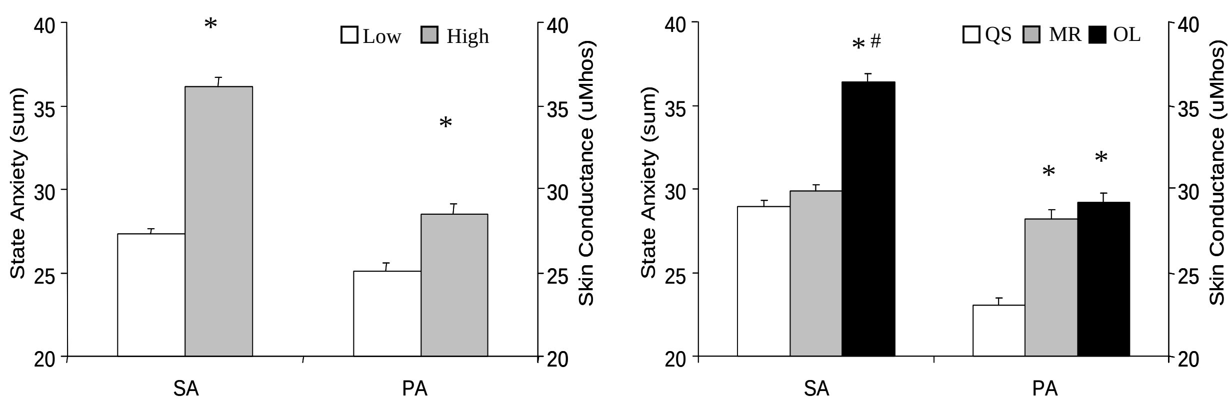

Figure 2.3: Main effects of postural threat and task on state and physiological anxiety (A) *significant difference (B) *significantly different from QS, #significantly different from MR

2.3.3 Correlations between Psychological Measures and Balance Performance

Significant correlations were found between the changes in subjective psychological measures and the change in quantitative postural measures between the "high" and "low" threats (Table 1). Increased overall confidence was significantly associated with reduced AP-MPF during quiet stance as well as increased OL duration. Increased confidence in the ability to avoid a fall and to overcome worry was also found to be significantly associated with OL duration. Additionally, increased confidence in the ability to overcome worry was significantly associated with increased MR. Increased ratings of perceived stability were associated with increased AP-RMS during the quiet stance and increased OL duration. Finally, increased state anxiety was significantly associated with reductions in the OL duration, while no significant correlations were found between postural measures and physiological anxiety.

Table 2.1: Correlations between postural and psychological *Significant correlation

	AP-RMS	AP-MPF	AP-MP	Max-reach	Time-held
Overall Confidence (TSBE)	0.011	-0.396*	0.166	0.044	0.388*
Avoid a Fall Confidence (AF)	0.125	-0.081	0.289	-0.266	0.391*
Maintain Concentration Confidence (MC)	0.121	0.113	0.228	-0.204	0.282
Overcome Worry Confidence (OW)	0.145	-0.003	0.178	-0.421*	0.385*
Reduce Anxiety Confidence (RA)	0.080	-0.009	0.047	-0.147	0.211
Perceived Stability (S)	0.431*	-0.115	0.308	0.037	0.652*
State Anxiety (SA)	-0.307	0.123	-0.088	-0.005	-0.395*

2.3.4 Reliability of Measures Across Repeated Observations

Table 2.2 displays the reliability of dependent measures across repeated observations during the balance tasks of QS, MR, and OL. Moderate reliability was found for AP-RMS and AP-MPF during QS. Strong reliability was shown for AP-MP during QS, max-reach during MR, and duration of OL. Balance efficacy measures demonstrated the highest reliability during OL, followed by MR and QS. The reliability of perceived stability ratings improved with increasing task difficulty. Lastly, measures of anxiety demonstrated strong reliability across all balance tasks.

Table 2.2: Reliability coefficients across repeated observations

	Quiet Stance (QS)	Maximal Reach (MR)	One-legged Stance (OL)
AP-root-mean-square (AP-RMS)	0.66	-	-
AP-mean-power-frequency (AP-MPF)	0.50	-	-
AP-mean-position (AP-MP)	0.89	-	-
Time-held	-	-	0.92
Max-reach	-	0.81	-
Overall Confidence (TSBE)	0.67	0.67	0.86
Avoid a Fall Confidence (AF)	0.68	0.79	0.81
Maintain Concentration Confidence (MC)	0.60	0.77	0.85
Overcome Worry Confidence (OW)	0.59	0.78	0.82
Reduce Anxiety Confidence (RA)	0.77	0.78	0.78
Perceived Stability (S)	0.63	0.79	0.88
Physiological Anxiety (PA)	0.88	0.87	0.87
State Anxiety (SA)	0.83	0.86	0.85

2.4 Discussion

Increased frequency and decreased amplitude of COP displacement were observed during quiet standing in conditions of “high” compared to “low” postural threat, which replicates previous findings[5-6, 8-10]. We have provided new empirical evidence that postural threat also affects measures of clinical balance performance such as one-leg stance and functional reach.

Diminished performance on one-leg stance and functional reach tests has been observed in healthy older adults and patient groups[23-27]. These populations also commonly report a fear of falling[2-4]. Future research should examine the relationship between psychological measures and clinical balance performance in elderly and patient populations.

Changes in psychological measures resulting from height-induced postural threat during quiet standing have been reported in young and older adults[6]. The current study supports these findings, and provides new evidence that balance efficacy, anxiety, and stability can also change as a result of changing task difficulty. As levels of postural threat and task difficulty were increased, ratings of efficacy and stability decreased, while state and physiological anxiety increased. Hence, more challenging balance tasks are likely to reveal the limiting influence of psychological factors on balance performance.

The correlation analyses revealed significant associations between psychological measures and postural control measures, suggesting that questionnaires may be used to predict changes in balance performance. Although the reliability of center of pressure measures during quiet standing varies within the literature[28], our results showing moderate reliability are consistent with the results of previous studies employing similar methodology[29]. The high reliability observed for both the functional reach and one-leg stance was also consistent with previous reports[13-15, 30]. Reliability of balance efficacy and stability measures ranged from 0.59 to 0.88, improving as task difficulty increased. Reliability of state anxiety measures was high and similar to physiological measures of anxiety. Future work should address the validity and reliability of these questionnaires in elderly and patient populations.

2.5 Conclusions

Postural threat can modify not only physical measures of postural control but also psychological measures of perceived efficacy, anxiety, and stability during both quiet standing and more dynamic balance tasks. It is thus recommended that evaluation of psychological factors be incorporated into assessment and rehabilitation programs.

Conflict of interest statement

There are no known conflicts of interest.

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Chapter 3

Study 2 Part 1: The Influence of Postural Threat and Cognitive Loading on Psychological and Clinical Balance Measures in Community-Dwelling Older Individuals

3.1 Introduction

3.1.1 Aging and Clinical Balance Performance

Many researchers have studied the consequences of aging on postural control in order to improve the understanding of the nervous system and the motor control strategies used to maintain upright posture. Cognitive, psychological, neurological, mechanical, and physiological changes occurring with age have been implicated in falls and fall-risk[1-12]. These risk factors, alone or in combination, may result in decrements to clinical measures of balance performance. For example, several studies have reported reductions in forward and lateral reach distances associated with increasing age[13-16]. As compared to young and middle-aged adults, older adults have been reported to take longer to complete the Timed-up-and-Go test[15,17] and scored lower on Berg Balance Scale[17,18]. One-leg and tandem stance performance is also affected by age as revealed by reduced times and changes to posturographic measures such as increased trunk sway and greater variability of ground reaction forces[19-23]. Fear of falling and cognitive processing limitations may further compromise balance control in elderly individuals. However, there is limited published research directly evaluating the effects of postural threat and dual-tasking on clinical measures of balance performance.

3.1.2 Postural Threat and Balance Control

The majority of the research manipulating fear of falling via postural threat has focused on two-legged standing and has shown modifications in balance control and changes to psychological measures in both elderly and young adults[24-31,32,33]. Such changes to standing balance control include increased frequency of sway and reduced sway displacements/variability as well as a change in mean center of pressure position reflecting an effort to move the body's center of mass away from the threat; these changes are scaled to the level of threat presented. Reported modifications of psychological measures in these studies of postural threat include reduced balance confidence and perceived stability as well as increased state anxiety and fear of falling[24,25,27,34].

Two studies also provide evidence that postural threat results in changes to performance of voluntary movements. Adkin et al. (2002) reported effects of postural threat on control of voluntary rise-to-toes movements in young healthy adults. Results demonstrated reductions in magnitude and peak velocities of centre of foot pressure for both anticipatory postural adjustments (APAs) and forward movements, when participants were required to perform the movement on an elevated platform. Magnitude and peak accelerations of the forward center of mass movements (COM) were also significantly decreased as a result of increased postural threat. Furthermore, under conditions of high as compared to low postural threat participants reported reduced balance confidence and perceived stability as well as increased state anxiety[35]. Finally, postural threat had a negative impact on the overall success rate of the voluntary movements; the number of unsuccessful rise to toes trials was significantly increased under conditions of highest threat. Doan and colleagues (2010) evaluated the effects of postural threat on performance of an upper-limb reaching task, wherein participants were required to reach for, grasp and transport a glass of water[36]. In healthy older adults, postural threat resulted in changes upper and lower limb movements and whole body kinematics including: increased relative time-to-peak velocity in arm transport phase, increased shoulder angle range in the reach phase, reduced knee angle range during the reach phase and increased peak velocity of centre of mass during the transport phase.

Effects of postural threat have also been found in responses to perturbations generated by rotational support surfaces. Carpenter et. al (2004) found that unexpected multi-directional perturbations delivered under threatening conditions led to increases in the magnitude of long-latency reflexes (triggered postural responses) in trunk, arm and leg musculature. Moreover, increased postural threat resulted in larger arm movements with earlier onset, reduced COM deviations as well as reduced leg, trunk and pelvis angular displacements[37]. A recently published study by Adkin et al. (2008) evaluated the effects of postural threat on cortical activity following unexpected perturbations delivered to the trunk of standing participants. This work found that postural threat resulted in increased cortical activity in a similar fashion to studies wherein participants were presented with negative emotional stimuli [38]. Both of these studies also report reduced balance confidence and perceived stability as well as increased anxiety resulting from increased postural threat.

A small number of studies have also evaluated the effects of postural threat on measures of gait kinematics. Brown et al.(2002) manipulated the width and height of walkway parameters, and found that both young and older adults reduced walking speed, increased time in double-support and reduced stride length in response to these changes. Moreover, these gait alterations were greatest for conditions where the walkway was both narrowed and elevated, more so for older than younger adults[39]. Gage et al. (2003) employed a dual-task paradigm and found that the aforementioned changes in gait patterns due to postural threat were accompanied by independent reductions in reaction time. The authors suggested that increased anxiety served to increase the cognitive demands of the locomotor task, and reduced the ability of participants to perform a secondary task[40]. Subsequently, McKenzie and Brown (2004) evaluated the effects of postural threat on obstacle avoidance during gait. They reported that both young and older adults demonstrated alterations to obstacle negotiation reflective of more cautious stepping when the walkway was both narrowed and elevated, and that these changes were greater in older than young adults[41]. Delbaere and colleagues (2009) presented a similar study wherein older adults, stratified by physiological falls risk (Physiological Profile Assessment) and concern about falls (Falls Efficacy Scale - International), were required to walk under conditions of postural threat with or without the additional challenge of dimmed lighting. Regardless of stratified groupings, physiological arousal (as indicated by galvanic skin response and blood pressure) was increased only in the condition of combined threat and dimmed lighting, while concern about falls increased as a function of threat. Individuals with higher physiological risk demonstrated gait kinematics indicative of more cautious walking in all conditions compared to those with low physiological risk. Importantly however, individuals with greater concern about falls demonstrated more conservative gait patterns only under conditions of postural threat. In contrast to the aforementioned reports wherein gait changes resulting from threat were deemed protective, these authors suggested that an excess of concern may in fact result in gait instability and a heightened risk of falls[42].

Finally, postural threat has been shown to modify measures of clinical balance performance in healthy young individuals[34], including reduced anterior reach distances and one-leg stance times. However, it is unknown whether postural threat will similarly affect performance of clinical balance measures and related task-specific psychological scores in elderly individuals.

3.1.3 Dual-tasking and Balance Control

Historically, postural control was thought to be an automated process[43]. However, based on the results of dual-tasking studies, it now is well accepted that the maintenance of upright stance it not such a simple task, and that a certain amount of attention is allocated to normal balance control. Under the assumption that attentional resources are finite, tasks performed concurrently require resources to be divided and, as a result, performance decrements are often seen on one or both tasks (postural and/or secondary cognitive). Dual-tasking studies have reported inconsistent effects of dual-tasking on two-legged stance performance: some studies have shown increased sway variability/velocity[44,45] others have shown decreased sway/sway variability/sway area[43-48], and still others have shown no change in postural sway as a result of cognitive load[49-51]. These contradictory findings have been attributed to a number of methodological and interpretive considerations[52], including the selection of cognitive tasks employed across studies[48], the different measures of stability evaluated[53], the varied instructions regarding focus of attentional resources[46] and the diverse populations studied.

Additionally, the question remains as to whether changes to performance in two-legged quiet standing with the addition of a cognitive task are functionally significant. In more challenging postural tasks, the costs of reduced balance control are more severe (e.g. falling) and could lead to more grave consequences in elderly as compared to young populations (e.g. fracture as a result of the fall). Research using a simple reaction-time secondary task suggests that in more challenging balance and locomotor tasks, attentional capacity is taxed to a greater extent than in quiet standing, more so in older than younger adults[54,55], and therefore cognitive loading may have a more detrimental effect to clinical measures of balance control.

Very few studies have examined the influence of dual-tasking on performance of clinical balance tasks. In tandem stance (heal-to-toe), the addition of a cognitive task led to poorer balance control in young to middle aged adults as indicated by increased medial-lateral center of pressure sway[56]. However, other data suggests that total area, medial-lateral and anterior-posterior center of pressure excursions in tandem stance were unaffected by the addition of a cognitive task in young adults[57]. Morris et al (2000) found that tandem stance and one-leg stance times were unaffected by addition of a secondary verbal task in healthy middle-aged and older individuals[58]. In contrast, Vaillant and colleagues (2006) found reduced one-leg stance times with the addition of a secondary arithmetic task (as compared to single-task balance performance), in community-dwelling older women[59].

In everyday life, dual-tasking situations are typical rather than exceptional circumstances[46] and as such, it is important to understand dual-tasking effects on more challenging balance tasks, particularly in older adults. Moreover, in their review of dual-tasking literature with a focus on differentiating elderly fallers and non-fallers, Zijlstra et al. (2008) pointed to evidence suggesting that dual-tasks may have an advantage over single-task balance assessments in predicting future falls [60]. It is currently unclear whether performance of a secondary cognitive task will affect clinical balance measures in community-dwelling older individuals. Furthermore it is unknown whether dual-tasking will influence psychological measures related to fear of falling in this population.

3.1.4 Interaction of Postural Threat and Dual-tasking

One theory of how postural threat influences balance control is that fear of falling causes a shift to more conscious control of upright stance, resulting in decrements to performance analogous to the "paralysis by analysis" idiom in sport psychology. Huffman et al. (2009) found that postural threat resulted in more conscious management of certain aspects of postural control, with significant correlations between variations in conscious motor processing and changes to anterior-posterior mean centre of pressure position[24]. A second theory suggests that postural threat modifies balance control as a result of increasing the attentional and cognitive demands of the balance task. A study by Gage et al. (2003) using a dual-task paradigm, demonstrated that increasing postural threat resulted in a more cautious gait pattern and increased simple probe reaction time, particularly in older adults. Moreover, stride length showed a significant negative correlation with reaction time[40].

Therefore, following the assumption that attentional resources are finite, and the supposition that increased fear of falling due postural threat further taxes attentional capacity and/or allocates a greater proportion of resources to postural tasks, it could be argued that fewer resources will be available for a secondary cognitive task and greater decrements to performance will be evidenced under these circumstances. In other words, one might expect an interaction effect when balance performance is evaluated under dual-task situations with or without the addition of postural threat. Moreover, Craske (2003) suggests that cognitive processing may be increasingly restricted as fearfulness intensifies[61].

3.1.5 Purpose and Hypotheses

The objective of this research is to determine the independent and combined effects of postural threat and cognitive loading on performance measures of clinical balance tests and reports of fear of falling and related psychological measures of balance confidence, perceived stability and state anxiety in elderly individuals. Based on previous literature, it is expected that both postural threat and cognitive loading will result in changes to posturographic measures during two-legged quiet standing reflective of a stiffening strategy[26,27,44,46,48]. Furthermore, diminished performance on clinical balance tasks is expected as a result of both postural threat and cognitive loading[34 56,62]. We also expect changes to psychological measures due to postural threat as in previous research[27,34]. Finally, it was hypothesized that greater decrements to balance and/or cognitive performance would be seen due to postural threat and cognitive loading combined than either independently.

3.2 Methods

3.2.1 Participants

Fifty-two elderly participants aged 66-86 (75.31±5.6) living independently in the community were recruited from the Waterloo Research in Aging Participant Pool (WRAP). Participants were excluded if they were unable to stand or walk unsupported (required an assistive device to maintain upright posture or to ambulate). Twenty males and thirty-two females participated. All procedures were approved by the University of Waterloo Office of Research Ethics (ORE

#14176). For further details about sample size calculations as well as WRAP and recruitment information see appendices W and X .

3.2.2 Procedure

Participants were provided with an information letter outlining the testing procedures, risks and benefits of participation, and the commitment required. The participant received the information letter at least one week in advance to their scheduled participation. Upon arrival at the testing facility, participants were given the opportunity to ask questions of the investigators and invited to sign a consent form if he/she agreed to participate (Appendix B).

While seated, participants were fitted with surface electrodes on thenar and hypothenar eminences for measurement of physiological arousal (Galvanic Skin Response or GSR)[63]. All participants then completed general fear of falling (FOF), balance self-efficacy, and comorbidity/health questionnaires (Appendix C/D).

Balance ability and functional mobility were assessed by two widely used clinical measures: the Berg Balance Scale (BBS) and the Timed-Up-and-Go (TUG) were performed once by each participant and assessed across participants by the same rater using the same instructional set.

Participants were then required to complete 6 balance tasks under 4 types of challenge: each task was performed once in each challenge condition. The 6 balance tasks included: (1) quiet standing with eyes open (EO), (2) quiet standing with eyes closed (EC), (3) one-leg stance (OL), (4) functional reach (FR), (5) tandem standing (TS), and (6) repeated sit-to-stand (STS 5 times). Five of the balance tasks are components of the BBS, while the STS is a timed measure of functional mobility[64]. The 4 challenge conditions included: (1) no challenge (NC), in which balance tasks were performed at floor level, (2) postural challenge (PC), in which balance tasks were performed on an elevated surface, (3) cognitive challenge (CC), in which balance tasks were performed at floor level while silently rehearsing a list of grocery items, and (4) postural and cognitive challenge (P+CC), in which balance tasks were performed on an elevated surface while silently rehearsing a list of grocery items. Presentation of the 4 challenge conditions was randomized to control for order and learning effects. During performance of all balance tasks, participants were asked to visually focus on a target located at a 3m distance from the platform location. For EO, EC, FR and STS tasks participants stood with the toes of both feet aligned with the front edge of the elevated platform. For the OL task, participants began with the toes of both feet aligned with the front edge of the elevated platform, and following a go-signal lifted one foot off the support surface while keeping the other foot in the starting position. For the TS task, participants stood with the toes of the anterior foot aligned with the front edge of the elevated platform. For all tasks the participant was positioned centrally in the medial-lateral span of the platform.

During performance of all balance tasks, two spotters were present to lend support in the event of a fall or loss of balance. This methodology required the participants to perform the balancing tasks without the use of a safety harness in an attempt to gain more externally valid measures of psychological state under the four challenge conditions. Safety harnesses used in previous postural threat studies may have diminished the effects of the threat and resulted in reductions to reported fear of falling. The custom-built platform was constructed of wood (plywood standing surface) and measured 121cm in width to allow for lateral stepping), 243cm in length to allow for backwards stepping and space for a spotter behind the participant and 50cm in height to create a postural threat/challenge. This support surface elevation was chosen to represent the height of an average chair, something that an elderly individual would stand or balance on in everyday situations such as when watering plants or reaching into a high cupboard.

To minimize fatigue, participants were provided with brief rest periods (3-5 minutes) between challenge conditions. During this time, questionnaires were completed that addressed the psychological measures of task-specific balance confidence, perceived stability[34], and fear of falling, as well as condition-specific anxiety. One questionnaire for each psychological measure was completed for each challenge condition (4 questionnaires x 4 conditions); task-specific balance confidence was assessed prior to performance of the balance tasks, while perceived stability, fear of falling and condition-specific anxiety were assessed following completion of the balance tasks. The confidence, stability, and fear of falling questionnaires addressed each of the 6 balance tasks independently, while the anxiety questionnaire required the participants to rate aspects of anxiety averaged across tasks (Appendix C).

3.2.3 Data Collection and Outcome Measures

The BBS (Appendix F) consists of 14 tasks, each rated on a 5-point scale of 0-4, for a total score of 0-56 (higher scores indicative of better performance). For the TUG task, participants began in a seated position, and when given a go signal, stood and walked 3 meters (as determined by a marked position on the floor), turned around and walked back to the chair, returning to a seated position. Time(s) to complete this series was recorded. Participants were directed to walk as quickly but as safely as possible.

Baseline measure of physiological arousal (GSR - Coulbourn Instruments; Whitehall, PA 571-22 Skin Conductance Meter; 0.5V DC excitation, calibration at 10microMhos, range 100mV/microMho) were taken for 60s while the participants were seated quietly, focusing on a target at 3m distance, and prior to performance of any balance task. GSR was also evaluated during performance of the 6 balance tasks in each of the 4 challenge conditions. The skin resistance signal was collected with a sampling frequency of 60 Hz and low-pass filtered at 5 Hz using a dual-pass second order Butterworth filter. Mean conductance values (μMhos) were calculated (inverse of resistance) for each balance task and averaged across tasks within a challenge condition in order to compare the effects of challenge on physiological arousal to perceived/state anxiety as measured by psychological questionnaires.

Trunk sway movements were measured for all balancing tasks using a device attached to the trunk at the level of the lumbar spine (SwayStar®). This device makes use of two digitally based angular velocity transducers to measure upper-body movements at approximately the centre of mass, and is related to an earth-fixed reference frame with a constant baseline drift of approximately 0.01degree per second. Angular velocities and angular deviations (by way of trapezoid integration) are measured/calculated[20] producing the principal dependent measures of (total angular range (deg^2), total velocity range ($(deg/s)^2$), roll angle range (deg), roll velocity range (deg/s), pitch angle range (deg), and pitch velocity range (deg/s)). The SwayStar® was selected for its portability, ease of use and immediate generation of results – all important device characteristics for practicing clinicians.

EO and EC tasks were performed for 60(s) while OL and TS were performed to the individual's ability, to a maximum of 30(s). No direction was given regarding selection of stance leg, although stance leg was consistent within each participant across challenge condition. Distance (cm) reached was the primary outcome measure for FR. The participant was asked to lean forward as far as possible with arms outstretched anteriorly while maintaining full foot to floor contact, and with the whole body acting as an inverted pendulum (no/minimal hip flexion). The STS task was scored based on the time(s) to complete the series of movements. From a seated position on a standard height chair without arm rests, the participant stood and returned to a seated position five times as quickly as possible with arms at their sides.

The secondary cognitive task (cognitive loading) was a list of 12 grocery items that participants were asked to commit to memory and silently rehearse during performance of the postural tasks. More difficult secondary tasks (e.g. digit span, backwards counting) may be biased by level of education[65,66]; therefore, a simple task of strong ecological validity was chosen. Furthermore, Maylor et al. (2001) and Ramenzoni et al. (2007) found that verbal working memory tasks performed during the rehearsal/maintenance stage of cognitive processing significantly affected postural sway velocities/variabilities during two-legged quiet stance[44,45]. Secondary tasks that require a motor response or visual fixation may result in changes to balance outcome measures that are not due to the cognitive demands of the task per se[67]. Therefore a task was selected that required a response action that followed completion of balance data collection. Finally, silent rehearsal was chosen in order to avoid the effects of articulation on balance performance[68]. Following a thirty second seated encoding phase, the list of grocery was returned to the investigator and the participant was asked to mentally/silently rehearse the encoded items while performing the six balancing tasks for that challenge condition. Following completion of the challenge condition participants were asked to write down as many of the rehearsed items from the grocery list as possible within a thirty second period. The number of correctly recalled items was recorded. A different grocery list was presented for each of the cognitive loading conditions, and the order of presentation was randomized across participants relative to the loading condition. Under the single-task balance condition, participants were instructed to maintain balance to the best of their ability. Under the dual-task conditions, participants were told that they would have a dual focus - to maintain their balance and to perform the secondary task, each to the best of their ability. A previous study employing a similar protocol (unpublished data found in Chapter 3) was limited by the lack of a control condition for memory task performance. This protocol therefore included a single-task condition wherein participants were asked to commit to memory as many grocery items as possible (from a different list of twelve items) during a 30(s) period. Following this encoding phase, the list was returned to the investigator and the participant was asked to mentally/silently rehearse the encoded items while in a seated position for a one minute period, which approximated the time required to complete the two balance tasks under dual-task conditions. For each participant, this control condition was completed prior to the four randomized experimental/challenge conditions.

Psychological questionnaires were scored as in previous research; balance confidence was rated on a scale of 0-100% (no confidence – completely confident), state anxiety was a sum of the ratings (9-point scale) on 16 items, and perceived stability was rated on a scale of 0-100% (not stable at all – completely stable)[27,34]. Task-specific FOF was also rated on a scale of 0-100% (not fearful at all – extremely fearful) to provide consistency across single-items questionnaire scales. Somatic, concentration and worry aspects of state anxiety were also derived from subcomponents of the anxiety questionnaire and evaluated for differential effects of postural threat and cognitive loading (see Appendix C).

3.2.4 Data Analyses

Rather than including all possible trunk-sway outcome measures in each within-task analysis and thus reducing the power of association, dependent variables were selected based on the nature of each task independently. For example, it is well known that tandem stance primarily evaluates/taxes medial-lateral control of balance, and therefore trunk roll angle and velocity ranges were selected as the measures of interest. For quiet stance tasks, both trunk pitch and roll angles and velocity ranges were assessed. For the One-Leg Stance and Tandem Stance tasks trunk roll angle and velocity ranges were selected. Trunk pitch angle and velocity ranges were assessed for the Sit-to Stand task. Clinical outcome measures included functional reach distance, One-Leg stance time, Sit-to-Stand time-to-completion.

Task-specific psychological measures of balance confidence, perceived stability, and fear of falling were averaged across tasks for condition-specific analysis. Condition-specific state anxieties as well as component/subscale anxieties (somatic, concentration, worry) were also evaluated.

Multivariate repeated measures analyses of variance were performed to examine the within-task, within-subject effects of postural threat and cognitive load on selected dependent measures of balance control (α=0.05). Significant main effects were further examined through within-task, within-subject univariate ANOVAs (α=0.05). Multivariate repeated measures analysis of variance were also performed to examine the within-subject effects of postural threat and cognitive load on condition-specific psychological measures (α=0.05). Significant main effects were further examined through within-subject univariate ANOVAs (α=0.05).

Differences between the no threat and postural threat conditions were calculated for both clinical performance and psychological measures. Correlation analyses were then performed to examine relationships between the changes in balance control and psychological measures resulting from postural threat (two-tailed Spearman's rho values, alpha=0.05). Correlation analyses were performed to examine the relationship between physiological arousal and state anxiety within challenge conditions (two-tailed Pearson values, alpha=0.05).

Paired t-tests were conducted to compare the number of items correctly recalled in the cognitive loading condition without postural threat to that of the cognitive loading - postural threat combined condition, as well as the number of items recalled from each of the two memory-task lists (α=0.05). One participant was removed from all analyses due to technical difficulties. Statistical analyses were performed using SAS version 9.1.3 and SPSS version 17.0.2.

3.3 Results

Multivariate ANOVAs revealed no significant interaction effects of postural threat and cognitive loading for balance measures within task. Moreover, no significant interaction effects were found in physiological arousal or condition-specific psychological measures of balance confidence, perceived stability, state anxiety and fear of falling.

3.3.1 Effects of Postural Threat

Multivariate analyses revealed significant main effects of postural threat for balance control measures during OL (Wilks'=0.78$_{(3,41)}$3.96,p=0.01), STS (Wilks'=0.71,$F_{(3,46)}$=6.21,p=0.001), and TS (Wilks'=0.88,$F_{(2,46)}$=3.11,p=0.05). No significant effects of postural threat were seen for balance measures during two-legged quiet standing, with or without vision. Condition-specific psychological measures were also affected by postural threat (Wilks'=0.59,$F_{(5,38)}$=5.30,p=0.001). Furthermore, component anxieties were affected by postural threat (Wilks'=0.728,$F_{(3,48)}$=5.98,p=0.002).

Univariate analyses revealed significantly increased roll angle (21%) in TS ($F_{(1,47)}$=5.97,p=0.018) and reduced trunk pitch velocity (5%) in STS ($F_{(1,43)}$=10.15,p=0.003) due to postural threat; roll angle for OL was unchanged (Figure 3.1). Furthermore, significant reductions due to postural threat were found in clinical measures of FR distance (18%) and OL time (16%), along with increased time-to-completion in STS (4%) (($F_{(1,48)}$=85.59,p<0.0001), ($F_{(1,43)}$=12.10,p=0.001), ($F_{(1,48)}$=5.19,p=0.027), respectively) (Figure 3.2).

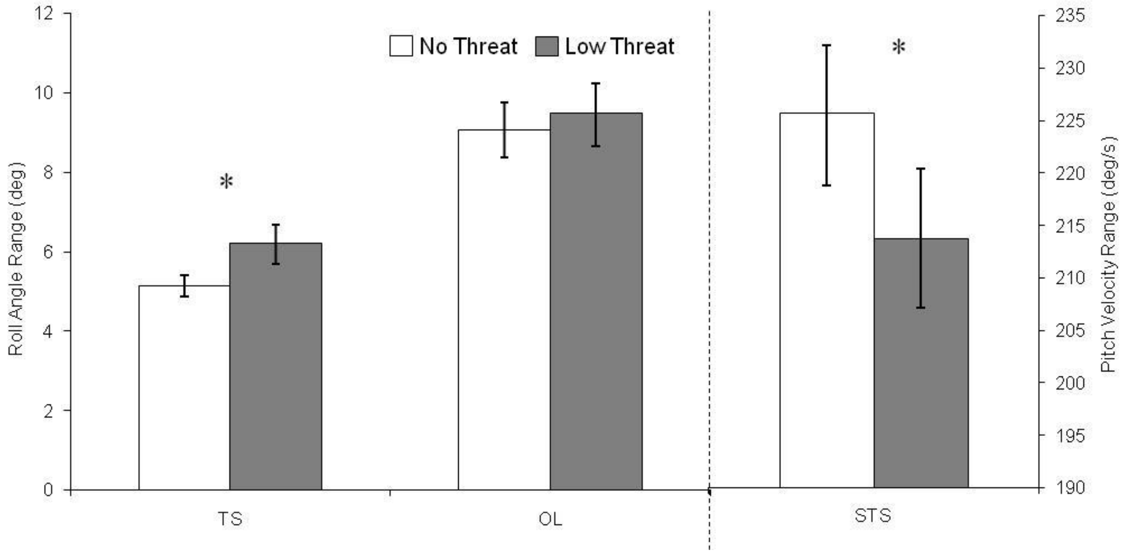


Figure 3.1: Effects of postural threat on trunk sway measures (means and standard error bars). TS=Tandem Stance, OL=One-leg Stance, STS= repeated Sit-to-Stands. *significant at 0.05 Vertical dashed line indicates separation of variables to left and right axes.

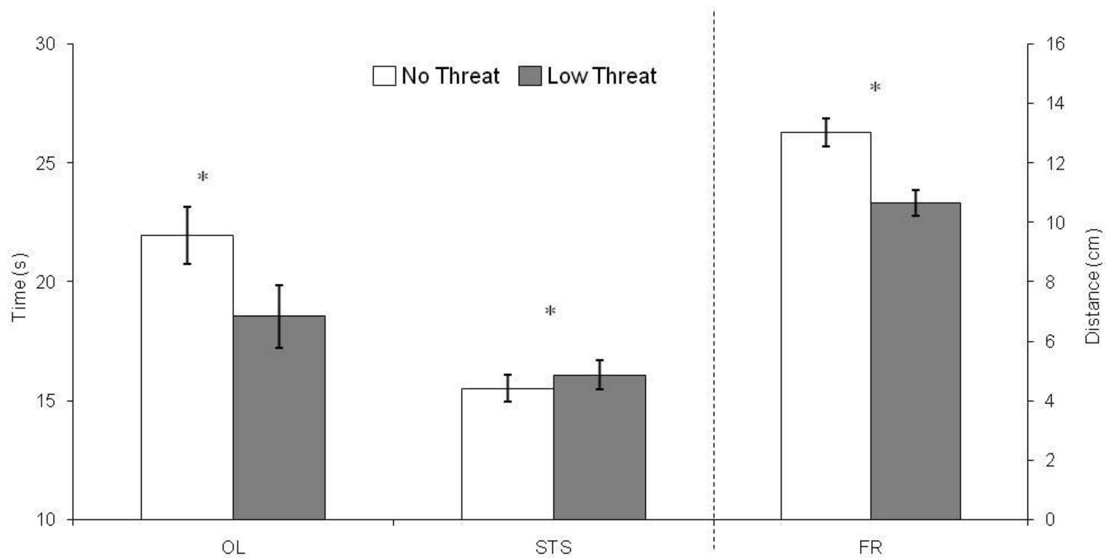


Figure 3.2: Effects of postural threat on clinical measures of balance control (means and standard error bars). OL=One-leg Stance, STS= repeated Sit-to-Stands, FR=functional reach. *significant at 0.05. Vertical dashed line indicates separation of variables to left and right axes.

Univariate analyses revealed significant effects of postural threat for psychological measures shown by reductions in balance confidence (10%) ($F_{(1,42)}$=14.73,p<0.0001) and perceived stability (6%) ($F_{(1,42)}$=11.69,p=0.001) along with significant increases in fear of falling (57%) ($F_{(1,42)}$=13.23,p=0.001) and state anxiety (17%) ($F_{(1,42)}$=11.23,p=0.002) (Figure3.3). Significant increases were seen in somatic (20%), concentration (20%), and worry (14%) aspects of state anxiety (($F_{(1,50)}$=14.83,p<0.0001), ($F_{(1,50)}$=12.77,p=0.001) and ($F_{(1,50)}$=7.50,p=0.009) , respectively) . Physiological arousal was unaffected by postural threat.

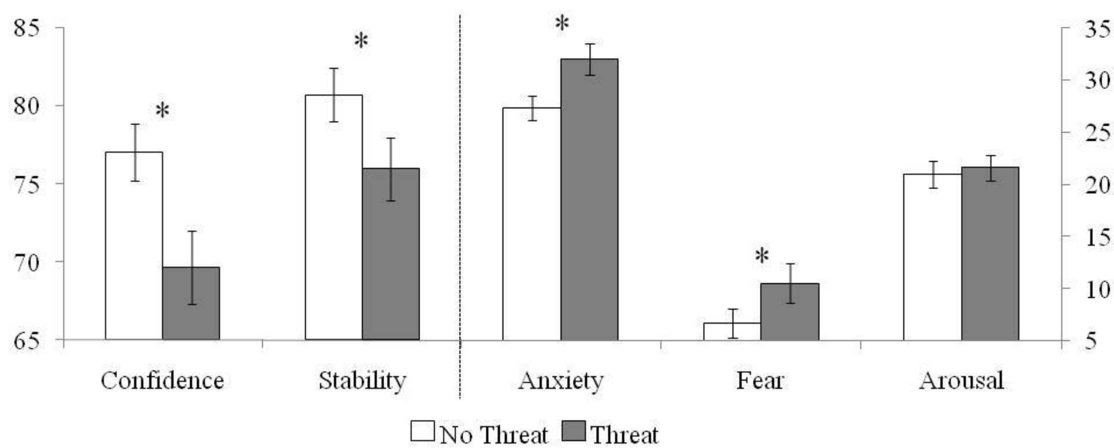


Figure 3.3: Effect of postural threat psychological and physiological measures (means and standard error bars). Vertical dashed line indicates separation of variables to left and right axes. Units: Confidence, Stability, Fear (%); Anxiety (sum); and Arousal (μMhos). *significant at 0.05

3.3.2 Effects of Cognitive Loading

Multivariate analyses revealed significant main effects of cognitive loading for balance control measures during two-legged quiet stance with vision (Wilks'=0.76, $F_{(4,47)}$3.78,p=0.010), but no significant effects during quiet stance without vision or in any clinical balance tasks. Condition-specific psychological measures were also affected by cognitive loading (Wilks'=0.62,$F_{(5,38)}$=4.59,p=0.002). Moreover, component anxieties were affected by cognitive loading (Wilks'=0.67,$F_{(3,48)}$=8.00,p<0.0001).

Univariate analyses revealed that cognitive loading resulted in increased trunk pitch (23%) and trunk roll (24%) velocity ranges in QSEO (($F_{(1,50)}$=5.46,p=0.023) and ($F_{(1,50)}$=6.67,p=0.013)). Univariate analyses also revealed significant reductions in balance confidence (8%) ($F_{(1,42)}$=9.04,p=0.004) and significant increases in state anxiety (16%) ($F_{(1,42)}$=10.86,p=0.002) due to cognitive loading (Figure 3.4). The concentration aspect of state anxiety was significantly increased (30%) due to cognitive loading ($F_{(1,50)}$=24.12,p<0.0001), while somatic and worry aspects were unaffected. Physiological arousal, fear of falling and perceived stability were also unaffected by cognitive loading.

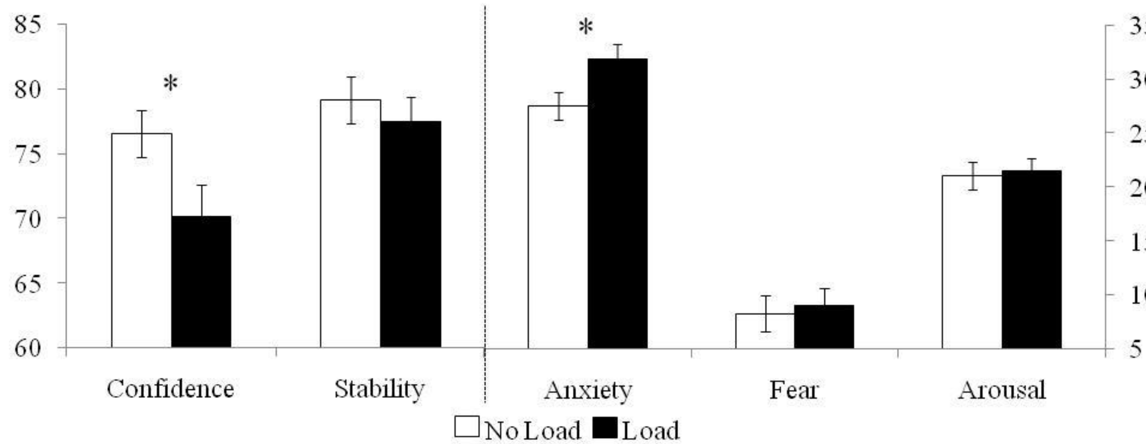


Figure 3.4: Effect of cognitive loading on psychological and physiological measures (means and standard error bars). Vertical dashed line indicates separation of variables to left and right axes. Units: Confidence, Stability, Fear (%); Anxiety (sum); and Arousal (μMhos). *significant at 0.05

3.3.3 Performance of the Cognitive Task

Fewer items were recalled following completion of the combined postural threat and cognitive loading condition as compared to the cognitive loading alone condition (7.00±2.10 and 7.52±2.02 respectively), although this difference was not statistically significant.

Paired t-test comparing the grocery lists revealed that significantly fewer items from list 2 were recalled than from list 1 ($t(51) = 4.93$, $p < .0001$), which suggests that list 2 was a more difficult list for these particular participants. However, the list presentation order was randomized relative to challenge condition and therefore this finding does not influence or alter the effects of cognitive load on psychological and balance control measures revealed by the ANOVA.

3.3.4 Correlation Analyses

Significant associations were found between changes in subjective psychological measures and changes in quantitative clinical balance measures from no postural threat to postural threat conditions (Table 3.1). Increased fear of falling was significantly associated with reduced reach distance in the functional reach task. Increased time-to-completion in repeated sit-to-stands was significantly associated with reduced balance confidence.

Table 3.1: Correlations between task-specific psychological and clinical balance measures. Effects of Postural threat. Spearman's rho coefficient (p value); * significant at 0.05

Measure	Confidence	Stability	Fear
Reach distance	0.027 (0.856)	0.123 (0.396)	-0.367 (0.010)*
Time One-Leg	-0.226 (0.132)	-0.011 (0.943)	0.115 (0.453)
Time Sit to Stand	-0.238 (0.049)*	-0.234 (0.102)	0.209 (0.153)

No significant correlations were found within challenge condition between physiological arousal and psychological state anxiety.

3.4 Discussion

The objective of this research was to determine the independent and combined effects of postural threat and cognitive loading on performance measures of clinical balance tests and reports of fear of falling and related psychological measures of balance confidence, perceived stability and state anxiety in elderly individuals. Consistent with our hypothesis, postural threat influenced the performance of clinical balance tests as well as psychological measures. However, the effect of cognitive loading was limited to a reduction in balance confidence and an increase in anxiety, with no change in balance performance, perceived stability or fear of falling. Contrary to our hypothesis, combining postural threat with cognitive loading did not result in further changes to balance performance, fear of falling or related psychological measures.

3.4.1 Postural Threat and Balance Control

The results of this study support previous research in young individuals indicating that postural threat affects performance of clinical balance tasks such as functional reach, one-leg stance[34], and are the first to illustrate this phenomenon in elderly individuals. The study also extends the finding to the tandem stance and sit-to-stand tasks. Instrumented measures of trunk sway revealed increased trunk roll displacement during tandem stance and decreased trunk pitch velocity during sit-to-stand when performed on an elevated surface. Simple time and distance measures revealed decreased one-leg stance time, increased sit-to-stand time and reduced maximum reach distance when performed on an elevated surface.

In contrast to previous research [27,29,31], the postural threat introduced in this study did not affect measures of balance control during two-legged quiet standing. This discrepancy can be explained by the difference of surface height used. While the aforementioned studies have employed surface heights ranging from 0.85-1.60m, the current protocol used the low height of 0.50m which may not be threatening enough to elicit significant changes to postural control, in the relatively simple two-legged quiet standing task, for this population. Brown et al. (2007) also employed a lower support surface elevation (0.6m) and found that older individuals demonstrated reduced sway variability and a displacement of the center of pressure away from the direction of postural threat[32]. However, caution should be employed when comparing these data to those of Brown et al. (2007) given the methodological discrepancies. Although presented as a postural threat study, Brown et al. (2007) did not directly manipulate postural threat but rather restricted stepping responses. Moreover, Brown et. al (2007) evaluated centre of pressure measures while the current data were based on measures at or near the centre of mass.

The current findings show that postural threat also elicits changes to psychological measures of balance confidence, perceived stability and state anxiety in elderly individuals during quiet standing, supporting the work of Carpenter et al (2006). Furthermore, postural threat influences these psychological measures during performance of more challenging clinical balance measures similar to previous research in young individuals[34].

Many of the aforementioned studies examining the effects of postural threat on standing balance control either assumed or inferred a fear of falling as a result of changes in other psychological or physiological measures, such as balance confidence, state anxiety and/or arousal. This inference may be faulty as evidence suggests that fear and anxiety have different neuroanatomical substrates and functional response profiles[69,61]. Furthermore, data have shown that fear of falling affects levels of balance self-efficacy/confidence, which in turn influences balance and physical functioning. In other words, balance efficacy may act as the mediator between fear of falling and functional ability, which supports the notion that these are independent constructs[70,71]. To our knowledge, only two other postural threat studies have directly evaluated fear of falling [24,25]: Huffman et al (2009) found that fear of falling, physiological arousal, and perceived anxiety increased when participants stood on an elevated surface of 3.2m as compared to ground level, although correlations between these measures were not reported; Davis et al. (2009) found that postural threat brought about increases in anxiety in the absence of robust changes in fear and that significantly increased fear of falling was reported in only a portion of participants (27%), even at a high surface elevation of 3.2m. The current data show that postural threat increased fear of falling across all balance tasks, which suggests that increased fear of falling can be elicited with surface heights as low as 0.5m in older adults during performance of simple and more challenging balance tasks. Differences in population of interest (elderly vs. young), protocol (no safety harness in the current study), and balance tasks evaluated (more challenging clinical measures employed in the current study) may account for the variation in these findings. The current data show no significant increases in physiological arousal but significant changes to fear of falling, balance confidence and perceived anxiety as a result of postural threat. It is clear therefore, that fear of falling should not be measured indirectly by physiological outcomes, and that fear and anxiety are not equivalent constructs. Future work should confirm this assertion by directly relating these measures. It has also been suggested that anxiety (or worry) is on a continuum with fear [61]. Therefore, it is possible that lower levels of postural threat are sufficient to induce increases in anxiety without similar increases in reported fear of falling. Finally, the scaling of this continuum may differ between populations of interest such that circumstances eliciting only anxiety in young adults may yield responses more akin to fear in older adults. Furthermore, low levels of anxiety may arise without concomitant increases in arousal, while greater levels of anxiety activate autonomic arousal responses as perceived threat is increased [61], which may explain the uncorrelated physiological arousal and reported anxiety results of the current data.

The current data show that fear of falling is significantly correlated to performance on the functional reach task and balance confidence is significantly correlated to performance on the repeated sit-to-stand task. Although previous research has shown relationships between changes in psychological and clinical balance control measures as a result of postural threat[34], this is the first study to our knowledge, which demonstrates these relationships in older adults and that a direct measure of increased fear of falling is related to poorer clinical balance performance.

3.4.2 Dual Tasking and Balance Control

Analyses revealed no significant effects of cognitive loading on balance control measures during performance of more challenging clinical balance tasks. This supports the work of Morris et al. (2000)[58] wherein tandem stance and one-leg stance performance in older adults was unaffected by the addition of a secondary verbal-cognitive task. VanderVelde et al. (2005)[57] also found that addition of a cognitive task had no effect on postural stability (as indicated by COP sway measures) during tandem stance in young adults. In contrast, Barra et al. (2006) found that the addition of a verbal secondary task resulted in decreased COP displacements during the performance of tandem stance[56]. The results of the latter two studies are difficult to compare to those of the current findings for two primary reasons: first, their evaluation did not include trunk sway measures and; second, their sample population was one of young adults. The analysis of hip and head sway measures provided by Barra et al., which are arguably more similar to trunk sway measures, did not show a significant effect of cognitive loading. Vaillant et al (2006) found diminished performance of one-leg stance due to cognitive loading with an arithmetic task, although their sample comprised frail older women suffering from osteoporosis.

Although performance measures of more difficult clinical tasks were unaffected by cognitive loading, trunk-sway velocity ranges during two-legged quiet standing with vision were significantly affected. This finding suggests that when cognitive tasks are performed simultaneously with a balance task in which the demands on the postural control systems are minimal and the probability of a fall is low (such as in two-legged quiet standing), the current sample of elderly individuals ‘allowed’ changes to postural control. However, when dual-tasking during performance of more challenging balance tasks, in which the likelihood of a fall was greater, elderly individuals chose (implicitly or explicitly) to adopt a “posture-first” strategy. This conclusion is however, limited in the following ways: it is not possible to definitively determine the focus of attention given the silent nature of the task and memory task performance was assessed following the completion of all balance tasks rather than after each task individually.

The limited effect of cognitive loading on balance performance measures may also be due to the inclusion of only one level of cognitive task difficulty. Huxhold et. al (2006) found, in older adults, that the addition of easy secondary cognitive tasks resulted in improved postural control in quiet stance (as indicated by reductions in COP displacements), but the addition of more complicated secondary cognitive tasks resulted in degraded postural control (as indicated by increased COP displacements)[46]. The current study was, however, designed primarily to compare the independent and combined effects of postural threat and cognitive loading on clinical balance and psychological measures, rather than to evaluate the effects of dual-tasking per se. As such, no single-task cognitive loading condition, and only one level of cognitive task difficulty was included, and these are limitations of the study. Nevertheless, it is generally accepted that the capacity of short-term memory (STM) is limited to a very small number of items (7±2) and that the information dissipates rapidly (on the order of mere seconds)[72-74]. With rehearsal however, items can be held in working memory for longer periods of time. The mean number of items recalled from the grocery lists was 7.3 (±1.6) following a period of 5-10 minutes (the time required to complete all balancing tasks under a given condition) which would suggest that the participants were in fact performing the secondary cognitive task (silently rehearsing the items) while also performing the balancing tasks. Furthermore, it was hypothesized that groups of individuals with divergent balance abilities might be differentially affected by postural threat and cognitive loading. This hypothesis could not be tested however, due to the homogeneous nature of balance and mobility scores in this sample. Future studies might address these limitations by including a range of cognitive task difficulties and employing a more diverse sample population.

Minimal effects of cognitive loading were seen on psychological measures. Most notably, no significant increases in fear of falling were observed. Immediately following participation in the study, question and answer periods were offered by the investigators to each participant. These discussions revealed that many participants reported reduced ratings of confidence in dual-tasking conditions due to their perceived inability to succeed in the memory task, despite explicitly being asked to rate their confidence in their ability to maintain balance. This would suggest that the significant effects of cognitive loading on confidence ratings were not synonymous with the significant effects of postural threat on confidence ratings. Moreover, aspects of state anxiety were differentially affected by postural threat and cognitive loading: while postural threat significantly affected all measured components (somatic, concentration and worry), cognitive loading affected only the concentration aspect. This supports previous research showing that different circumstances or performance measures elicit independent effects on various aspects of anxiety[75].

3.4.3 Interactions of Dual-Tasking and Postural Threat

It was hypothesized that combining postural threat and cognitive loading would have a detrimental impact on balance performance and psychological measures that was additive in nature. Analyses revealed no such interaction effect on any of the outcome measures. Examination of figures derived from 2(threat) x 2(load) contingency tables with means for balance performance measures shows some evidence of divergence and a trend towards significant interaction, particularly for one-leg stance times. It is possible that the simplicity of the cognitive task could not reveal the potential additive effects of the combined challenge condition, and is a study limitation.

3.5 Conclusions

Exposure to low levels of postural threat had a detrimental impact on both clinical balance performance and psychological measures in community-dwelling elderly adults. However, cognitive loading had no significant impact on clinical balance performance measures and minimally affected psychological measures in this population. Lack of significant interactions would suggest that the effects of postural threat and cognitive loading were not additive. Furthermore, given the dissimilarity of the independent effects due postural threat and cognitive loading on clinical balance control and psychological measures, it would appear that the driving force resulting in changes to balance control due to postural threat is not simply a taxing of attentional resources. Increased fear of falling and decreased perceived stability were observed under threatening conditions but not in cognitive loading; this suggests that changes in balance performance during postural threat may result from a psychologically motivated focus on maintenance of stability in threatening environments where the potential of a fall and the resulting consequences are more evident.

These findings are clinically relevant in at least two ways. First, these data show that changes in fear of falling and related psychological measures are associated with changes in clinical balance performance supporting the notion that psychological factors be accounted for in clinical balance assessments. Secondly, these data suggest that a clinician need not have expensive lifts, posturographic measurement systems or harnessing/safety devices to reveal the limiting influence of psychological state on clinical measures of balance control.

Chapter 4

Study 2 Part 2: Fall Prediction in Community-Dwelling Elderly Individuals: Can Fall Risk Assessments be Improved by Evaluating Combined Clinical Balance, Psychological, and Comorbidity Measures? An exploratory evaluation.

4.1 Introduction

Prediction and thereby prevention of falls in the elderly remains problematic. The multifactorial nature of both the risk factors and causes of falls[1] makes identification of those at risk extremely difficult. Moreover, independent community-dwelling older individuals who have never fallen are unlikely to seek medical attention for a potential fall or to enroll in exercise or educational fall prevention programs, which makes predicting and preventing the first fall in these individuals challenging. Development of a screening tool, that easily could be administered in a clinical setting (e.g. by a family practitioner during an annual exam) would aid in overcoming these challenges.

A multitude of researchers have studied the consequences of aging on postural control in an attempt to better understand the nervous system and the motor control strategies used to maintain upright posture. Cognitive, psychological, neurological, mechanical, and physiological changes occurring with age have been implicated in falls and fall-risk[2-13]. Polypharmacia and environmental factors also have been correlated with falls in elderly populations[14-18]. Despite the amount of research in aging and balance control, efforts to predict and thus prevent falls in the elderly have met with little success. Continued efforts to improve fall prediction models and screening tools must however ensure the feasibility of use for clinicians. In other words, models must find a balance between comprehensiveness and simplicity.

4.1.1 Predicting Falls Using Clinical Balance Tests

In contrast to laboratory and posturographic measures of balance control, clinical balance tests typically require little or no equipment, are quick and easy to perform, require little training to administer and can be employed in a wide variety of settings. These tests therefore would be useful measures to include in generalized fall-risk screenings. The following sections review evidence presented in the literature regarding common clinical tests and their ability to predict falls status in community-dwelling older individuals.

The Berg Balance Scale

The Berg Balance Scale (BBS) is one of the most widely recognized clinical tools used to assess balance in older individuals. It was developed primarily to assess balance changes over time due to aging, disease progression or to monitor progress in rehabilitation[19-22]. Despite reports of generally high (0.77-0.99) intrarater, interrater, and test-retest repeatability over two decades[19,21,23-32], and being termed the "gold standard in measuring falls risk"[20], the BBS has not reliably predicted falls across samples of community-dwelling elderly individuals with any measure of consistency. For example, Thorbahn and Newton (1996) examined the predictive ability of the BBS and found that although individuals who scored higher were less likely to fall than those scoring below the standardized cut-off score (45/56), the sensitivity of the measure was only 53%[25]. This means that a large proportion of the individuals who fell were not identified as at-risk for a fall by their balance score. Shumway-Cook et al. (1997) attempted to improve the ability of the BBS to distinguish fallers from non-fallers by using a cut-off score of 49/56. The sensitivity of the measure improved to 77%[33]. This improvement however remains inadequate, as nearly one quarter of fallers was misclassified as non-fallers. Using the combined data of the two aforementioned studies, Riddle and Stratford (1999) examined varying cut-off scores for improving the predictive ability of the BBS. By progressively increasing the cut-off score from 45 to 55, the sensitivity of the measure improved from 64 to 97%. This improvement in sensitivity however was met with inevitable decreases in specificity, or increases in the number of false positives (individuals identified by the BBS as being fallers when in actuality they were non-fallers)[22]. Use of a higher cut-off score in a predictive model may result in increased rather than decreased costs to the health care system, by false identification of at-risk individuals and thereby unnecessary enrolment in prescribed intervention programs. It is also important to note that these studies are based on retrospective rather than prospective fall data. Inherent limitations to retrospective analysis include inaccuracy in the recall of number and details of falls events[34-36], as well as the questionable utility of evaluating history of falls. In other words, in order to prevent falls, it is far more useful to be able to predict the future risk of falls than to be able to identify those who have fallen in the past.

Brauer et al. (2000) as well as Lajoie et al. (2004) also evaluated the predictive ability of the BBS in older individuals, with contradictory results[37,38]. Brauer et al (2000) found that the BBS could neither distinguish between fallers and non-fallers (total scores were similar between the groups), nor could it prospectively identify those who fell over a 6-month follow-up period. In contrast, Lajoie et al. (2004) reported that the BBS could retrospectively distinguish between fallers and non fallers (total scores for fallers were significantly lower than non-fallers) and using a cut-off of 46/56 to dichotomize the participant group, could correctly identify fallers with a sensitivity of 83% and specificity of 93%. Differences in sample populations (community-dwelling vs. community-dwelling and nursing home residence) and falls analysis (prospective vs. retrospective) may account for the contradictory findings.

In patient populations where prevalence of falls is greater than in healthy populations[39,40], the ability of the BBS to predict fall-risk also presents mixed results. The following three studies examined the predictive performance of the BBS in samples of patients who had suffered from stroke. Harris et al. (2005) reported that the BBS could not distinguish between non-fallers and single-event fallers (experienced only one fall), nor could it distinguish between non-fallers and multiple-fallers (experienced two or more falls)[41]. Belgen et al. (2006) using non-parametric analysis found that the BBS could distinguish between non/single-fallers and multiple fallers wherein the latter had significantly lower total scores. Moreover, using a cut-off score of 52/56, the BBS could retrospectively identify multiple fallers with a sensitivity of 90% and specificity of 53%[42]. In contrast, Andersson et al. (2006) found that although fallers scored significantly lower on the BBS than non-fallers, prospective logistic regression analysis (using a cut-off score of 45/56) could not predict fall risk (63% sensitivity, 65% specificity)[43]. In a sample of participants suffering from multiple sclerosis, the BBS again was able to distinguish between non-fallers and fallers, but could not predict retrospective fall status (using a cut-off score of 44/56, 40% sensitivity and 90% specificity)[44]. In a sample of individuals suffering from Parkinson's disease, Dibble and Lange (2006) found that retrospectively categorized fallers scored significantly lower on the BBS than non-fallers but a cut-off score of 46/56 could not predict fallers, with a resulting sensitivity of only 41% and specificity of 100%. However, using a cut-off score of 54/56, predictive ability improved and resulted in a significant AUC value of 0.83, sensitivity of 79% and specificity of 74%[45]. In a similar Parkinson's disease population, discriminant function analysis revealed that the BBS was able to identify fallers retrospectively using a cut-off score of 43.5 (AUC of 0.851)[46].

Based on the evidence presented here, it remains unclear whether the BBS can adequately assess fall-risk across various groups of community-dwelling older individuals. Furthermore, it is plainly evident that use of a single cut-off score cannot be employed in a generalized risk-assessment tool.

The Timed-up-and-Go Test

Another widely recognized clinical tool used to assess mobility related to activities of daily living in older individuals is the Timed-up-and-Go test (TUG). This measure has shown strong interrater, intrarater, and test-retest reliability (intraclass correlations ranging from 0.85 to 0.99) in older individuals[26,27,44,47-50] but has not demonstrated consistency in predicting fall-risk across samples of community-dwelling older individuals. For example, two studies published in 2000 reported that the TUG could discriminate between fallers and non fallers where fallers took longer to complete the task than non-fallers. Moreover, these studies found that the TUG could correctly classify individuals by retrospective falls status with 87% (using cut-off score of 13.5s) and 72% (continuous score) overall positive prediction ability[51,52]. Similarly, Chiu et al. (2003) reported that the TUG could discriminate between non-fallers and multiple fallers as well as retrospectively predict fall status with 77% sensitivity and 88% specificity when using a cut-off score of 24.7seconds[53]. In contrast, Lin et al (2004) found that the TUG could not prospectively predict fall status (Area Under the Curve (AUC) = 0.610)[48]. Vaillant et al. (2006) reported that the TUG could not correctly classify older women based on retrospective falls status[54]. Buatois et al. (2006) found that TUG times were similar in prospectively categorized non-fallers, single-fallers, and multiple fallers[55]. Finally, Thrane et al. (2007) reported that the TUG demonstrated poor performance in retrospective fall status classification with AUC values of 0.50 in older women and 0.56 in older men living in the community[56].

In patient populations with increased prevalence of falls, the TUG has not demonstrated consistency in fall prediction. Belgen et al. (2006) found that the TUG could neither discriminate fallers from non-fallers nor retrospectively predict fall status in patients suffering from stroke[42]. Similarly, Cattaneo et al. (2006) found that the TUG could not distinguish between fallers and non-fallers in patients suffering from multiple sclerosis[44]. In patients suffering from Parkinson's disease, the TUG could correctly classify individuals based on retrospective falls status, reporting a significant odds ratio of 3.80, indicating that those patients who took longer to perform the task were more likely to have experienced a fall[57]. In a similar population, Dibble and Lange (2006) found that the TUG (using the standardized cut-off score of 13.5s) could not retrospectively discriminate fallers from non-fallers with a resulting sensitivity of merely 39% and specificity of 87%. However, when a cut-off score of 7.9s was applied in this sample, the sensitivity improved to 93%, but the specificity dropped dramatically to 30% [45]. In patients suffering from amyotrophic lateral sclerosis, increased TUG time was significantly associated with increased fall risk in a prospective evaluation[58].

As with the BBS, based on the evidence presented here, it is unclear whether the TUG can reliably assess fall-risk in community-dwelling older individuals.

Other Common Clinical Balance Tests

Other commonly employed clinical balance measures include the Functional Reach test (FR), One-Leg Stance test (OL) and repeated Sit-to-Stands test (STS). Each have reported good to excellent test-retest, intrarater, and interrater reliability in older populations with intraclass correlations ranging from 0.73-0.99[26,30,48,59-63], 0.75-0.99[48,60-62], and 0.73-0.99[61,62,64-66], respectively. The ability to predict falls or fall-risk in community dwelling older individuals based on performance of these tests however is not consistent.

For example, Duncan et al. (1992) found, when comparing non-fallers to recurrent fallers in a 6-month prospective study (n=217), that the FR test could significantly predict falls status when using cut-off scores of 6 inches (odds ratio 4.0) as well as 10 inches (odds ratio 2.0)[67,68]. In contrast, Wallman et al (2001) found no significant difference in the scores between retrospectively-categorized fallers and non-fallers, although findings of this study may have been limited by a small sample-size (n=25)[68]. In a large cohort of community-dwelling older individuals (n=1200) Lin et al. (2004) found that the FR test could not prospectively predict falls (1-year follow-up period) with reported non-significant odds ratios and a near-chance AUC value of 0.51[48].

Researchers have also examined the ability of one-leg stance (OL) scores to predict fall-risk in community-dwelling elderly. Vellas et al.(1998) reported that unipedal performance in women was significantly related to injurious falls (relative risk (RR) 2.97) but not falls in general, while in men performance was related to falls in general (RR 2.01) but not injurious falls. Differences in fall strategies/protective mechanisms were suggested as the cause for the discrepancies in RR between the genders[69]. Thomas et al. (2005) found that one-leg stance times of less than 1.02s could distinguish retrospectively between non-fallers and recurrent fallers (OR 15.2) in a sample of frail community-dwelling elderly[70]. Muir et al. (2010) also reported an increased risk of falls in community-dwelling individuals associated with one-leg stance times of less than ten seconds (RR 1.58)[71]. In contrast to the aforementioned results, other reports suggests that one-leg stance performance cannot be used to distinguish between fallers and non-fallers nor predict fall-risk. Lin et al. (2004) reported non-significant odds ratios and near-chance AUC values (0.527), derived from a large-scale prospective falls analysis in community-dwelling Taiwanese individuals[48]. Vaillant et al. (2006) reported that OL performance, with or without the addition of a secondary cognitive task, could not distinguish retrospectively between fallers and non-fallers in a sample of community-dwelling older women[54]. Buatois et al (2006) observed that OL times of less than five seconds could not distinguish prospectively non and single-fallers from multiple-fallers[55].

The repeated sit to stand test (STS), used to evaluate lower limb strength[64,72] and functional mobility[55,65] also has been evaluated for its ability to predict fall-risk. Buatois et al. (2006) reported that STS times were not different between prospectively categorized non-fallers, single-fallers, and multiple fallers[55]. In a 2008 report by the same group in a larger sample of older adults, STS times of less than 15 seconds could prospectively distinguish between non/single-fallers and multiple fallers. However, the sensitivity of this test was only 55% with a coinciding specificity of only 65% [73]. Tiedemann et al. (2008) reported that the five-time STS performance could distinguish between non-multiple fallers and multiple fallers (t-tests) and when using a cut-off score of 12 seconds, STS performance could predict prospective fall-status, although sensitivity and specificity were only moderate (66% and 55%, respectively)[74]. Khazzani et al. (2009) reported that poorer STS performance was significantly associated with a history of falls, and that the number of falls per year was positively correlated with STS times in a sample of community-dwelling older women[75].

Based on the supposition that clinical balance measures may not be able to detect more subtle changes in postural stability or identify mechanisms of dysfunction in balance, Brauer et al. (2000) evaluated the ability of 4 clinical balance measures as well as posturographic measures to predict falls in independent community-dwelling elderly women. None of the clinical measures, including the Berg balance scale, Functional Reach, Lateral Reach and Step-up tests (alone or in combination) were able to predict falls. Moreover, neither a model combining eight laboratory measures (COP excursions, muscle onset times, and step/movements times) nor a model combining the clinical and laboratory measures was able to predict fallers (with reported 51% and 59% sensitivity, respectively)[37].

Laessoe et al. (2007) developed a test battery to evaluate balance in elderly individuals, which included clinical measures of standing balance, stepping ability, physical function, reaction time and leg strength as well as a dual-task situation and laboratory measures of gait variability, gait cadence, and visual acuity. Despite the seemingly comprehensive nature of this battery, it was unable to distinguish between fallers and non-fallers, resulting in a sensitivity of only 50%[76].

Based on the literature reviewed here it clear that clinical balance scores, including composite scores (such as the BBS) and individual measures (such as the FR, OL, or STS), cannot be used alone in fall screening tools to adequately predict fall-risk in community-dwelling elderly individuals.

4.1.2 Predicting Falls Using Psychological Measures

Fear of falling and low balance confidence are commonly reported in elderly individuals[77-84]. Recent accounts report that 56% of 500[77] and 54% of 4, 031[78] community-dwelling elderly individuals reported a fear of falling. Furthermore, 38% of these individuals curtailed their activities of daily living as a result of their fear of falling[78]. Tools frequently used to assess fear of falling (FOF) include single questions (Are you afraid of falling?), the Falls Efficacy Scale (FES), the Survey of Activities and Fear of Falling in the Elderly (SAFE), and the Activities-Specific Balance Confidence Scale (ABC)[14,77,78,85-94]. These tools can be divided into measures of self-efficacy and measures of fear-of-falling, although the terms (and tools) are often used interchangeably in the literature.

In a 2005 review paper, Joarstad et al. reported that, of the self-efficacy tools, the FES and ABC were the most widely used and provided comparable reliability, validity and responsiveness. The most widely used fear-of-falling tools included a single item question (yes/no) and the SAFE, neither reporting high reliability or validity[95]. Furthermore, efficacy measures may provide a more valid representation of psychological state given their grounding in the well-accepted social cognitive theory (Bandura, 1997). Since the Jorstad review, test-retest reliabilities have been reported for the ABC with scores ranging from 0.85-0.94 in healthy and patient community-dwelling older individuals[30,96,97] while test-retest reliabilities of the FES were found to have moderate reliability with scores ranging from 0.66-0.83[98]. Overall, these psychological tools however have shown poor fall predictive abilities.

Hotchkiss et al. (2004) retrospectively evaluated the ABC, FES, and SAFE for their discriminative ability in a sample of 118 community-dwelling elderly individuals. Unexplained variances (Pearson correlations) ranged from 0.95 to 0.99, indicating that none of the FOF assessment tools could adequately distinguish between fallers and non-fallers[99]. On the other hand, a 2004 study found that the total ABC score (cutoff score of 67%) could distinguish between retrospectively identified fallers and non-fallers in a diverse sample of 125 elderly individuals, with a specificity of 88% and sensitivity of 84%[38]. Talley 2008 found that ABC scores were significantly and negatively correlated with retrospective fall status[100], while SAFE scores were unrelated to falls history. In the face of these contradictory findings, it is unclear whether the ABC can be used to identify those individuals at risk of falls. Moreover it is unlikely that the SAFE can be used to reliably predict falls status. Delbaere et al. (2010) report that the FES can distinguish (using independent t-tests) between non-fallers and multiple fallers, although there is a bias towards better discrimination among more frail community-dwelling elderly populations. The ABC may be more appropriate for use among healthy/active community-dwelling individuals, resulting from its inclusion/evaluation of more demanding balance-related activities[95,98].

Delbaere et al. (2006) evaluated medical, psychological, sensory, physical, and postural control measures in 263 community-dwelling elderly. Regression analysis was used to determine the best fall predictors. General FOF (assessed by a single question on a 4-point Likert scale) was revealed as the best psychological predictor of falling (odds ratio 3.25), followed by the

SAFE (odds ratio of 1.13). Stepwise regression analysis however, eliminated the psychological measures from the model[14]. Inclusion of more expansive/appropriate tools for the sample populations, such as the ABC or task-specific psychological measures, may have yielded differing results.

4.1.3 Predicting Falls Using Health/Comorbidity Assessments

The Charlson comorbidity index developed in the 1980s and its 1992 Deyo adaptation have been commonly used to assess disease burden and predict mortality in various patient populations[101]. In 1998 a more extensive index was developed, evaluating 31 rather than 17 comorbidities[102]. These indices that were developed around the 9th revision of the International Classification of Disease system (ICD-9), were later modified to the 10th revision[103], and are typically used evaluate data extracted from hospital medical records. However, Sangha et al. (2003) developed a self-administered comorbidity questionnaire (SCQ), which was correlated to scores based on the Charlson index (convergent/construct validity), and would be useful particularly in situations where hospital medical records are unavailable[104].

Several studies have shown relationships between various individual comorbidities (or their treatments) and falls[1,2,4-6,14,82,105-109]. We are unaware however of any fall-risk identification and/or fall prediction models that have included a comprehensive comorbidity assessment.

4.1.4 Analysing Falls Data - A Mini-Review

Comparison of various fall prediction models presented in the literature is complicated by the assortment of statistical models employed, outcome variables and effect measures presented, outcome event types evaluated, fall evaluation type (retrospective vs. prospective), and fall evaluation period (time span in which number/details of falls is recorded). Furthermore, when evaluating multivariate models (more than one predictor), measures used to compare models also vary in the literature. Table 4.1 presents the statistical modelling tools most commonly employed in the literature to evaluate falls information.

Table 4.1: Regression approaches used to analyze falls data

Regression Model	Outcome Type	Outcome Variable	Effect Measures	Model Strength Comparisons	Outcome Event Type
Logistic	Binomial (Binary)	Non-fallers vs. fallers Non-fallers vs. Multiple-fallers Non/single-fallers vs. Multiple fallers	OR	AIC, Sens, Spec, PPV, PLR AUC (95% CI) ROC plots	Non-recurrent
Logistic	Multinomial (Categorical)	Non-fallers vs. single-fallers vs. multiple fallers	OR	AIC AUC	Non-recurrent
Poisson	Count	# of falls	IRR	Chi-square, AIC	Recurrent
Negative Binomial	Count	# of falls	IRR	Chi-square, AIC	Recurrent

OR= Odds Ratio
IRR= Incidence Rate Ratio
AIC=Akaike Information Criterion
AUC=Area Under the (Receiver Operator) Curve
ROC=Receiver Operator Curve
Sens=Sensitivity (true positives)
Spec=Specificity (true negatives)
PPV=Positive Predictive Value
PLR=Positive Likelihood Ratio

Logistic Regression

Of those presented in Table 4.1, the most common method of analyzing fall data is binomial logistic regression, where individuals are grouped into one of two categories (binary outcome variable)[110]. However, discrepancies in the literature for this categorization make comparisons across publications difficult: some researchers classify individuals as either non-fallers (no falls experienced) or fallers (one or more falls experienced)[16,33,37,38,42-44,48,54,56,68,71,76,99,111-115] ; others compare non-fallers to multiple fallers (two or more falls experienced) excluding single-event fallers[51,67,70,116,117]; and still others contrast non and single-fallers to multiple fallers[42]. To complicate matters even further, some researchers operationally define multiple or recurrent-fallers based on the number of falls in a specific time period. For example, Stel et al (2003) required an individual to fall two or more times in a 6-month period to be deemed a recurrent faller[118]. Therefore, during a 3 year follow-up period, an individual may have fallen on multiple occasions, but never twice within a 6-month period, and therefore not have been considered a recurrent faller. This same individual would have been classified as a multiple faller in studies using different operational definitions, such as that employed by Arden et al. (1999) and Delbaere et al. (2006) where an individual was considered a multiple-faller when he/she experienced two or more falls in a 1-year period, regardless of the time between falls. Moreover, follow-up periods differ between research groups. An individual classified as a single-faller in a 6-month follow-up study, may be classified as a multiple or recurrent-faller in a 12-month follow-up study.

In order to measure the ability of the logistic regression model to accurately predict falls, researchers present one or more of the following: odds ratios of individual predictor variables (in univariate analyses), sensitivity and/or specificity (when using cut-off scores or dichotomized predictors) and AUC values (when employing univariate or multivariate techniques using continuous and/or dichotomized predictors). A growing number of researchers also present ROC plots which illustrate the overall predictive ability of a model (overall model fit). The following sections discuss advantages and disadvantages of these measures.

Odds ratios represent effect sizes in logistic regression and are useful for evaluating how strongly an individual predictor influences the outcome: an odds ratio greater than 1 reflects an increase in the odds of an outcome while odds ratios of less than one reflect a decrease in the probability of an outcome[119], when all other variables are held constant. For example, gender in a model may reveal an odds ratio of 3.5 suggesting that women are 3.5 times more likely than men to experience a fall, when all other variables are held constant. This value however does not demonstrate how well one can predict the risk of a fall particularly when evaluating multiple predictor variables, only the contribution of an individual predictor. Sensitivity is defined as those individuals correctly identified by a test as having the condition of interest as a percentage of all those who truly have the condition of interest [true positives/(true positives + false negatives)*100] while specificity is defined as those people correctly identified by a test as not having the condition of interest as a percentage of all those who truly do not have the condition of interest [true negatives/(true negatives + false positives)*100][22]. These measures of a model are dependent however on the scores employed to create dichotomized predictor variables. As previously discussed, a cut-off score that is appropriate for predicting the outcome of interest in one population (e.g. healthy community-dwelling elderly) may not be appropriate for predicting risk in another sample of individuals (e.g. community-dwelling elderly suffering from Parkinson's disease). A positive predictive value (PPV) is defined as those people correctly identified by the test as having the condition of interest as a percentage of all those identified by the test as having the condition of interest [true positives/(true positives + false positives)*100]. PPVs however, are prevalence dependent and in the case of falls in the elderly, the prevalence changes with age and differs across patient populations[39,120]. Therefore, use of PPV for fall prediction is discouraged[22]. Positive likelihood ratios (PLR) combine the measures of sensitivity and specificity into one score (sensitivity/1-specificity). Pre-test probabilities and likelihood ratios are then combined to determine the post-test probability of an event (e.g. a fall) (for an example see Landers et al, 2008)[46]. However, clinicians would require a great deal of experience to assign a pre-test probability, based on known fall risk factors presented. Furthermore, this method would require the clinician to have access to sensitivity and specificity measures of the selected test or predictor variable, which as previously discussed, depends on population of interest and the associated cut-off points for the selected test. This method would make risk prediction time consuming and cumbersome – this therefore could not be readily incorporated into an efficient and generalized risk-assessment or screening tool.

Area under the (receiver operator) curve (AUC) values (or the c-statistic) are measures of effect size for a model[119]and can be thought of as the average sensitivity across all specificities or vice versa. An AUC value of 0.5 indicates that the model has no discriminative ability beyond chance, while an AUC value of 1.0 indicates a model with perfect discriminative ability[119]. Receiver Operating Characteristic (ROC) plots derived from models with perfect discrimination pass through the upper left corner, where the true-positive fraction is 1.0, or 100% (perfect sensitivity), and the false-positive fraction is 0 (perfect specificity). The curve for a model with no discrimination (chance) is a 45 degree diagonal line from the lower left corner to the upper right corner[121,122]. ROC curve analysis is non-parametric and non-prevalence dependent[123], and is therefore useful in falls analysis data.

Multinomial or categorical logistic regression is not as commonly used in fall prediction models. Similar effect measures (odds ratios) are employed for evaluating individual predictors in binomial and multinomial regression; however c-statistic confidence intervals, sensitivity/specificity and ROC plots cannot be generated for non-binary outcome variables, which limits the ability to compare the overall fit of various multivariate models. Furthermore, it is intuitive that larger sample sizes would be required for this type of analysis to ensure adequate modeling power.

Poisson and Negative Binomial Regression

Frequency data has become increasingly common in clinical research[124] notably in the evaluation of falls events in prediction research. Rather than evaluating falls occurrences as binomial or categorical data, counts and/or times (to first fall, between falls etc) can be employed[110]. Frequency data require statistical models such as Poisson or negative binomial regression.

Grimley-Evans (1990) suggested that fall frequencies do not follow a poisson distribution and recommended employing binomial regression comparing non-fallers to recurrent fallers. These recommendations however were founded on a data set wherein gender differences resulted in an excess of heterogeneity in the outcome measures. It was further suggested that Poisson modeling requires that individuals included in analysis be followed for the same length of time. More recently however, Gardner et al. (1995) and Pedan (2001) demonstrated how analysis using both Poisson and Negative binomial models can account for differences in follow-up time[124,125]. Moreover, Pedan (2001) suggested that inspection of goodness of fit statistics be used to evaluate variance and for selection of the appropriate statistical model - moderate overdispersion (where there is greater variability among counts than would be suggested by a Poisson distribution) can continue to employ a Poisson model with use of a correction in the dispersion parameter; if count data are grossly overdispersed then analysis should be conducted using a negative binomial model. Recent publications have employed Poisson regression to evaluate fall risk relating to balance dysfunction (as dictated by performance on clinical tests)[75,106] as well as renal dysfunction and it's treatment[106]. Although fit statistics were not presented, both groups evaluated fall risk in only female populations. Beauchet et al. (2008) also employed Poisson modeling to assess fall risk relating to dual-task walking abilities. Although this group evaluated risk in both genders, univariate logistic regression did not reveal differences due to gender in categorical falls outcomes[126]. However, without fit statistics one cannot determine if the appropriate statistical model was employed in these studies. An important note by Pedan (2001) suggests that the negative binomial model "has greater flexibility in modeling the relationship between the expected value and the variance" than the decidedly limiting Poisson model[124]. Therefore, the negative binomial extension of the Poisson model, which accounts for greater heterogeneity in a population (e.g. one that includes both genders) may be more appropriate in fall-risk assessments.

The effect measure in frequency based models is the incidence rate ratio (IRR) and is obtained by exponentiating the regression coefficient. These measures can be interpreted in a similar manner to odds ratios in logistic regression; for a one unit increase in the predictor variable, the rate ratio of the outcome variable would change by a factor of x, where x is the IRR and all other variables in the model are held constant. Values greater than 1.0 indicate increases, while values less than 1.0 indicate decreases[127]. For example, an IRR of 0.5 for a continuous score on a balance test would suggest that by increasing the balance test score by one point, the rate ratio for falls would decrease by a factor of 0.5. A second example with a categorical predictor like gender and an IRR of 1.5 suggests that females are one and a half times more likely to experience a fall in a given time period compared to males, when all other variables are held constant.

Comparison of the model strength when using multivariate Poisson or negative binomial analysis can be complicated. When models are nested (e.g. model 1(outcome = X) versus model 2 (outcome = X + Y)) a chi-squared evaluation on the likelihood ratio test is valid [128] following the formula $\chi2$=(2*(model 2 log likelihood - model 1 log likelihood)). However, when models are not nested but rather have different predictor variables (e.g. model 1 (outcome = X+Y+Z) versus model 2 (outcome = A+B+C)), only rankings of the models can be achieved, by examination of the Akaike information criterion (AIC values) for example. AIC values are a measure of the goodness of fit of an estimated statistical model. In other words, the lower the AIC value the stronger the model, although direct statistical comparison of their strength is not possible[129].

4.1.5 Purpose and Hypotheses

Most prospective fall prediction models employ only a solitary measure or score, and as yet, there is no single risk assessment tool that is recommended for generalized use in falls prediction [130,131]. The objectives of this exploratory study were: 1) to evaluate standard clinical and general psychological measures, alone or in combination, in their ability to predict prospective fall status 2) to evaluate and compare selected clinical balance measures performed under postural threat and/or cognitive loading with respect to their ability to predict prospective fall status and 3) to determine the value of including task-specific psychological and comorbidity scores in balance measures models for prediction of falls in community-dwelling elderly. It was hypothesized that balance tasks performed under challenging conditions would yield improved fall prediction rates (over that of standard balance measures) by mimicking real-life circumstances where fall-risk may be increased. Furthermore, it was expected that a comprehensive model accounting for a greater number of factors associated with increased fall risk would improve our ability to predict prospective fall status.

4.2 Methods

4.2.1 Participants

Participants were the same as those reported in Study 2: Part 1. Fifty-two elderly participants aged 66-86 (75.31±5.6) living independently in the community were recruited from the Waterloo Research in Aging Participant Pool (WRAP). Participants were excluded if they were unable to stand or walk unsupported (required an assistive device to maintain upright posture or to ambulate). Twenty males and thirty-two females participated. Procedures were approved by the University of Waterloo Office of Research Ethics (ORE #14176).

4.2.2 Procedure

Procedures related to communication with participants and obtaining signed consent (Appendix B), measurements of physiological arousal and questionnaires delivered (Appendix C/D) are outline in Study 2: Part 1.

Participants were required to complete two widely used balance ability and functional mobility tests: the Berg Balance Scale (BBS) and the Timed-Up-and-Go (TUG).

This was followed by the completion of 6 balance tasks under 4 types of challenge, as described in Study 2: Part 1. However, only the more challenging balance tasks were incorporated into the analysis in this study: one-leg stance, tandem stance, functional reach and repeated sit-to-stands. Quiet stance tasks were excluded as they are not sufficiently challenging to related to falls and/or falls risk.

To minimize fatigue, participants were provided with brief rest periods (3-5 minutes) between challenge conditions. During this time, questionnaires were completed that addressed the psychological measures of task-specific balance confidence, perceived stability[132], and fear of falling, as well as condition-specific anxiety. Detailed procedures are outline in Study 2: Part 1. Following completion of the balance tasks under all four challenge conditions, participants were again given the opportunity to ask questions of the investigators and provide feedback regarding their participation in the laboratory component of the study.

Participants then were introduced to the follow-up falls reporting component of the study. Number and conditions of prospective falls were assessed through weekly follow-up letters for a period of twelve months. A fall was defined as an unintentional loss of balance such that hands, arms, knees, buttocks or body touched or hit the ground or floor. Participants were asked to select either regular post or email as a method of communication. Those who preferred regular post were provided with a package including 54 falls information questionnaires (Appendix D) and 13 postage-paid return envelopes. Participants completed one falls information questionnaire per week and forwarded these to the student investigator monthly. Those who preferred email were provided with a sample falls information questionnaire and asked to submit their responses on a weekly basis. Follow-up phone calls from the investigator were required on occasion when submissions were not received and/or to request clarification of questionnaire responses.

4.2.3 Data Collection and Outcome measures

To assess general FOF, a single question was asked employing a percentage scale, where 0% indicated no fear at all and 100% indicated completely fearful, in order to provide participants with a wider range of possible ratings (than previously employed scaling) and consistency of scales across questionnaires (Appendix B/C). To assess levels of general self-efficacy (balance confidence) the ABC was used (Appendix B), which was designed to assess balance confidence in activities of daily living using a 16-item questionnaire, each question rated on a scale of 0% (no confidence) to 100% (completely confident). In order to glean the most information possible regarding comorbidity and known individual fall risk factors (Rubenstein, 2006), a questionnaire was developed (Appendix E) based on the combined Charlson-Deyo and Elixhauser indices and formatted similarly to the self-administered comorbidity questionnaire[104]. An individual received 1-3 points for each of the 35 medical conditions: 1 point for the presence of the ailment, a second point for treatment of the ailment, and a third point for the ailment affecting activities of daily living. Therefore, the maximum score achievable was 105, with higher scores indicating a greater disease burden and greater risk of falls. Comorbidities reported in the "other" category were evaluated for their relationship to fall risk and included in the total if published evidence was found supporting the association[116,133,134].

The BBS (Appendix F) consists of 14 tasks, each rated on a 5-point scale of 0-4, for a total score of 0-56 (higher scores indicative of better performance). The TUG test is scored as a total time to: rise from a chair, walk 3 meters, turn around and return to the original chair to a seated position. Participants were directed to walk as quickly but as safely as possible.

Measures on the four balance tasks were restricted to typical clinical outcome measures only: time on OL and TS to a maximum of thirty seconds, time to completion for STS and maximum distance reached on the FR tests. Details regarding these outcome measures appear in Study 2: Part 1. Trunk displacement and velocity measures were not used to examine fall risk.

Task-specific psychological questionnaires were scored as in previous research; balance confidence was rated on a scale of 0-100% (no confidence – completely confident), state anxiety was a sum of the ratings (9-point scale) on 16 items, and perceived stability was rated on a scale of 0-100% (not stable at all – completely stable)[132,135]. Task-specific FOF was rated on a scale of 0-100% (not fearful at all – extremely fearful) to provide consistency across questionnaire scales.

4.2.4 Statistical Modeling Selection and Data Analyses

Given the possibility for both discrete (non-normally distributed) and continuous independent variables, logistic regression analysis was selected as the most appropriate method of evaluating prediction of group membership, rather than discriminant analysis used for continuous normally distributed predictors or logit analysis used for discrete independent variables[119].

As previously stated, the vast majority of fall prediction literature makes use of binomial logistic regression to evaluate various fall-prediction models. Despite its widespread use however, this method of analysis is limited by its inability to include participants unable to complete the follow-up period and there is some recent evidence to suggest that fall-risk may be more appropriately evaluated using recurrent models with outcome variables that are frequency or time oriented[110]. Recurrent models can make use of all data by evaluating fall rates, and therefore participants unable to complete longitudinal aspects of the study are not excluded from the analyses. Recurrent models are not yet extensively used in the literature however, making comparisons to previous research more challenging. Furthermore, direct comparison of recurrent models using different predictor variables is not possible since measures such as AUC values and their confidence intervals, sensitivity, and specificity cannot be derived for models with non-binary outcome variables. As such, results from both logistic and negative binomial regression approaches will be presented. Chi-squared analysis was performed to examine seasonal effects on fall frequency. Correlation analysis was performed to evaluate the relationship among selected clinical balance measures within each of the four challenge conditions. All statistical analyses were performed using SAS 9.1.3.

Dichotomous Outcome - Logistic Regression Analysis

Univariate binomial logistic regression was used to determine the predictive ability of various balance/mobility and psychological measures, the comorbidity score, as well as participant characteristics (age and gender). Furthermore, the predictive ability of combined balance, psychological and comorbidity measures was evaluated using sequential binomial logistic regression. In order to evaluate the hypothesis that models including balance, psychological and comorbidity measures improve upon models that include only balance measures, the first of multiple runs included only balance measures, the second added psychological measures and the third added the comorbidity score. This method of variable entry was chosen over statistical/stepwise entry due to the small number of outcome events (twenty-nine); Tabachnik and Fiddell (2007) recommend the use of stepwise analysis only when the ratio of cases/outcome events to predictor variables included in the model exceeds 40:1. When the number of cases to predictor variables is less than 40:1, the risk of statistically eliminating a variable significantly correlated to the outcome is high, thereby increasing the risk of drawing faulty conclusions that cannot be generalized beyond the sample population[119].

The outcome measure (falls) was classified as a binary variable, where 0 represented no falls experienced during the follow up period, and 1 represented one or more falls experienced during the follow up period. Thirteen individuals were single-fallers, i.e. individuals who experienced only one fall during the follow-up period. Some researchers would argue that single fallers are more akin to non-fallers than multiple fallers (falls due to exceptional circumstance) [136] and would either exclude these individuals from the analysis or group them with the non-fallers. Others would suggest that single fallers should be grouped with multiple-fallers based on performance of clinical gait tests[52].Upon examination of the questionnaire responses in this data set, the circumstances of the falls for individuals that experienced only one fall appeared no different than those experienced by multiple fallers (Appendix O). Based on this examination and in order to maintain the sample size for analysis, the single-fallers were grouped with multiple fallers. Age was entered as both a continuous variable and as a dichotomy (less or greater than 75 years)[98]; gender was entered as dichotomy (0 for male, 1 for female); all balance performance tests and psychological measures were entered as continuous variables.

Odds ratios and their 95% confidence intervals were examined to evaluate fall risk for univariate balance, psychological and comorbidity scores. Area Under the Curve (AUC) values were also examined, as a measure indicative of combined sensitivity and specificity [122,137] for overall model fit of both univariate and multivariate models. Furthermore, in order to compare the effectiveness and precision of various models, 95% confidence intervals of the AUC value and Receiver Operating Characteristic (ROC) plots were generated[138][1]. ROC curves were further examined to determine cut-off scores for continuous balance measures that best discriminated between fallers and non-fallers (based on the Youden index of overall accuracy as well as the best trade-off (intersection) of sensitivity and specificity)[139].

Frequency Outcome - Regression Analysis

The outcome measure (frequency of falls) was a continuous variable. Age was entered as both a continuous and dichotomized (less or greater than 75 years) predictor; gender was entered as dichotomy (0 for male, 1 for female); all balance performance tests and psychological measures were entered as continuous predictor variables. Where the alpha coefficient (dispersion parameter) was not significantly different from zero (the confidence limits around it included zero), suggesting that the alpha dispersion parameter was not needed, Poisson regression models were employed; otherwise, negative binomial models were employed.

Incidence rate ratios and their 95% confidence intervals were examined to evaluate fall risk for univariate models of balance, psychological and comorbidity scores. For multivariate models, significance was determined using log likelihood comparisons as previously described (comparing the model of interest to the null). Log likelihood comparisons were also made for nested models. AIC rankings were used to compare model strength of non-nested models. AIC

[1] Although seldom presented in fall-prediction literature, Cox and Snell R2 or Nagelkerke R^2 values can be presented as a measure of model fit analogous to R^2 in multiple linear regression although neither have the same variance interpretation as R^2 for linear regression[119]. For the interested reader, these are presented in Appendix N

values corrected for sample size (AICc) were evaluated and are presented throughout, as is important for smaller samples (n/parameter ratio < 40)[140] (n=52, parameters=3 to 5 (intercept, coefficient of the predictor(s), scale parameter); ratios of 10.4-17.3).

4.3 Results

4.3.1 Fall Incidence and Characteristics

Six of fifty-two participants (12%) were unable to complete the 12-month follow-up period (submitted less than 75% of the weekly reports), and were therefore excluded from the binary logistic regression analysis. Those excluded submitted an average of only 23% of the required fifty-two questionnaires. Twenty-nine (63%) of the remaining participants were categorized as fallers (experienced at least one fall). There were 65 falls in total. All fifty-two participants were included in the frequency regression analysis. Thirty-two (62%) of these participants experienced at one fall or more. Nineteen (37%) of the participants experienced more than one fall. There were 71 falls in total. Table 4.2 shows participant characteristics by type of regression analysis and by fall status, on general measures of balance, mobility, fear of falling, balance confidence, health, age and gender; means and standard deviations are presented.

Table 4.2: Participant Characteristic. Mean (SD)

	Binary Outcome (n=46)		**Frequency Outcome (n=52)**		
	No Falls (n=17)	**1+ Falls (n=29)**	**No Falls (n=20)**	**1 Fall (n=13)**	**2+ Falls (n=19)**
BBS	53.82 (1.33)	53.31 (1.73)	53.90 (1.25)	54.00 (1.22)	52.89 (1.85)
TUG	10.71 (2.46)	10.66 (2.20)	10.67 (2.44)	9.99 (1.86)	11.36 (2.46)
GFoF	17.94 (14.48)	25.17 (21.65)	18.50 (13.96)	26.31 (24.42)	25.26 (20.17)
ABC	90.37 (8.45)	87.66 (8.50)	89.78 (8.15)	88.38 (8.71)	86.54 (8..49)
Health	7.12 (3.90)	7.38 (4.44)	6.95 (3.65)	7.38 (5.47)	7.37 (3.85)
Age	77 (5.92)	75 (5.27)	76.80 (5.70)	73.77 (5.47)	74.58 (5.03)
Gender	M=9 F=8	M=10 F=19	M=9 F=11	M=4 F=9	M=7 F=12

Although the greatest number of falls occurred during the winter months, no significant seasonal effects were found (Logistic data (χ^2(3, N = 65) = 6.20, p=0.10), and Frequency data (χ^2(3, N = 71) = 5.56, p=0.13)). Table 4.3 shows fall characteristics by type of regression analysis.

Table 4.3: Fall Characteristics, percentage

Characteristic	**Binary**	**Frequency**
At home	58	55
Outdoors	47	49
Slips	26	27
Trips	25	25
Loss of Balance	22	21
Injuries	35	32
Hospitalizations	3	3
Winter (Dec-Feb)	37	35
Spring (Mar-May)	23	25
Summer (June-Aug)	25	24
Fall (Sep-Nov)	15	16

4.3.2 Fall Prediction using Balance Measures Alone

Univariate regression analyses, regardless of whether binary or frequency outcomes were employed, revealed that none of age, gender, or general health was a significant predictor of fall status/risk. Logistic analysis revealed that Berg Balance Scale (BBS) and Timed-Up-and-Go (TUG) were also unable to discriminate fallers from non-fallers. Moreover, none of the selected individual balance tasks (functional reach distance, one-leg stance time, sit-to-stand completion time, tandem stance time) performed under postural threat and/or cognitive load was able to discriminate fallers and non-fallers, as demonstrated by non-significant odds ratios and AUC values (confidence intervals including 1.0 and 0.5, respectively) (Table 4.4). Similar results were obtained using frequency analysis. However, Poisson regression revealed that increased scores on the BBS (p=0.001) and increased tandem stance times (under cognitive loading alone (p=0.001) as well as combined cognitive loading and postural threat(p=0.003)) were associated with a decreased risk of falls, as demonstrated by significant IRR less than 1.0 (with confidence intervals excluding 1.0) (Table 4.4).

Table 4.4: Univariate regression results for balance measures; NC= No challenge, PC=Postural Threat, CC=Cognitive Loading, P+CC=combined Postural Threat and Cognitive Loading; OR=Odds Ratio, AUC = Area Under Curve Value; IRR=Incidence Rate Ratio, AICc=Akaike Information Criterion; C.I. = Confidence Interval; #Poisson Regression, ^Different result between Negative Binomial and Poisson, *significant

	Binary Outcome Analysis				**Frequency Outcome Analysis**		
Measure	**OR**	**95% C.I.**	**AUC**	**95% C.I.**	**IRR**	**95% C.I.**	**AICc**
BBS	0.80	0.53-1.21	0.58	0.41-0.75	**0.61**#*	0.45-0.82	172.34
TUG	0.99	0.76-1.29	0.50	0.32-0.68	1.03	0.72-1.46	168.26
Reach NC	0.72	0.42-1.12	0.62	0.45-0.78	1.00	0.58-1.75	169.90
Reach CC	0.81	0.49-1.34	0.53	0.35-0.71	0.91	0.47-1.77	166.23
Reach PC	0.65	0.35-1.20	0.62	0.45-0.80	0.80	0.39-1.63	169.52
Reach P+CC	0.72	0.42-1.23	0.63	0.46-0.80	0.79	0.42-1.50	169.38
Time OL NC	1.03	0.95-1.10	0.57	0.39-0.74	0.99	0.90-1.07	160.75
Time OL CC	1.02	0.95-1.10	0.54	0.36-0.72	1.02	0.92-1.12	160.78
Time OL PC	1.03	0.96-1.09	0.58	0.40-0.76	0.98	0.90-1.06	160.61
Time OL P+CC	1.03	0.96-1.10	0.56	0.38-0.74	1.03#	0.97-1.10	152.79
Time STS NC	1.08	0.92-1.27	0.57	0.40-0.74	1.02#	0.89-1.19	163.43
Time STS CC	1.14	0.96-1.35	0.60	0.43-0.77	1.06#	0.93-1.20	160.67
Time STS PC	1.08	0.93-1.25	0.56	0.39-0.74	1.03#	0.92-1.16	163.20
Time STS P+CC	1.09	0.95-1.26	0.61	0.44-0.79	1.02#	0.91-1.15	161.32
Time TS NC	1.11	0.87-1.41	0.50	0.42-0.57	0.97	0.70-1.35	171.87
Time TS CC	1.00	0.82-1.21	0.48	0.39-0.57	**0.82**#^*	0.74-0.93	173.79
Time TS PC	0.99	0.90-1.09	0.42	0.29-0.54	0.96	0.86-1.06	171.21
Time TS P+CC	1.03	0.92-1.15	0.55	0.45-0.66	**0.91**#^*	0.85-0.97	175.55

Multivariate direct logistic regression analysis revealed that the combination of all four selected balance measures within each of the four challenge conditions demonstrated a significant predictive ability with AUC values ranging from 0.7014-0.7833, and confidence intervals that excluded 0.5. However, quasi-separation of the data and questionable model fit resulted for the combined models. Sequential examination of each balance measure revealed that tandem stance time was the perpetrator of quasi-separation (large parameter estimates and standard errors) and removal of this variable resulted in convergence criterion being satisfied. An average of 89% of the participants were able to complete the tandem stance to the maximum of 30 seconds (94% in NC, 92% in CC, 80% in PC, and 88% in P+CC) suggesting that this measure suffered from a ceiling effect, resulting in non-convergence due to cells with too few cases. This variable was therefore eliminated from further analysis. The combination of the three remaining balance measures (functional reach distance, one-leg stance time and sit-to-stand completion time (FR-OL-STS)) within each of the four challenge conditions revealed significant predictive abilities with AUC confidence interval that excluded 0.5 (Table 4.5 left panel). Note that the highest AUC value (and narrowest confidence interval range) was found when balance tasks were performed under the combined postural threat/cognitive loading condition. Results are comparable for models with the three measures entered as continuous variables or using dichotomies derived from the Youden Index of overall accuracy (see table 4.13 for cut-off scores). Frequency analysis using poisson modeling found similar results, demonstrating that the combination of the functional reach distance, one-leg stance time and sit-to-stand completion time within each of the four challenge conditions revealed significant predictive abilities, although the lowest AIC value was found when tasks were performed under cognitive loading alone (table 4.5 right panel).

Table 4.5: Multivariate logistic regression results for selected clinical balance measures; NC= No challenge, PC=Postural Threat, CC=Cognitive Loading, P+CC=combined Postural Threat and Cognitive Loading; AUC = Area Under Curve Value, C.I. = Confidence Interval, AICc=Akaike Information Criterion, * significant.

	Binary Outcome Analysis		**Frequency Outcome Analysis**
Measure	**AUC**	**95% C.I.**	**AICc**
FR-OL-STS NC*	0.74	0.58-0.90	153.72
FR-OL-STS CC*	0.70	0.53-0.87	148.77
FR-OL-STS PC*	0.73	0.56-0.89	154.67
FR-OL-STS P+CC* (continuous)	0.76	0.60-0.91	152.28
FR-OL-STS P+CC* (dichotomies)	0.76	0.61-0.91	149.32

4.3.3 Fall Prediction using Psychological Measures Alone

Univariate regression analysis, using both binary and frequency outcomes, revealed that the Activities-Specific Balance Confidence scale (ABC) was unable to discriminate fallers from non-fallers or estimate fall risk. While binary logistic analysis revealed that general Fear of Falling (GFoF) was unable to discriminate fallers from non-fallers, Poisson regression demonstrated that increased GFoF was significantly associated with an increased risk of falls (p=0.002). Univariate logistic regression showed that none of the condition-specific psychological measures demonstrated the ability to predict fall status when tasks were performed without challenge, with cognitive challenge alone or with postural challenge alone. However, both balance confidence (averaged across FR, OL, STS) and condition-specific anxiety ratings, when tasks were performed under combined postural threat and cognitive load, could predict prospective fall status with significant odds ratios and AUC values (confidence intervals excluding 1.0 and 0.5, respectively) (Table 4.6).Using frequency outcomes for condition-specific psychological measures, univariate Poisson regression analysis generally appeared to be a better model fit than the Negative Binomial. Results showed that increased balance confidence (except under postural threat alone) and perceived stability were associated with reduced risk of falling, while increased anxiety and fear of falling (under postural threat as well as combined postural threat and cognitive loading) were associated with an increased risk of falling (Table 4.6).

Table 4.6: Univariate regression results for psychological measures; NC= No challenge, PC=Postural Threat, CC=Cognitive Loading, P+CC=combined Postural Threat and Cognitive Loading; OR=Odds Ratio, AUC = Area Under Curve Value; IRR=Incidence Rate Ratio, AICc=Akaike Information Criterion; C.I. = Confidence Interval; #Poisson Regression, ^Different result between Negative Binomial and Poisson, *significant

	Binary Outcome Analysis				**Frequency Outcome Analysis**		
Measure	**OR**	**95% C.I.**	**AUC**	**95% C.I.**	**IRR**	**95% C.I.**	**AICc**
ABC	0.96	0.88-1.04	0.61	0.43-0.79	0.92	0.86-1.00	168.51
GFoF	1.02	0.99-1.06	0.57	0.42-0.74	**1.03#***	1.01-1.06	173.63
Confidence NC	0.96	0.92-1.01	0.64	0.47-0.80	**0.95#^***	0.92-0.99	172.67
Confidence CC	0.99	0.96-1.02	0.57	0.38-0.77	**0.97#^***	0.94-0.99	167.24
Confidence PC	0.99	0.96-1.03	0.54	0.35-0.73	0.97	0.93-1.01	167.62
Confidence P+CC	**0.97***	0.94-0.99	**0.69***	0.53-0.84	**0.96#***	0.94-0.98	167.84
Stability NC	0.97	0.92-1.01	0.62	0.46-0.79	**0.96#***	0.94-0.98	172.69
Stability CC	0.98	0.95-1.03	0.54	0.36-0.73	**0.96#^***	0.94-0.99	173.82
Stability PC	0.97	0.93-1.01	0.61	0.45-0.78	**0.95#***	0.92-0.98	170.91
Stability P+CC	0.97	0.93-1.01	0.64	0.48-0.81	**0.95#***	0.92-0.97	168.69
Anxiety NC	1.01	0.93-1.09	0.57	0.39-0.74	**1.11***	1.02-1.19	165.55
Anxiety CC	1.02	0.97-1.08	0.63	0.45-0.81	**1.05#***	1.02-1.09	171.01
Anxiety PC	1.03	0.98-1.08	0.60	0.42-0.77	**1.05#***	1.03-1.08	169.74
Anxiety P+CC	**1.07***	1.01-1.14	**0.72***	0.56-0.88	**1.09#***	106-1.13	156.88
Fear NC	1.02	0.96-1.07	0.55	0.38-0.72	1.02	0.96-1.08	165.82
Fear CC	1.01	0.96-1.07	0.51	0.34-0.68	1.03	0.97-1.09	168.90
Fear PC	1.04	0.99-1.10	0.59	0.43-0.76	**1.04#***	1.02-1.07	170.76
Fear P+CC	1.04	0.99-1.09	0.61	0.44-0.77	**1.06#***	1.03-1.08	168.29

4.3.4 Fall Prediction using Combined Balance, Psychological and Health Measures

Multivariate logistic regression revealed that combination models of Berg Balance Scale (BBS) or Timed-Up-and-Go (TUG) paired with either the Activities-Specific Balance Confidence scale (ABC) or general fear of falling (GFoF) were not able to discriminate fallers from non-fallers. Moreover, the addition of the comorbidity/health score did not improve the predictive ability to significant levels. Frequency analysis demonstrated comparable results where no combination of the aforementioned measures resulted in a significantly increased or decreased risk of falls based on log likelihood comparisons to the null model (Table 4.7).

Table 4.7: Multivariate logistic regression results of standard clinical and general psychological measures in combination; AUC = Area Under Curve Value, C.I. = Confidence Interval, AICc=Akaike Information Criterion, #Poisson Regression

	Binary Outcome Analysis		**Frequency Outcome Analysis**
Measure	**AUC**	**95% C.I.**	**AICc**
BBS + ABC	0.62	0.45-0.79	171.66#
BBS + ABC + Como	0.61	0.44-0.78	174.00#
BBS + GFoF	0.57	0.40-0.74	171.38#
BBS + GFoF + Como	0.59	0.42-0.76	173.64#
TUG + ABC	0.62	0.44-0.80	167.31
TUG + ABC + Como	0.60	0.42-0.78	169.78
TUG + GFoF	0.61	0.44-0.78	172.41#
TUG + GFoF + Como	0.61	0.44-0.78	174.71#

In order to evaluate the hypothesis that multivariate models including task-specific balance, psychological, and health measures would better predict falls than univariate balance models, individual measures were selected for their strength based on univariate analysis results; functional reach distance (performed under combined postural threat and cognitive loading) demonstrated the highest AUC value in logistic regression (0.63), while one-leg stance time (performed under combined postural threat and cognitive loading) demonstrated the lowest AIC value in frequency based regression (152.79). Moreover, effects of postural threat were greatest for reach distance followed by one-leg stance times (based on effect sizes presented in Appendix L). Balance confidence was selected as the psychological measure of interest for three reasons: 1) condition-specific balance confidence demonstrated significant predictive ability for falls status, 2) task-specific balance confidence was measured (as compared to anxiety which was estimated as an average across tasks) and 3) of all the psychological measures, balance confidence was most affected by postural threat (based on effect sizes presented in Appendix L).

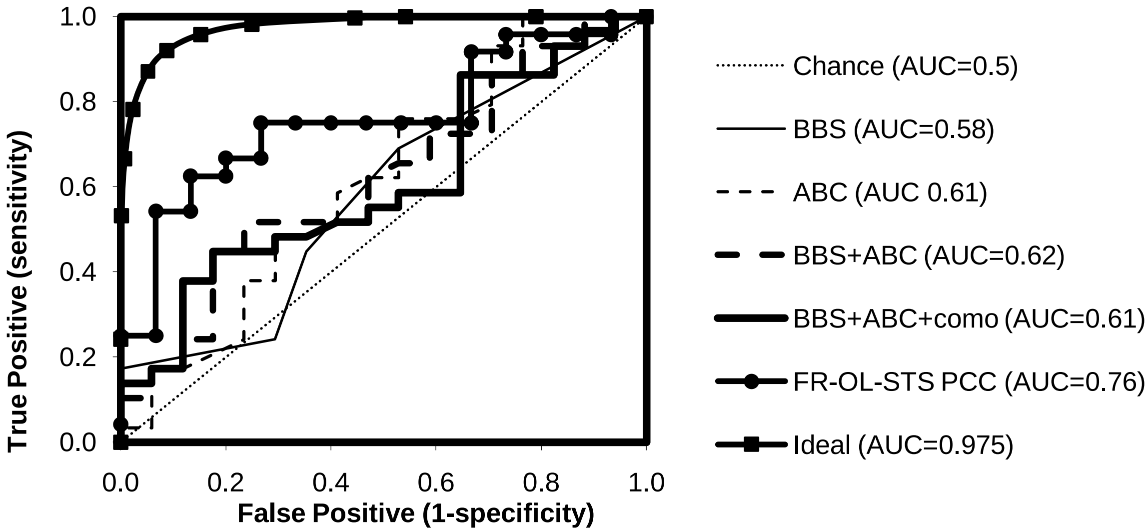
Multivariate logistic regression revealed that AUC values moved from non-significant with reach distance only (0.63) to significant with reach distance and confidence combined (0.72). The addition of the comorbidity score further improved the AUC value (0.74), although paired contrasts show the models to be statistically equivalent. When selecting the arbitrary minimum of 75% sensitivity, the specificity is improved from 46% in the balance only model, to 50% in the balance and psychological measures model. The sensitivity remains at 50% when the comorbidity score is included. Although AUC values and specificity for the multivariate models are higher than the one-leg stance time univariate model, none demonstrate significant predictive ability. It is interesting to note that AUC values are comparable between the univariate reach confidence model and the multivariate reach distance combined with reach confidence model with higher specificity achieved in the univariate model. Frequency analysis and log likelihood comparisons of nested models showed no improvement in the ability of the model to predict fall risk with either the addition of balance confidence or the addition of balance confidence and comorbidity scores to the balance only model (Table 4.8).

Table 4.8: Multivariate logistic regression results of reach distance or one-leg stance time paired with task-specific confidence when performed under combined postural threat and cognitive load; AUC = Area Under Curve Value, C.I. = Confidence Interval, Sens=sensitivity, Spec=Specificity, AICc=Akaike Information Criterion, #Poisson Regression, *significant

	Binary Outcome Analysis			**Frequency Outcome Analysis**
Measure	**AUC**	**95% C.I.**	**Sens/Spec**	**AICc**
Reach Distance	0.63	0.46-0.80	0.75/0.46	169.38
Reach Confidence	0.73*	0.58-0.88	0.75/0.55	168.61#
Reach + Confidence	0.72*	0.57-0.87	0.75/0.50	169.15#
Reach + Confidence + comorbidity	0.74*	0.59-0.88	0.75/0.50	170.60#
One-leg Time	0.56	0.38-0.75	0.75/0.31	152.79#
One-leg Confidence	0.54	0.36-0.73	0.75/0.35	165.98
One-leg + Confidence	0.60	0.41-0.78	0.75/0.50	150.70#
One-leg + Confidence + comorbidity	0.62	0.43-0.80	0.75/0.44	151.46#

ROC curves, derived from binary logistic regression analysis, and generated for selected predictive models are presented in Figure 4.1. This figure illustrates, across the pairings of sensitivity and specificity, that standard clinical balance (BBS) and general psychological (ABC) measures had poor fall prediction abilities (non-significant AUC values). Moreover, no significant improvement in discriminative ability was revealed when employing multivariate logistic regression analyses evaluating combinations of the aforementioned scores with or without the comorbidity/health score. However, selected challenging balance measures (performed under combined postural threat and cognitive load; FR-OL-STS PCC) yielded a clearly improved and significant fall prediction capability (more closely approximated the ideal curve) (A). The addition of reported balance confidence ratings to reach distance (as compared to reach distance alone) resulted in noticeably improved sensitivity at high levels of specificity, and moved the model from non-significant to significant in its ability to distinguish fallers from non-fallers. The addition of comorbidity scores to this combined model resulted in little noticeable improvement to predictive ability, although this model evaluating combined balance, psychological and health measures achieved the highest overall model effect size (B).

A



B

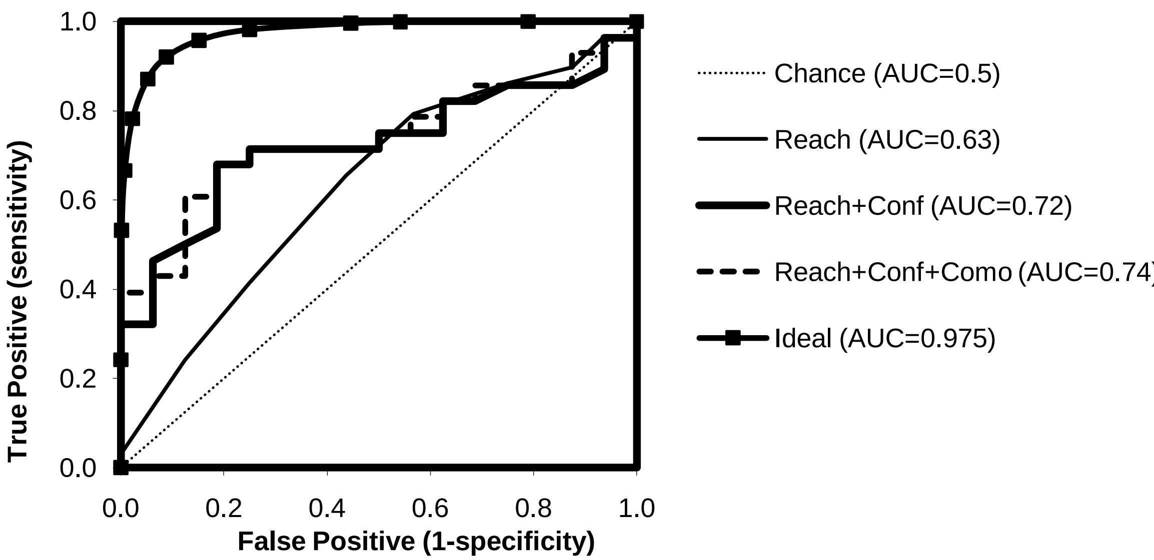


Figure 4.1: Receiver Operator Curves for selected fall prediction models: A - BBS=Berg Balance Scale, ABC=Activities-Specific Balance Confidence, como=comorbidity score; B - Reach=reach distance, Conf=balance confidence, como=comorbidity score.

Correlations among selected balance measures (reach distance, sit-to-stand (STS) time, and one-leg stance (OL time)) within challenge condition are presented in tables 4.9-4.12 and show that no balance measure is significantly correlated with another. ROC cut-off scores for selected balance measures are presented in table 4.13.

Table 4.9: Correlations among balance measures without challenge. Pearson coefficient (p value)

Measure	OL time	STS time	Reach Distance
OL time	1.0	-0.215 (0.17)	0.024 (0.87)
STS time		1.0	0.036 (0.81)

Table 4.10: Correlations among balance measures with cognitive challenge. Pearson coefficient (p value)

Measure	OL time	STS time	Reach Distance
OL time	1.0	-0.070 (0.64)	0.054 (0.72)
STS time		1.0	0.052 (0.73)

Table 4.11: Correlations among balance measures with postural challenge. Pearson coefficient (p value)

Measure	OL time	STS time	Reach Distance
OL time	1.0	-0.187 (0.21)	0.185 (0.21)
STS time		1.0	-0.026 (0.86)

Table 4.12: Correlations among balance measures with cognitive and postural challenge combined. Pearson coefficient (p value)

Measure	OL time	STS time	Reach Distance
OL time	1.0	-0.150 (0.32)	0.082 (0.59)
STS time		1.0	-0.014 (0.92)

Table 4.13: Cut-off scores that best discriminate fallers from non-fallers

Index	OL time	STS time	Reach Distance
Sensitivity-Specificity	15.5s	15.0s	9.8cm
Youden	16.0s	16.2s	11.5cm

4.4 Discussion

The objective of this exploratory study was to evaluate and compare various univariate and multivariate models for fall prediction with variables including clinical balance and mobility tests, generalized and task-specific psychological measures, as well as comorbidity scores. It was hypothesized that balance tasks performed under challenging conditions would yield improved fall prediction rates, over that of standard balance measures, by mimicking real-life circumstances where fear of falling and fall-risk may be increased. Furthermore, it was expected that a more comprehensive model accounting for a greater number of factors associated with increased fall risk would improve our ability to predict prospective fall status. Results indicated that standard clinical balance and generalized psychological measures, independently or in combination could not predict future falls. However, a combination of three more difficult balance tasks could identify individuals at risk for falls, and increased predictive precision resulted when these tasks were performed under conditions of increased challenge. Inclusion of health scores in various models demonstrated minimal improvements to predictive ability.

4.4.1 Fall Incidence and Characteristics

Recent publications report fall incidence rates in community-dwelling elderly ranging from 15-48%[1,14,66,76,130] with 49-63% resulting in injuries[14,66], and 2.5-4% resulting in hospitalization [1,130,66]. Our research found a higher incidence rate of 62-63%, a lower injury rate of 35-37%, and a comparable hospitalization rate of 3%. Although initially surprising, the incidence rate discrepancy can be explained by methodological differences in the prospective falls analysis. The 15% incidence rate reported by Laessoe et al. (2007) was likely severely underestimated as participants were contacted following 6-month intervals and asked to report any falls experienced during that period[76]. Studies evaluating the accuracy of remembering falls events in elderly argue that this methodology is inadequate as recall diminishes over time and results in underreporting of occurrences[34-36]. The current research required participants to report weekly, with instructions to complete a detailed questionnaire as soon after the incident(s) as possible. Delbaere et al. (2006) reported an incidence of 33.5% and used daily calendars which were mailed monthly to the investigators. In this case, participants were contacted following receipt of the calendar by the investigator, at which point the participant was asked to recall details of the event(s)[14]. Although superior to the methodology of Laessoe et al. (2007), this process still relies on recall over periods greater than one month (with delays in submission, mailing and contact with the participant). Participants of the current study were asked to complete a falls questionnaire reporting both falls and near falls and providing all relevant details as soon after the event as possible, thus reducing the likelihood of forgotten details, and allowing the investigators to determine if a "true" fall was experienced based on the operational definition. However, despite clearly written instructions, there is no method to ensure that participants who chose to report via regular post completed their questionnaires on a weekly basis, as participants were directed to submit responses in monthly batches to minimize envelope consumption and reduce mailing costs. Although the current methodology is thought to be superior to long-interval recall interviews and calendars, fall incidences and especially near-fall incidences were still likely under-reported.

4.4.2 Fall Prediction Using Standard Clinical and General Psychological Measures

In contrast to the research by Shumway-Cook et al. (1997) in which the Berg Balance Scale was used to distinguish fallers from non-fallers with 77% sensitivity and 86% specificity[33], our results show that this test could not be used to predict fall status (69% sensitivity, 47% specificity, and AUC of 0.58). This difference may be explained by disparities in sample populations. In the Shumway-Cook sample, fallers scored significantly lower on the BBS (40/56) as compared to non-fallers (53/56). The current sample found that both fallers and non-fallers scored very high on the BBS (53/56 and 54/56, respectively). Furthermore, the Shumway-Cook article reported that 23% of fallers used assistive devices, where the current study excluded individuals that could not stand or walk unsupported. Moreover, because of the homogeneous nature of the BBS scores in our sample, we could not cluster our data using a standardized cut-off score and employ a dichotomous value in the predictive model, as in previous research. We observed a ceiling effect for the BBS in our sample, and suggest that this scale cannot be used to evaluate or predict fall- risk for the independent community-dwelling individuals from which our sample was drawn.

Lin et al. (2004) evaluated the Timed-Up-and-Go, one-leg stance, and functional reach tests for fall prediction in community-dwelling individuals[48]. Their results demonstrated poor predictive ability as shown by non-significant odds-ratios and near-chance AUC values (0.61, 0.53, and 0.51, respectively). The current data support these findings having similar non-significant odds-ratios and AUC values (0.50, 0.57 and 0.62, respectively).

The current data support the work of Hotchkiss (2004)[99] suggesting that the ABC cannot predict falls in healthy community-dwelling elderly. Their data report that only 1% of model variance in predicting fall history is accounted for by the ABC score. Our data result in a non-significant AUC value of 0.61. In contrast, the current data are not supportive of the claim by Lajoie (2004) that the ABC can distinguish fallers and non-fallers[38]. In their work, fallers scored significantly lower than non-fallers (48% and 85%, respectively), while our data show similar confidence ratings between the groups (90% and 80%, respectively). Again, sample differences may explain these diverging results; the current work recruited from a pool of community-dwelling individuals, while the Lajoie group also included individuals from senior residences and institutions. Furthermore, no delineation of the proportion of fallers to non-fallers within each group of individuals was provided - it is possible that only a small portion of the fallers were community dwelling individuals. Huang et. al. (2009) reported that both the ABC and FES suffered ceiling effects in community dwelling older adults[141]. Similarly, given the homogeneity of ABC scores within our sample, we suggest that the ABC cannot be used to predict falls for community-dwelling elderly.

Delbaere et al. (2006) suggested that general fear of falling was a significant predictor of falls with an odds-ratio of 3.25[1414,117]. Our data report non-significant odds ratio (1.022) and AUC (0.58) values. Although sample populations appear similar, methodology and statistical analyses differed. The Delbaere group evaluated fear of falling using a 4-point Likert scale and predicted falls to a combined retrospective-prospective outcome measure comparing non-fallers to frequent fallers, while the current work evaluated fear of falling using a continuous scale and predicted falls to a binomial prospective outcome measure (fallers compared to non-fallers). It is therefore difficult to directly compare the findings. It may also be that this data set is simply underpowered to detect the influence of fear of falling using binary logistic regression[123].

The current results demonstrate that neither age nor gender can predict prospective falls status. Although women were more likely than men to experience a fall (OR 2.25) the difference was non-significant. This agrees with the results of Shumway-Cook (1997)[33] but contrasts the results of Delbaere (2006)[14] which suggest that both increasing age and being female significantly increase fall risk. Again however, statistical difference and sample size differences (46 vs. 257) may explain the disparate findings.

It was hypothesized that regression combining balance, psychological, and comorbidity scores would lead to improved prediction ability. However, when standardized balance/mobility and general psychological measures were combined, with or without the comorbidity score, effect size values remained non-significant, demonstrating that these measures cannot be used to predict fall risk in this group of community-dwelling elderly.

4.4.3 Fall Prediction Using Challenging Balance and Task-Specific Psychological Measures

Selected balance measures collected under challenging conditions performed no better than standard clinical balance scales for fall prediction, when examined individually. However, when three balance scores were combined (reach distance, one-leg stance time and repeated sit-to-stand time) significant AUC values were found under each challenge condition (no challenge, cognitive load, postural threat, as well as combined postural threat and cognitive load). Although these tasks are components of the BBS, and it may seem perplexing that improved prediction ability was found, the discrepancy can be explained by the ceiling effect from which the BBS suffers in this population. Examination of AUC values and AUC confidence intervals of the combined score models in each challenge condition, as well as planned contrast results, reveal that no one model is significantly better than another. However, the combined postural threat and cognitive loading conditions results in the highest combined sensitivity and specificity and the narrowest confidence interval range, indicating greater predictive precision. Although this result will need to be replicated in a larger sample, this data provides evidence that evaluating performance under combined postural threat and cognitive load may better predict prospective fall status. Using regression with a frequency outcome, the smallest effect size was found for the model wherein the three aforementioned balance scores were combined and performed under dual-tasking conditions. This results supports the findings of Zijlstra et al. (2008) where, in their review of dual-tasking literature with a focus on differentiating elderly fallers and non-fallers, the authors pointed to evidence suggesting that dual-tasks may have an advantage over single-task balance assessments in predicting future falls[142]

Performance on functional reach, one-leg stance, and the five-times sit-to-stand task were unrelated. Functional reach can be thought of as a measure of limits of stability, one-leg stance a measure of lateral stability, and the sit-to-stand a measure of lower limb strength or functional mobility. Correlations were insignificant, and suggest that performance on one task does not predict or dictate performance on another.

Individually, performance scores on functional reach, one-leg stance, and repeated sit-to-stand tasks could not predict fall status. However, when all three were entered into a direct multivariate logistic regression model, fall-status was significantly predicted. Correlation results suggest that these tasks measure distinct aspects of balance control, and therefore together may provide a more comprehensive assessment of balance. Moreover, these measures did not suffer ceiling effects in this population of community-dwelling elderly, performed better than the BBS (or TUG) for predicting fall status, and would require less time to administer than the full 14-item BBS. A similar study by Muir et. al. (2010), found that one-leg stance times (dichotomized with a cut-off of 10 seconds) and reach distances (dichotomized with a cut-off of 24.5cm) independently could predict fall-risk. A composite (the summed number of balance tests with impairments ranging from 0-4) could also significantly predict falls. Additionally, as the number of balance tests demonstrating impairment increased, the risk of experiencing a fall increased[71]. Taken together, these data would suggest that a composite of performance on three or four simple tasks, as compared to any individual measure, may be most useful for fall-risk screening tools.

When evaluated under combined postural threat and cognitive load, task-specific balance confidence (for functional reach), as well as condition-specific balance confidence and anxiety (averaged across FR-OL-STS tasks) demonstrated the ability to predict prospective fall status. This noteworthy finding provides strong evidence to support the notion that psychological state plays a significant role in determining whether or not an individual is likely to experience future falls and is an important factor to include in risk-assessment models.

The addition of task-specific psychological scores to models evaluating only balance measures resulted in increased effect size and demonstrated a significant ability to distinguish fallers from non-fallers. Although there was little further improvement by also including the health/comorbidity score, the highest logistic effect size value combined with the most precise coinciding confidence interval was achieved by including balance, psychological and health scores into the model. These results provide preliminary evidence supporting the inclusion of both psychological and health-status measures in fall-risk screening tools.

4.4.4 Statistical methods selection

Most researchers would agree that the choice of statistical tool depends on the data as well as the question being asked. In the case of fall prediction with discrete binomial or multinomial outcomes, logistic regression is more appropriate than linear or ordinary least square regression because it is not restricted by assumptions of normality[119]. Furthermore, one might select binary logistic regression (for a dichotomous outcome) in order to compare results to much of the existing literature. More recent evidence would suggest that statistical tools accounting for recurrent outcome events may be more suitable for fall prediction[110], although which model is most appropriate is, as yet, unclear. Negative binomial and Poisson models can be applied to count or frequency outcomes, although the choice between them depends on the relationship between the outcome and predictor variables in the data set (i.e. the interplay between conditional means and variances)[143]. It is also worth noting that frequency models are not recommended for small data sets, although what is considered small is not clearly defined in the literature[144]. Signorini (1991) suggests that for a univariate Poisson model and a mean outcome rate of 1.0 (the current data demonstrates a mean rate of 1.6) sample sizes required to detect incidence rate ratios of 0.5 and 1.5 are 29 and 52, respectively (with 5% significance and 95% power). In order to detect rate ratios closer 1.0 (smaller changes in risk) much larger samples are required, ranging from 1000-1100[145]. With the current sample therefore, we are not likely adequately powered to detect the significant changes in rate ratios seen for the univariate psychological measures models, although we can with a modicum of certainty suggest that increasing scores on the BBS are related to a reduction in fall risk.

In order to identify individual factors which affect fall risk, and the degree to which they do so, it may be important to employ recurrent or frequency models and evaluate rate ratios. However, it may be more appropriate to ask whether or not performance on a given task (or set of tasks) and/or ratings on self-administered questionnaires can identify individuals who are expected to fall, regardless of whether they are likely to experience one fall or multiple falls. Therefore, for development of clinically useful screening tools it may be best to employ binary logistic regression.

4.5 Limitations

The most salient limitation of this study was the relatively small sample size and number of outcome events (falls) experienced by the participants. These findings will need to be replicated in other samples of community-dwelling elderly individuals. Future large scale studies, with number of fallers and non-fallers exceeding 100 each, may be better able to compare the various fall-prediction models presented as a result of reduced confidence interval bounds and thereby improved power in the analysis [123]. Furthermore, although the sample of individuals was drawn from a large pool of community-dwelling elderly, it's representativeness may be questionable. The nature of the recruiting process for the participant pool (potential/interested participants contact recruiters based on information contained in posters, flyers, and radio/newspaper advertisements) suggests that the sampled individuals are likely the more active, healthy, and higher-functioning of the community-dwelling elderly population. This supposition is supported by the high scores on the clinical balance scales and Activities-Specific Balance Confidence scale as well as low scores on the comorbidity index and general fear of falling scale. Recruitment through insurance or medical databases may yield a more representative sample of community-dwelling individuals, reporting a greater range of clinical balance, psychological and comorbidity scores. Moreover, due to ethical constraints relating to the perceived safety of the participants, it is thought that reported fear of falling was severely underestimated, a notion supported by anecdotal reports during debriefing periods. Therefore, it is very likely that sampling and ethical restrictions limited the potential influence of psychological measures and comorbidity scores, and the resultant outcomes for various fall-prediction models.

Several studies have shown relationships between various individual comorbidities (or their treatments) and falls[1,2,4-6,14,82,105-109]. We are unaware however of any fall-risk identification models that include a comprehensive comorbidity assessment. The health questionnaire developed for use in this work was based on well known comorbidity assessments often used to assess disease burden and risk of mortality in patient populations[101]. However, it is likely that refinement is required to improve ease of understanding/use. Moreover, the scoring method treats all conditions equally, and fall-risk may be influenced by different factors to varying degrees. It is however, beyond the scope of this dissertation and expertise of the researchers to assign weightings to the risk factors included, and future work will need to address this issue. There are a small number of publications that may help guide this process: Swift (2006) highlighted the need to include in-depth medical assessments in fall prevention programs and suggested a focus on the following medical factors: circulatory disorders, visual problems, lower limb weakness, peripheral neuropathic signs, balance impairment (one-leg stance performance), impaired cognition, and depression[146]; De Breucker et al. (2007) suggested the following medical conditions as those most relevant in assessing fall-risk: arthritis, history of stroke, orthostatic hypotension, dizziness, anemia, visual acuity, hearing assessment, extremity deformity/neuropathy, and carotid sinus hypersensitivity[147]; finally, Lord et al. (2007) identified the following medical factors as associated with falls: impaired cognition, stroke, Parkinson's disease, depression, abnormal neurological signs, incontinence, arthritis, foot problems, dizziness, orthostatic hypotension, and vestibular disorders[148]. An updated review of the literature regarding comorbidities, focused on identifying conditions with strong and reliable associations with increased fall-risk, would also be helpful in the refinement of the comorbidity assessment questionnaire.

4.6 Conclusions

Supporting our hypotheses and the supposition of Pijnappels et al (2010) that models including a "more comprehensive range of medical and psychological factors" would better predict fall-risk[149], our data show that including task-specific psychological and comorbidity scores with challenging balance measures improves the precision with which we are able to identify community-dwelling elderly individuals likely to fall. This also agrees with the vast body of literature illustrating the multifactorial nature of causes for falls and demonstrating correlations between fear of falling and/or disease burden with fall-risk.

Chapter 5

Study 3: Validity and reliability of psychological measures related to fear of falling in older community-dwelling individuals

5.1 Introduction

Fear of falling (FOF) is common in elderly individuals. Lach (2005) found that more than fifty percent of community dwelling elderly individuals reported having a FOF, although nearly a quarter of those had not previously experienced a fall[1]. Zijlstra et al. (2007) reported a similarly high prevalence of FOF (54%) in community-dwelling elderly and also found that nearly forty percent of those individuals curtailed their activities of daily living as a result of their fear[2]. Age-related changes in sensory and motor systems leading to a decline in balance control are associated with an increased risk of falls[3]. Activity restriction due to fear of falling may accelerate the inevitable decline in physical function and further increase the risk of falls[4].

Over the last 30 years, increasing attention has been devoted to psychological issues as they relate to falls with a handful of constructs emerging as the most studied and widely-recognized; fear of falling, falls efficacy and balance confidence[5]. Despite increased devotion to measurement of psychological issues, consensus among researchers and/or clinicians has not been reached regarding a criterion measure or benchmark tool to assess psychological factors as they relate to falls and fall-risk.

Fear of falling has been and continues to be measured with single-question formats such as "Are you afraid of falling (falling again)" and assessed using a variety of scales: 4-point Likert scales (not at all/never, a little/almost never, quite a lot/sometimes, and very much/often or very often)[2,61], 3-point Likert scales (very fearful, somewhat fearful, and not fearful)[1], and a dichotomized scales (yes or no)[7]. Although efficient from a clinical perspective, single question methods for gauging general affects such as fear have been criticized for being poor predictors of behaviour and may not adequately reveal the influences of such fear on activities of daily living[5,8-12]. As a result, a number of multi-item measures have been developed to assess fear across a variety of situations. Such scales include the Survey of Activities and Fear of Falling in the Elderly (SAFFE, sometimes labeled SAFE) and modified versions thereof (mSAFFE), the University of Illinois at Chicago Fear of Falling Measure (UIC FFM), and the Geriatric Fear of Falling Measure (GFFM)[5].

Falls efficacy, defined by Tinetti et al (1990) as the confidence in one's ability to perform activities of daily living without falling, has been most commonly measured using the 10-item Falls Efficacy Scale (FES) and a host of modified versions including the FES-International (FES-I 16-item and 7-item), the 10-item Amended FES (amFES), the 16-item Revised FES (rFES), and the 14-item Modified FES (mFES)[5]. While the response format of the FES, rFES and mFES address falls efficacy as defined above, the amFES and FES-I were modified to employ a 4-point scale and address the level of concern about falls.

Balance confidence, defined by Powell and Myers (1995) as the confidence in one's ability to maintain balance and remain steady across a variety of tasks has been measured using the 16-item Activities-specific Balance Confidence Scale (ABC), a shortened version (ABC-6), a modified 16-item ABC (using a 21-point scale), and the 20-item Balance Self-perceptions Test[5].

Jorstad et al. (2005) presented one of the earliest systematic reviews evaluating the measurement properties of psychological tools assessing constructs relating to fear of falling, identifying 23 different measures. Their findings indicated that external validity (generalisability to community-dwelling elderly) of the scales might be questionable due to lack of adequate experimental control. Moreover, the authors suggested that use of terminology like "worry", "concern", "troubled" or "bothered" in a number of the tools (e.g. SAFFE, UIC FFM, GFFM, FES) may also compromise construct validity, in that these constructs may not be synonymous with fear. Moore and Ellis (2008) presented another systematic review of the aforementioned psychological measures. They focused on publications (1966-2006) in which the sample comprised independent community-dwelling elderly, and addressed measurement properties of the various scales including reliability and validity. Based on their review of the research, the authors identified the mFES, the FES-I and the ABC as forerunners (pending more research support) in addressing falls efficacy and balance confidence constructs. The authors could not suggest a validated and clinically feasible measure to address the fear of falling construct. Furthermore, the authors highlight that much of the published literature misuses fall-related psychological instruments by measuring constructs other than those the instruments were designed to assess. In other words, labels such as fear of falling and reduced balance confidence have been used interchangeably creating much confusion in the literature. To confirm this assertion, a search of items published in the last 5 years (2006-2011) using the PsychINFO and MEDLINE databases with "fear of falling" in either the keywords or title identified 415 publications, with 224 in peer-reviewed journals. Ninety-six of the 224 articles quantitatively assessed fear of falling itself or a construct relating to fear of falling. Fifty-seven of these reported measuring fear of falling and did in fact measure fear (25 using dichotomies, 5 using visual analog scales and 27 using Likert scales). Five articles had "fear of falling" as a keyword, but measured a related construct using the appropriate tool (e.g. balance confidence using the ABC). However, thirty-four articles (greater than one third) reported measuring "fear of falling" when in fact a tool was used that assessed a related but distinct construct (e.g. confidence, concern, efficacy, worry). Therefore, despite published evidence showing that fear is not synonymous with constructs including but not limited to, efficacy, confidence, worry and anxiety[13-22], and the accessibility of systematic reviews highlighting the need to use appropriate terminology and measurement tools[5,23,24], researchers continue to misuse or misrepresent fall-related psychological assessment tools. Moreover, review articles highlight that there are few publications that make comparisons of the various tools and their measurement properties, which limits the researcher's ability to identify the most relevant and feasible tool to implement[5,23].

In addition to the notion that fall-related psychological constructs are related but distinct, there is also evidence to suggest that these measures are task-specific[21,25] and it has been recommended that fall-related psychological outcomes be assessed in a task or context-specific manner[5]. Previous research evaluating the effects of postural threat on balance control and psychological set have employed task-specific measures of balance confidence, perceived stability, state anxiety, and fear of falling[19-21,26,27]. While these measures have shown moderate to strong reliability in healthy young adults[21], the reliability and validity of these measures in older populations has not been established. Moreover, the relationship between state-specific and other generalized measures of fear, anxiety and balance confidence has not been examined previously.

Therefore, the goal of this study was to explore the validity and reliability of measures used previously in this dissertation. Specifically, these aims included: 1) evaluating the experimental validity of previous results (unpublished data in Chapter 3) by determining if the effects of postural threat and cognitive loading on clinical balance performance and measures of psychological state could be replicated in a second sample of older adults 2) to calculate the test-retest reliability of clinical balance and psychological measures under different threat conditions in older adults 3) to examine the construct validity of psychological measures under different threat conditions in older adults and 4) to evaluate the internal consistency and dimensionality of the multi-item psychological measures: specifically, the task-specific state anxiety questionnaire measured across both young and older adults, as well as the Activities-specific Balance Confidence Scale measured in older adults.

5.2 Methods

5.2.1 Participants

Thirty-two elderly participants aged 65-89 (73.09±6.17 years) living independently in the community were recruited from the Waterloo Research in Aging Participant Pool (WRAP). Participants were excluded if they were unable to stand or walk unsupported (i.e. required an assistive device to maintain upright posture or to ambulate). Seven males and twenty-five females participated. Procedures were approved by the University of Waterloo Office of Research Ethics (ORE #14176). These individuals had not previously participated in this or similar studies and were therefore naive to the apparatus, measurement tools, and procedures used in the experiment. The chosen sample size was consistent with that reported in the published literature for evaluation of test-retest reliability[28].

5.2.2 Procedure

Participants were provided with an information letter outlining the testing procedures, risks and benefits of participation, and the commitment required. The participant received the information letter at least one week in advance to their scheduled participation. Upon arrival at the testing facility, participants were given the opportunity to ask questions of the investigators and invited to sign a consent form if he/she agreed to participate (Appendix B).

All participants completed general fear of falling (FOF), balance self-efficacy (ABC), and co-morbidity/health questionnaires (Appendix C/D). Retrospective falls status was evaluated by asking participants if they had experienced one or more falls within the previous 12 months (Y/N binary variable).

Two clinical balance tasks that are considered to be more difficult (due to reduced base of support or challenge to the limits of stability) and were most affected by postural threat (unpublished data in Chapter 3) were selected as balance tasks of interest: (1) one-leg stance (OL) and (2) functional reach (FR). Participants were required to complete both balance tasks under 4 types of challenge: (1) no challenge (NC), in which balance tasks were performed at floor level, (2) postural challenge/threat (PC), in which balance tasks were performed on an elevated surface (50cm), (3) cognitive challenge/loading (CC), in which balance tasks were performed at floor level while silently rehearsing a list of grocery items, and (4) combined postural and cognitive challenge (P+CC), in which balance tasks were performed on an elevated surface while silently rehearsing a list of grocery items. Presentation of the 4 challenge conditions was randomized to control for order and learning effects. Procedures for the performance of each balance task under each challenge condition were as outlined in Study 2: Part 1. The postural challenge involved standing on a platform elevated 50cm above the ground (average height of a chair). The cognitive challenge required participants to commit to memory a list of 12 grocery items and to silently rehearse this list during performance of the postural tasks.

To minimize fatigue, participants were provided with brief rest periods (3-5 minutes) between challenge conditions. During this time, questionnaires were completed that addressed the psychological measures of task-specific balance confidence, perceived stability, state-anxiety and fear of falling; perceived balance confidence was assessed prior to performance of the balance tasks, while anxiety, stability, and fear of falling were assessed following completion of the balance tasks.

This procedure was repeated on a second occasion for each participant exactly one week following their initial participation to assess test-retest reliability of the dependent measures.

5.2.3 Data Collection and Outcome measures

To assess general FOF, a single question was asked employing a percentage scale, where 0% indicates no fear at all and 100% indicates completely fearful. To assess levels of general balance confidence the ABC was used (Appendix B), which was designed to assess balance confidence in activities of daily living using a 16-item questionnaire, each question rated on a scale of 0% (no confidence) to 100% (completely confident). A comorbidity questionnaire (Appendix E) used in a previous study (unpublished data from Chapter 3) was used to assess general health and medical issues relating to fall-risk; an individual received 1-3 points for each of 35 medical conditions: 1 point for the presence of the ailment, a second point for treatment of the ailment, and a third point for the ailment affecting activities of daily living. Therefore, the maximum score achievable was 105, with higher scores indicating a greater disease burden and greater risk of falls.

One-Leg Stance (OL) and Functional Reach (FR) were performed while standing on an elevated surface and/or while performing a working memory task. OL was performed to the individual's ability, to a maximum of 30(s). No direction was given regarding selection of stance leg, although stance leg was consistent within each participant across challenge condition. Distance (cm) reached was the primary outcome measure for FR. The participant was asked to lean forward as far as possible with arms outstretched anteriorly while maintaining full foot-to-floor contact, and with the whole body acting as an inverted pendulum (no/minimal hip flexion). Each task was performed once under each challenge condition.

The secondary cognitive task (cognitive loading) was a list of 12 grocery items that participants were asked to commit to memory and silently rehearse during performance of the postural tasks. The rationale for selection of this task was presented in Study 2: Part 1. Following a thirty second seated encoding phase, the list of grocery was returned to the investigator and the participant was asked to mentally/silently rehearse the encoded items while performing the two balancing tasks for that challenge condition. Following completion of the challenge condition participants were asked to write down as many of the rehearsed items from the grocery list as possible within a thirty second period. The number of correctly recalled items was recorded. A different grocery list was presented for each of the cognitive loading conditions, and the order of presentation was randomized across participants relative to the loading condition. Under the single-task balance condition, participants were instructed to maintain balance to the best of their ability. Under the dual-task conditions, participants were told that they would have a dual focus - to maintain their balance and to perform the secondary task, each to the best of their ability. Participants also performed a single-task condition in which they were asked to commit to memory as many grocery items as possible (from a different list of twelve items) during a 30(s) period. Following this encoding phase, the list was returned to the investigator and the participant was asked to mentally/silently rehearse the encoded items while in a seated position for a one minute period, which approximated the time required to complete the two balance tasks under dual-task conditions. For each participant, this control condition was completed prior to the four randomized experimental/challenge conditions.

Psychological state in each challenge condition was assessed using task-specific questionnaires as in previous studies of postural threat[18-21,26,27,29,30]. Balance confidence was rated on a scale of 0-100% (no confidence – completely confident), state anxiety was a sum of the ratings (9-point scale) on 16 items and perceived stability was rated on a scale of 0-100% (not stable at all – completely stable)[21,27]. Fear of falling was also rated on a scale of 0-100% (not fearful at all – extremely fearful) to provide consistency across single-item questionnaire scales. Somatic (6-items), concentration (6-items) and worry (4-items) aspects of state anxiety were also derived from the state anxiety questionnaire and evaluated for differential effects of postural threat and cognitive loading (see Appendix C).

5.2.4 Data Analysis

Multivariate repeated measures analyses of variance were performed to examine the within-subject effects of postural threat and cognitive load on OL stance time and FR distance (α=0.05). Significant main effects were further examined through within-task, within-subject univariate ANOVAs (α=0.05). The same analysis was applied to condition-specific psychological measures (task-specific ratings averaged across OL and FR tasks). Positively skewed perceived anxiety and fear of falling data were $\log_{10}$ transformed for analysis. For graphical purposes, mean and standard error values of state anxiety and fear of falling were back-converted to original units following the formula $y=10^{(x)}$, where y=graphical mean/standard error and x=mean/standard error in log units.

Within-subject univariate ANOVAs ($\alpha=0.05$) were conducted to compare the number of items correctly recalled in the three different cognitive loading conditions: single-task memory, dual-task balance and cognitive loading, and dual-task balance and cognitive loading under postural threat. Bonferroni corrections for multiple comparisons were applied to post-hoc tests (adjusted level of significance = 0.017) .

Effects of postural threat have historically been evaluated by examining balance measures and/or psychological ratings within experimental levels/conditions (i.e. comparing absolute values in one condition to absolute values in another)[18-21,26,27,29,31-40]; therefore it is important to establish the reliability of these measures under individual conditions (i.e. within no challenge and postural challenge conditions independently). Moreover, clinical feasibility may necessitate identification of a single condition in which the measures are most reliable. On the other hand, relationships between balance and psychological measures have been evaluated by correlating the change in these measures resulting from postural threat (i.e. calculating a difference score or percent change to evaluate relationships between dependent measures)[18-21,26,27,29]. Therefore, intraclass correlation coefficients ($ICC_{3,1}$) were used to determine test-retest reliability of clinical performance measures and condition-specific psychological measures within each challenge condition, as well as the change from the no threat to low threat conditions. ICC coefficients were also derived for general fear of falling and the ABC. According to Rosner (2006), ICC values less than 0.40 signify poor reliability, ICC values ranging from 0.40-0.75 indicate fair to good reliability, and ICC values greater than 0.75 suggest excellent reliability[41]. The kappa statistic was derived to assess reliability of the dichotomous retrospective fall status. Viera (2005) suggests that kappa values ranging between 0.41 and 0.60 represent moderate reliability, values ranging between 0.61 and 0.80 represent substantial reliability, and values ranging between 0.81 and 0.99 represent near perfect reliability[42].

Construct validation as applied to psychological tests is when a test or tool is to be interpreted as a measure of some attribute (e.g. to what extent does an IQ questionnaire actually measure intelligence) and is typically carried out when there is no definite criterion measure; if two tests measure the same attribute or construct then a correlation between them is expected[43]. Spearman's rho correlations coefficients (*rs*) were derived to examine the construct validity of condition-specific balance confidence, state anxiety and fear of falling measures in relation to one another and to the total ABC score. Following the supposition that psychological constructs are task-specific and that comparisons between similar constructs evaluated under comparable conditions/constraints would yield greater association values, correlations *(rs)* were also computed between confidence ratings on the "chair reach" item alone (one of the most threatening tasks on the ABC) and task-specific psychological measures for the functional reach task performed under experimental conditions. The relationship between balance measures and psychological ratings was also evaluated by calculating *rs* values. Interpretation of the *rs* values followed the recommendations of Christmann (2009) and was as follows: 0.201-0.401 weak association; 0.401-0.600 moderate association; 0.601-0.800 strong association[44].

Evidence of homogeneity (internal consistency) within multi-items tests is also relevant in judging construct validity[43]; therefore, the internal structure of the state anxiety questionnaire was evaluated. State anxiety questionnaires demonstrated the strongest reliability in older individuals when attained under conditions of postural threat (see result Table 5.2). Since collapsing across repeated observations within a sample to increase sample size is discouraged[45], anxiety scores included for evaluation of internal consistency and dimensionality were those obtained in the postural threat condition in the first testing session for each individual only. A between-subjects MANOVA (α=0.05) was employed to compare ratings on the state anxiety questionnaire (sum and each intended element of somatic, concentration and worry) for three groups of individuals: young -study1, elderly-study2, elderly- study3. No significant differences were found between the groups. Preliminary factor analysis of young and older samples independently also revealed similar structures. Therefore, data were pooled across groups to improve the strength of the analyses[45], for a total of 115 cases (thirty-one from study 1, fifty-two from study 2 and thirty-two from study3). Internal consistency (alpha-reliability) of the state anxiety questionnaire was confirmed by computing Cronbach's coefficient alpha for the questionnaire as a whole, as well as for each of the three anxiety elements individually[46,47]. Confirmatory factor analysis using the principle components extraction technique was employed to evaluate the dimensionality of the state anxiety questionnaire and determine if correlations among the three state anxiety elements (somatic, worry and concentration) were consistent with the intended factor structure[45,48].

An independent-samples Mann-Whitney U-test was employed to compare the two groups of elderly individuals (fifty-two from study 2 and thirty-two from study 3) on their ABC scores prior to collapsing data across studies; no significant differences were found between the groups. Internal consistency (alpha-reliability) of ABC was confirmed by computing Cronbach's coefficient alpha. Exploratory factor analysis using principle components extraction was used to evaluate the internal structure (dimensionality) of the ABC.

Morgan (2006) suggests that Cronbach's coefficient alpha values of >0.80 are good, values of 0.70-0.80 are reasonable, and values of 0.60-0.69 are minimally adequate[47]. However, alpha values are sensitive to scale length (number of items)[49] and therefore, reliability estimates with corrections for this sensitivity are also presented following the formula $p=\alpha/(n-(n-1)\alpha)$, where p is the mean inter-item correlation and an estimator of reliability independent of scale length, α is coefficient alpha, and n is the number of items in the scale/subscale; mean inter-item correlations within the range of 0.40 and 0.50 considered acceptable[50].

All Statistical analyses were performed using PASW (formerly SPSS) version 18.

5.3 Results

Multivariate ANOVAs revealed no significant interaction effects of postural threat and cognitive loading for balance measures within task. Moreover, no significant interaction effects were found in condition-specific psychological measures of balance confidence, perceived stability, state anxiety or fear of falling.

5.3.1 Effects of Postural Threat

Multivariate analyses revealed significant main effects of postural threat for balance control measures (Wilks'=0.43,$F_{(2,30)}$=19.76,p<0.0001). Univariate analyses revealed significant reductions in both FR distance (11%) and OL stance times (16%) in the low threat compared to no threat condition (($F_{(1,31)}$=33.79,p<0.0001), ($F_{(1,31)}$=9.907,p=0.004), respectively) (Figure 5.1)).

Condition-specific psychological measures were also affected by postural threat (Wilks'=0.37,$F_{(4,26)}$=10.96,p<0.0001). Moreover, the individual aspects of the state anxiety questionnaire were affected by postural threat (Wilks'=0.691,$F_{(3,29)}$=4.33,p=0.012). Univariate analyses revealed significant effects of postural threat for psychological measures shown by reductions in balance confidence (23%) ($F_{(1,29)}$=39.48,p<0.0001) and perceived stability (7%) ($F_{(1,29)}$=4.00,p=0.05) along with significant increases in fear of falling (84%) ($F_{(1,29)}$=9.78,p=0.004) and state anxiety (18%) ($F_{(1,29)}$=14.44,p=0.001) in the low threat compared to the no threat condition (Figure 5.2). Significant increases were seen in somatic (18%), concentration (14%), and worry (16%) aspects of state anxiety in the low threat compared to the no threat condition (($F_{(1,31)}$=12.11,p=0.002), ($F_{(1,31)}$=6.05,p=0.020) and ($F_{(1,31)}$=6.77,p=0.014) , respectively) .

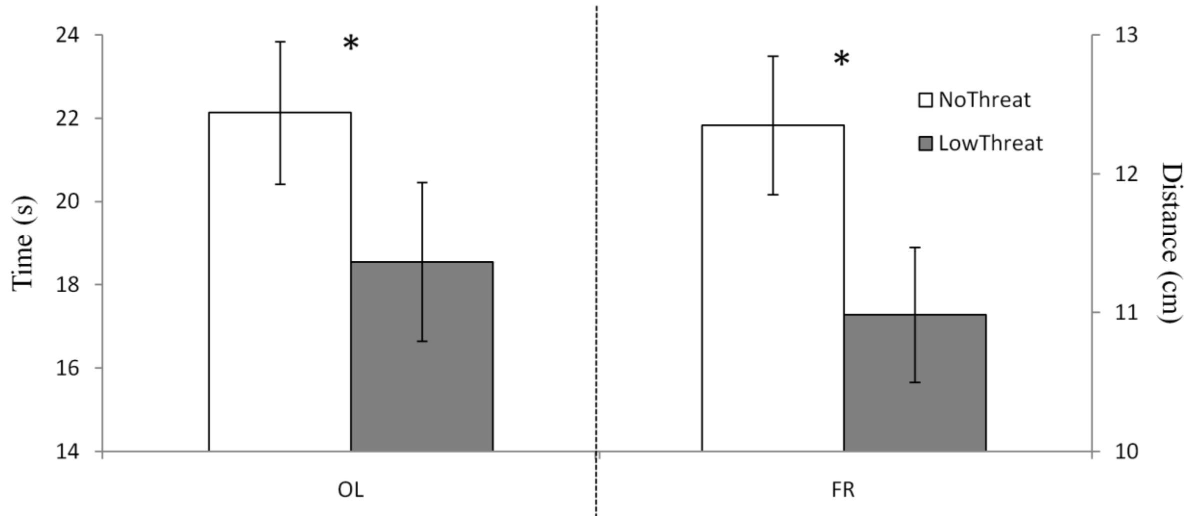


Figure 5.1: Effects of postural threat on clinical measures of balance control (means and standard error bars). OL=One-leg Stance, FR=functional reach. Vertical dashed line indicates separation of variables to left and right axes. *significant at 0.05

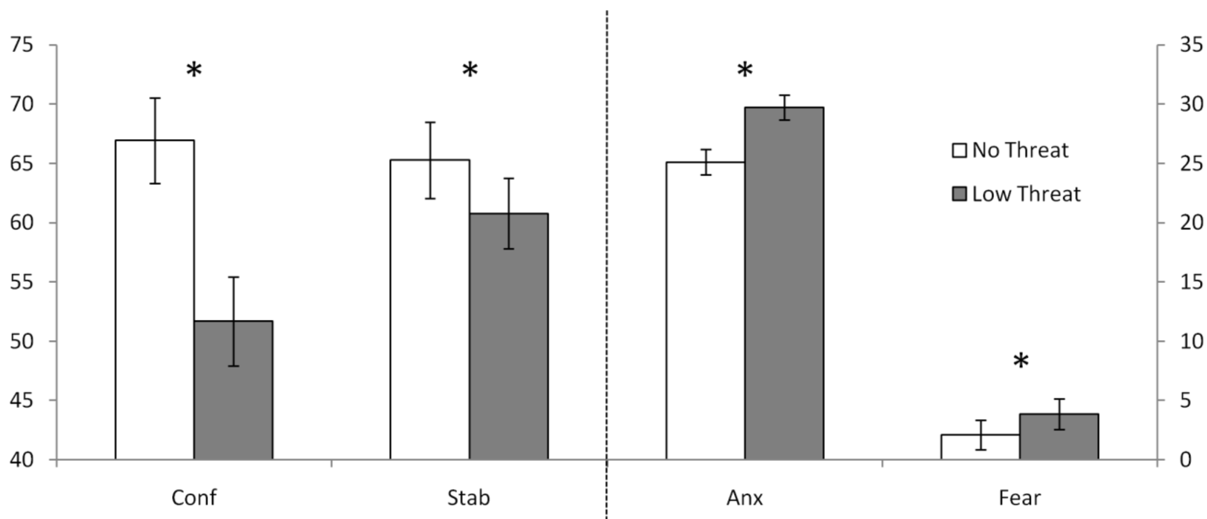


Figure 5.2: Effect of postural threat on psychological measures (means and standard error bars). Vertical dashed line indicates separation of variables to left and right axes. Units: Balance Confidence (Conf), Perceived Stability (Stab), Fear of Falling (Fear) (%); State Anxiety (Anx) (sum). *significant at 0.05

5.3.2 Effects of Cognitive Loading

Multivariate analyses revealed no significant effects of cognitive loading on clinical balance performance. However, condition-specific psychological measures were affected by cognitive loading (Wilks'=0.60,$F_{(4,26)}$=4.28,p=0.009). Moreover, the subscales/elements of the state anxiety questionnaire were affected by cognitive loading (Wilks'=0.54,$F_{(3,29)}$=8.37,p<0.0001). Univariate analyses revealed significant effects of cognitive loading for two psychological measures; reductions were seen in balance confidence (14%) ($F_{(1,29)}$=9.34,p=0.005) and increases in state anxiety (11%) ($F_{(1,29)}$=7.52,p=0.01) in the cognitive loading compared to no load condition (Figure 5.3). The concentration aspect of state anxiety was significantly increased (34%) due to cognitive loading ($F_{(1,31)}$=21.34,p<0.0001), while somatic and worry aspects were unaffected.

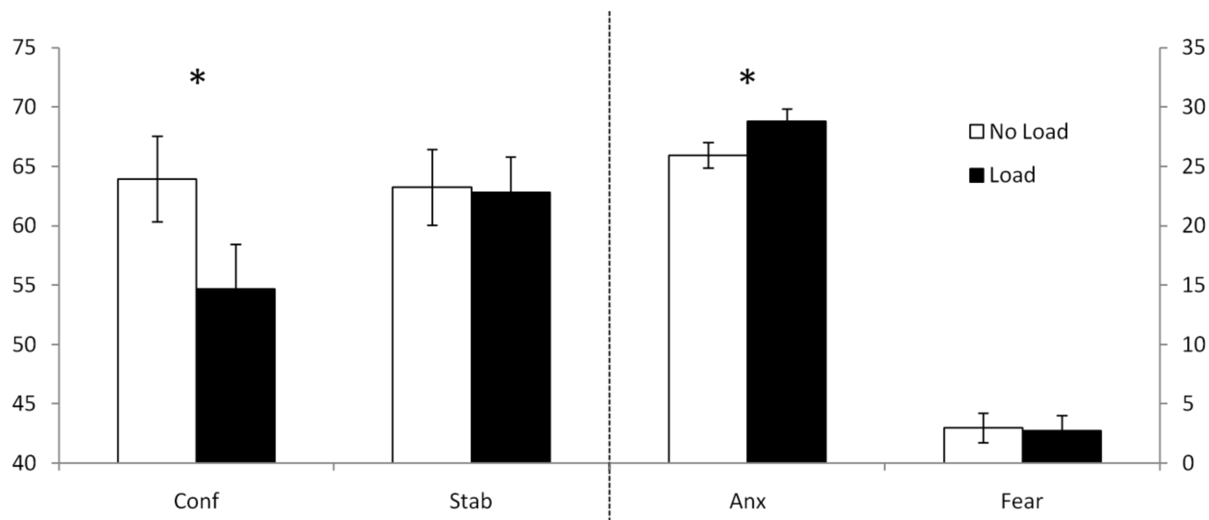


Figure 5.3: Effect of cognitive loading on psychological measures (means and standard error bars). Vertical dashed line indicates separation of variables to left and right axes. Units: Balance Confidence (Conf), Perceived Stability (Stab), Fear of Falling (Fear) (%); State Anxiety (Anx) (sum). *significant at 0.05

5.3.3 Performance of the Cognitive Task

Although participants recalled fewer items under both dual-task conditions (with or without postural threat) as compared to the single-task (seated) condition, post-hoc tests revealed no significant difference in performance of the memory task across the three conditions, suggesting that participants were in fact performing the memory task while also performing the balancing tasks. The mean number of items recalled across lists was 7.5 (±1.7) (Single-task 8.03 ±1.47; Dual-task no threat 7.06 ±1.84; Dual-task low threat 7.42 ±1.65).

5.3.4 Test-Retest Reliability of Measures

Intraclass correlations for clinical balance measures within each challenge condition were comparable and demonstrated fair to good test-retest reliability with values ranging between 0.56 and 0.73. Difference scores between non-threatening and threatening conditions show poor test-retest reliability as denoted by ICC values less than 0.40 (Table 5.1).

Table 5.1: $ICC_{(3,1)}$ values and the associated 95% confidence interval ranges.

Challenge Condition	One-Leg Stance Time (s)	Functional Reach Distance (cm)
No Challenge (NC)	0.72, 0.50-0.85	0.62, 0.36-0.80
Cognitive Loading (CC)	0.66, 0.41-0.82	0.73, 0.52-0.86
Postural Threat (PC)	0.61, 0.34-0.79	0.67, 0.42-0.82
Threat and Load (PCC)	0.60, 0.27-0.76	0.61, 0.33-0.79
Change NC to PC	-0.02, -0.36-0.32[#]	0.16, -0.20-0.48

[#] (-) ICC coefficient due to negative average covariance (See Appendix P)

Intraclass correlations for psychological measures within challenge conditions ranged between 0.48 and 0.78; only balance confidence measured during postural threat fell below this range. Difference scores between non-threatening and threatening conditions show poor reliability as denoted by ICC values less than 0.40, with the exception of fear ratings which demonstrated fair reliability with and ICC value of 0.55 (Table 5.2).

Table 5.2: $ICC_{(3,1)}$ values and the associated 95% confidence interval ranges.

Challenge Condition	Balance Confidence	Perceived Stability	State Anxiety	Fear of Falling
No Challenge (NC)	0.57, 0.27-0.77	0.60, 0.32-0.78	0.54, 0.24-0.74	0.78, 0.59-0.89
Cognitive Loading (CC)	0.61, 0.34-0.79	0.76, 0.56-0.88	0.48, 0.17-0.71	0.69, 0.46-0.84
Postural Threat (PC)	0.24, -0.12-0.54	0.65, 0.39-0.81	0.72, 0.50-0.85	0.74, 0.54-0.87
Threat and Load (PCC)	0.60, 0.32-0.78	0.70, 0.47-0.84	0.60, 0.32-0.78	0.50, 0.18-0.72
Change NC to PC	-0.31, -0.61-0.05[#]	0.17, -0.19-0.49	0.17, -0.19-0.48	0.55, 0.25-0.75

[#] (-) ICC coefficient due to negative average covariance (See Appendix P)

General fear of falling ratings demonstrated good reliability ($ICC_{(3,1)}$ of 0.64, 0.38-0.81), while the ABC demonstrated excellent reliability ($ICC_{(3,1)}$ of 0.87, 0.74-0.93). Self-reported comorbidity scores also demonstrated excellent reliability ($ICC_{(3,1)}$ of 0.89, 0.79-0.94). The kappa statistic for evaluation of dichotomous variables revealed that retrospective fall reports demonstrated moderate reliability (0.60); 5 of 32 individuals were inconsistent in their fall history reports, from one week to the next.

5.3.5 Construct Validity of Psychological Measures

Correlations among condition-specific psychological measures are presented in table 5.3. Balance confidence and state anxiety are negatively and moderately correlated in the no challenge condition; the change in these measures resulting from postural threat also show a weak negative correlation. Balance confidence is not related to fear of falling measures. Fear of falling and state anxiety demonstrate a near-significant positive association under the no challenge condition, and a significant moderate positive relationship under conditions of postural threat.

Table 5.3: Relationships between condition-specific psychological measures; 2-tailed Spearman's rho coefficients;*significant at 0.05,**significant at 0.01

	State Anxiety	Fear of Falling
Balance Confidence		
No Challenge (NC)	**-0.404 (p=0.024)***	-0.026 (p=0.889)
Postural Threat (PC)	-0.267 (p=0.146)	-0.209 (p=0.260)
Change NC to PC	**-0.392 (p=0.032)***	-0.192 (p=0.310)
State Anxiety		
No Challenge (NC)	1.0	0.344 (p=0.054)
Postural Threat (PC)	1.0	**0.481 (p=0.005)****
Change NC to PC	1.0	0.067 (p=0.715)

Values presented in table 5.4 are correlations between condition-specific psychological measures as well as general fear of falling ratings and ratings on the Activities-Specific Balance Confidence scale. State anxiety ratings in the postural threat condition were significantly correlated with the total ABC score (r= -0.561, r=0.372, and r=0.558, respectively). General fear of falling also correlated significantly with the total ABC score (r= -0.634). The ABC was unrelated to condition-specific balance confidence and fear of falling. None of the task-specific psychological measures in the no challenge or postural threat conditions were related to ratings on the "chair reach" item.

Table 5.4: Relationships between the ABC and condition-specific psychological measures (left panel) and between the ABC 'chair reach' and task-specific (functional reach) psychological measures (right panel); 2-tailed Spearman's rho coefficients; *significant at 0.05,**significant at 0.01

	ABC - 16 items		ABC - chair reach
Balance Confidence		FR-Balance Confidence	
No Challenge (NC)	0.078 (p=0.675)	No Challenge	0.136 (p=0.466)
Postural Threat (PC)	0.241 (p=0.192)	Postural Threat	0.056 (p=0.764)
Change NC to PC	0.325 (p=0.079)	Change NC to PC	-0.066 (p=0.728)
State Anxiety		FR - State Anxiety	
No Challenge (NC)	-0.312 (p=0.082)	No Challenge	-0.051 (p=0.780)
Postural Threat (PC)	**-0.561 (p=0.001)****	Postural Threat	-0.107 (p=0.561)
Change NC to PC	-0.252 (p=0.164)	Change NC to PC	-0.207 (p=0.256)
Fear of Falling		FR - Fear of Falling	
No Challenge (NC)	-0.336 (p=0.060)	No Challenge	0.166 (p=0.363)
Postural Threat (PC)	-0.201 (p=0.269)	Postural Threat	-0.038 (p=0.835)
Change NC to PC	-0.056 (p=0.760)	Change NC to PC	-0.104 (p=0.573)
General Fear of Falling	**-0.634 (p<0.0001)****	General Fear of Falling	0.194 (p=0.287)

Table 5.5 presents correlations between psychological measures and clinical balance performance measures. Task-specific balance confidence was significantly related to performance of the one-leg stance task under both threatening and non-threatening conditions; the change in these measures from no threat to postural threat conditions also showed a significant positive association. Task-specific state anxiety ratings were significantly related to performance of the one-leg stance task under conditions of postural threat. Task-specific balance confidence and state anxiety were unrelated to performance of the functional reach task, and task-specific fear of falling was unrelated to performance of either task. Generalized measures of balance confidence (ABC) and fear of falling were also unrelated to performance of clinical balance tasks in either threatening or non-threatening conditions.

Table 5.5: Relationships between task-specific psychological measures and balance performance measures; 2-tailed Spearman's rho coefficients; *significant at 0.05,**significant at 0.01

	One-Leg Stance Time	Functional Reach Distance
Balance Confidence		
No Challenge (NC)	**0.683 (p<0.0001)****	-0.144 (p=0.439)
Postural Threat (PC)	**0.606 (p<0.0001)****	0.017 (p=0.929)
Change NC to PC	**0.419 (p=0.021)***	-0.088 (p=0.642)
State Anxiety		
No Challenge (NC)	-0.321 (p=0.073)	-0.200 (p=0.273)
Postural Threat (PC)	**-0.385 (p=0.029)***	-0.303 (p=0.092)
Change NC to PC	-0.174 (p=0.340)	-0.070 (p=0.704)
Fear of Falling		
No Challenge (NC)	0.290 (p=0.170)	0.141 (p=0.440)
Postural Threat (PC)	-0.127 (p=0.489)	-0.218 (p=0.230)
Change NC to PC	-0.173 (p=0.344)	-0.075 (p=0.684)
ABC-16 item score		
No Challenge (NC)	0.057 (p=0.755)	0.022 (p=0.905)
Postural Threat (PC)	0.193 (p=0.290)	0.013 (p=0.945)
Change NC to PC	0.036 (p=0.845)	0.084 (p=0.646)
General Fear of falling		
No Challenge (NC)	-0.158 (p=0.388)	0.254 (p=0.160)
Postural Threat (PC)	-0.347 (p=0.052)	0.076 (p=0.678)
Change NC to PC	-0.286 (p=0.113)	-0.208 (p=0.253)

5.3.6 Internal consistency and dimensionality of the 16-item state anxiety questionnaire

The alpha-reliability of the state anxiety questionnaire as a whole (evaluating all 16 items together) was 0.911, demonstrating excellent internal consistency/alpha-reliability. However, Yu (2001) recommends that alpha also be computed for each known/intended subscale independently[46]. The somatic (6 items), concentration (6 items) and worry (4 items) components resulted in Cronbach's alphas of 0.843, 0.791and 0.803, respectively. However, after correcting for scale length, reliability was found to be within the acceptable range for somatic (0.472) and worry (0.505) subscales, but not for the concentration (0.387) subscale. Table 5.7 presents alpha-reliability scores when each question is eliminated individually (within subscales) to identify questions that may need to be removed, re-structured or re-worded to better reflect the intended aspect of anxiety. Improvements in consistency within the somatic subscale were seen when items 1, 10, 12, and 15 were removed; improvements in the concentration subscale were seen when items 11 and 16 were removed; improvements in the worry subscale were seen when items 9 and 14 were removed.

Table 5.6: State Anxiety: Alpha-reliability scores and corrections for scale length within intended subscales

	Item Deleted	Corrected Reliability
Somatic (0.843)		0.472
S1-I felt nervous	0.882	0.599
S4- I felt myself tense and shaking	0.787	0.425
S7-My body was tense	0.787	0.425
S10-I felt my stomach sinking	0.833	0.499
S12-My heart was racing	0.818	0.473
S15-I found myself hyperventilating	0.851	0.533
Concentration (0.791)		0.387
C2- I had lapses in concentration	0.754	0.380
C5-I was concerned about being able to concentrate	0.720	0.340
C8-I had difficulty focusing on what I had to do	0.730	0.351
C11-I did not pay attention to the point on the wall all of the time	0.807	0.455
C13-Thoughts of falling interfered with my concentration	0.752	0.378
C16-I found myself thinking about things unrelated to doing the task	0.787	0.425
Worry (0.803)		0.505
W3-I had self-doubts	0.732	0.477
W6-I was concerned about doing the balance task correctly	0.702	0.440
W9-I was worried about my personal safety	0.796	0.565
W14-I was concerned that others would be disappointed with my performance	0.765	0.520

Evaluation of the 16-item state anxiety questionnaire correlation matrix showed that each question correlated significantly ($p<0.05$) with at least 10 others (with 72% of R values exceeding 0.3), suggesting that questions measure the same or similar underlying dimension(s). Moreover, no question correlated too strongly with another ($R>0.9$) and the determinant of the matrix exceeded 0.00001, showing that the data avoid extreme multicollinearity (redundancy) and singularity, which can be problematic for factor analysis. Finally the Kaiser-Meyer-Olkin value at 0.872 exceeded the minimum recommended 0.6, demonstrating that the sample size was adequate. All together, these results suggested that factor analysis was appropriate for confirmation of underlying components in these data [45].

Factor analysis using principle component extraction employing Oblimin rotation with Kaiser normalization (used for related underlying factors)[45] identified three principle components with Eigenvalues greater than 1.0, together accounting for 65% of the variance. Variable loadings were deemed significant if the magnitude of the loading was ≥ 0.6 for individual items[51]. With this criterion, six items loaded onto component 1, three onto component 2, and four onto component 3. Three items loaded onto multiple components. Components and the loadings of each item are presented in Table 5.6. The component correlation matrix revealed that component 1 was significantly related to both components 2 and 3 (with correlation values exceeding 0.32)[45], but components 2 and 3 were unrelated. The rotated component plot is found in Figure 5.4.

Table 5.7: State Anxiety Questionnaire: Pattern matrix. Extraction method: principle component analysis; rotation method: oblimin with Kaiser normalization

	Component		
	1	2	3
W6: I was concerned about doing the balance task correctly	0.88		
W3: I had self-doubts	0.77		
S7: My body was tense	0.76		
S1:I felt nervous	0.71		
W14: I was concerned that others would be disappointed with my performance	0.70		
S4: I felt myself tense and shaking	0.60		
C5: I was concerned about being able to concentrate	0.59		0.36
C13: Thoughts of falling interfered with my concentration	0.50	0.46	
S10: I felt my stomach sinking		0.86	
S15: I found myself hyperventilating		0.84	
S12: My heart was racing		0.78	
W9: I was worried about my personal safety	0.39	0.54	
C16: I found myself thinking about things unrelated to doing the task			0.79
C2: I had lapses in concentration			0.68
C11: I did not pay attention to the point on the wall all of the time			0.67
C8: I had difficulty focusing on what I had to do			0.61

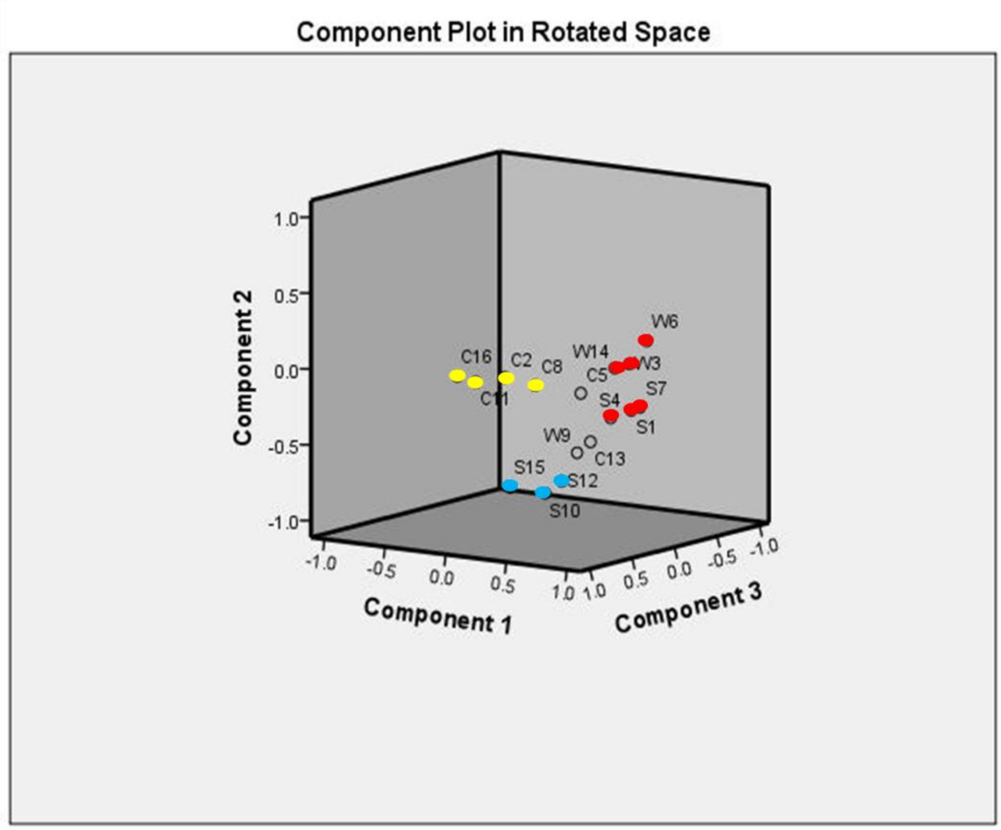


Figure 5.4: Component plot derived from factor analysis; red circles show questions identified as belonging to component 1, blue circles to component 2, and yellow circles to component 3; circles are labeled alpha-numerically with letters denoting the intended component of anxiety (C for concentration, S for somatic and W for worry) and numbers denoting the question number (1 through 16).

5.3.7 Internal consistency and dimensionality of the Activities-Specific Balance Confidence Scale (ABC)

The alpha-reliability of the ABC was 0.914 and 0.399 after correcting for scale length. Table 5.9 presents alpha-reliability scores (raw and corrected) when each question is eliminated individually; improvements in internal consistency were seen when items 1, 4, 6, 7, 9, and 16 were eliminated.

Table 5.8: ABC: Alpha-reliability scores and corrections for scale length

How confident are you that you will not lose your balance or become unsteady when you do the following:....	Item Deleted	Corrected Reliability
Average (0.914)		0.399
1.....walk around the house	0.911	0.406
2....walk up or down stairs	0.907	0.394
3.....bend over and pick a slipper up from the floor	0.907	0.394
4.....reach for a small can off a shelf at eye level	0.913	0.412
5.....stand on your tiptoes and reach for something above your head	0.905	0.388
6.....stand on a chair and reach for something	0.917	0.424
7.....sweep the floor	0.915	0.418
8.....walk outside the house to a car parked in the driveway	0.906	0.391
9.....get in or out of a car	0.909	0.400
10....walk across a parking lot to the mall	0.906	0.391
11....walk up or down a ramp	0.904	0.386
12....walk in a crowded mall where people rapidly walk past you	0.904	0.386
13....are bumped into by people as you walk through the mall	0.905	0.388
14....step onto/off an escalator while holding onto a railing	0.908	0.397
15....step onto/off an escalator while holding parcels (not railing)	0.906	0.391
16....walk outside on icy sidewalk	0.919	0.431

Evaluation of the 16-item ABC correlation matrix showed that all questions correlated significantly ($p<0.05$) with at least 12 others (with 87% of R values exceeding 0.3), suggesting that questions measure the same or similar underlying dimension(s). The determinant of the matrix was less than 0.00001 however, suggesting some multicollinearity. However, no question correlated too strongly with another ($R>0.9$) and inspection of communalities prior to extraction (the largest 0.866) showed that extreme multicollinearity/singularity was not a threat in the data[45,52]. Finally, the Kaiser-Meyer-Olkin value at 0.897 exceeded the minimum recommended 0.6, demonstrating that the sample size was adequate. All together, these results suggested that factor analysis was appropriate for identifying any underlying factors in these data [45].

Factor analysis using principle component extraction and employing Varimax rotation with Kaiser normalization identified three principle components with Eigenvalues greater than 1.0, together accounting for 71% of the variance. Variable loadings were deemed significant if the magnitude of the loading was ≥ 0.6 for individual items[51]. With this criterion, eight items loaded onto component 1, four onto component 2, and three onto component 3. Components and the loadings of each item are presented in Table 5.8. The rotated component plot is found in Figure 5.5

Table 5.9:ABC: Pattern matrix. Extraction method: principle component analysis; rotation method: varimax with Kaiser normalization; mean score and standard deviation on ABC

How confident are you that you will not lose your balance or become unsteady when you do the following:....	Component			Mean Score and standard deviation
	1	2	3	
10: walk across a parking lot to the mall	0.78			94.36 ± 9.68
8: walk outside the house to a car parked in the driveway	0.76			95.11 ± 9.14
7: sweep the floor	0.74			95.64 ± 13.16
3: bend over to pick a slipper up from the floor	0.73			92.64 ± 10.77
1: walk around the house	0.72			95.08 ± 7.62
11:walk up or down a ramp	0.72			92.04 ± 11.87
12:walk in a crowded mall where people rapidly walk past you	0.71			93.05 ± 10.70
13:are bumped into by people as you walk through the mall	0.60			89.73 ± 11.79
5: stand on your tiptoes to reach for something above your head	0.58		0.52	88.56 ± 13.65
15:step onto/off an escalator while holding parcels (not railing)		0.83		72.56 ± 21.89
16:walk outside on icy sidewalks		0.70		57.00 ± 25.96
2: walk up or down stairs	0.45	0.70		86.71 ± 15.77
14:step onto/off an escalator while holding onto a railing		0.67		86.89 ± 14.13
6: stand on a chair to reach for something			0.81	73.98 ± 21.94
4: reach for a small can off a shelf at eye level			0.74	96.30 ± 7.64
9: get in or out of your car	0.40		0.68	93.99 ± 8.69

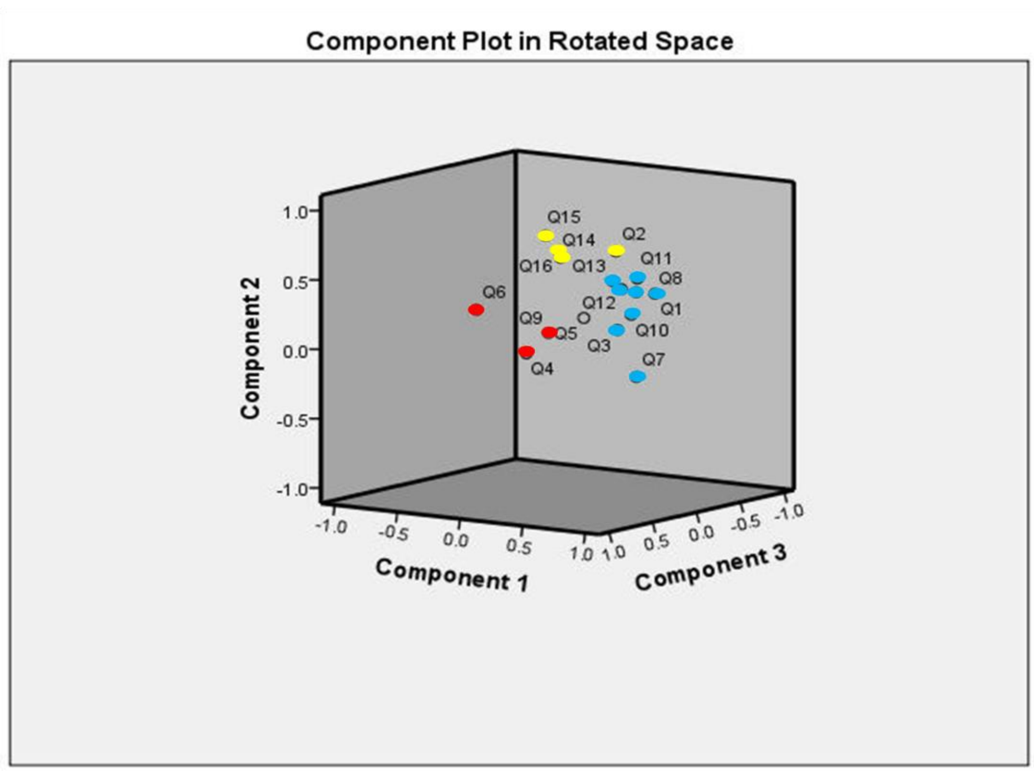


Figure 5.5 Component plot derived from factor analysis for ABC; blue circles show questions identified as belonging to component 1, yellow circles to component 2, and red circles to component 3.

5.4 Discussion

The goal of this study was to explore the validity and reliability of measures used previously in this dissertation. In this different sample of community dwelling elderly, the experimental validity of previous results was confirmed by demonstrating the consistent effects of postural threat and cognitive loading on clinical balance performance and measures of psychological state. Clinical balance and state-specific psychological measures generally demonstrate acceptable test-retest reliability across various challenge conditions. Correlation analysis revealed that state-specific psychological measures are distinct constructs and are not synonymous with more global measures of psychological state. The state anxiety questionnaire and the Activities-specific Balance Confidence Scale demonstrated strong internal consistency and factor analysis showed that both are multi-dimensional.

5.4.1 Effects of postural threat and cognitive loading on clinical balance performance and psychological state measures - experimental validity

The effects of postural threat and cognitive loading on clinical balance performance and psychological measures replicated previous results (unpublished data found in Chapter 3). Exposure to postural threat had an adverse impact on both clinical balance performance and psychological measures in community-dwelling elderly adults. Cognitive loading made no significant impression on clinical balance performance measures and minimally affected psychological measures in this population.

5.4.2 Test-retest reliability of clinical balance and psychological measures

Within challenge conditions, the reliability of one-leg stance times and functional reach distance was acceptable, with ICC values ranging from 0.50 to 0.73, and similar to previous reports[53-55]. Although balance measures demonstrated the lowest reliability under conditions of combined postural threat and cognitive loading, overlapping ICC confidence limits would suggest that there was no significant differences in the reliability between conditions[53].

Within challenge conditions, psychological measures also demonstrated acceptable reliability, with ICC values ranging from 0.48-0.78. The only exception to this finding was for balance confidence ratings measured under postural threat conditions, which demonstrated poor reliability with an ICC value of 0.24. This anomaly is likely a manifestation of a combined learning effect and requiring the participant to provide estimates of confidence prior to task performance. In other words, without having previously experienced postural threat as manipulated in this study, it may have been difficult for participants to estimate their confidence in their ability to perform the task under these conditions. In the second testing session however, previous exposure led to different and likely more accurate ratings of balance confidence.

When changes due to postural threat were calculated (difference in scores from no challenge to postural threat/challenge) clinical balance and state-specific psychological measures generally demonstrated poor reliability. This result differs from that in young adults (unpublished data) where the reliability of change measures generally demonstrate fair to good reliability (see Appendix U for direct comparisons). This discrepancy is likely a result of two factors combined: first, the change from low threat to high threat conditions was 1.0m for young adults, while the change from no threat to low threat was 0.5m for older adults; second, between subject variance in change measures was greater in young than in older adults. Reliability is an assessment of the reproducibility of replicate measures in the same subject and is the ratio of between-person variance divided by the sum of the between-person and within-person variance; when between-subject variance is high relative to within-subject variance high reliability is achieved, but when between-subject variance is minimal relative to within-subject variance low reliability results[41]. The smaller difference in postural threat experienced by the older adults likely led to lesser variability in change measures and therefore lower reliability values. Because of the difference in methodology with respect to levels of postural threat and sample populations however, the comparison of reliability in change values is tentative and it may be worthwhile to evaluate the reliability across populations using the same methodology.

In sum, when using the same conventions to derive ICC values, the state-specific psychological measures used throughout this dissertation generated comparable fair to excellent reliability scores in young and older adults. This holds true when these psychological constructs are evaluated within non-threatening and threatening conditions, as well as averaged across conditions. Changes in the psychological constructs as a result of increased postural threat however are less reliable measures.

General fear of falling demonstrated reliability comparable to condition-specific fear of falling ratings with an ICC of 0.64. Ratings on the ABC demonstrated excellent reliability, with an ICC of 0.89, similar to previous reports[51,55,56]. These measures therefore, generate consistent evaluations of more global psychological states. Reliability of retrospective fall reports was only moderate with a kappa value of 0.60, which supports previous reports suggesting that recall of falls is less sensitive than prospective collection of fall outcomes[57]. These data therefore, support the recommendation that generation of fall risk assessment and prevention/intervention models be based on prospective rather than retrospective methods[57].

Several studies have shown relationships between various individual comorbidities (or their treatments) and falls[6,10,58-67]. We are unaware however of any fall-risk identification models that include a comprehensive comorbidity assessment. The health questionnaire developed for use in this dissertation work was based on well known comorbidity assessments often used to assess disease burden and risk of mortality in patient populations[68]. Scores on the comorbidity questionnaire demonstrated excellent reliability with an ICC 0.89. However, it is likely that refinement is required to improve ease of understanding/use and assign weightings to various medical factors as they relate to falls and fall-risk. There are a small number of publications that may help guide this process. Swift (2006) highlighted the need to include in-depth medical assessments in fall prevention programs and suggested a focus on the following medical factors: circulatory disorders, visual problems, lower limb weakness, peripheral neuropathic signs, balance impairment (one-leg stance performance), impaired cognition, and depression[69]. De Breucker et al. (2007) suggested the following medical conditions as those most relevant in assessing fall-risk: arthritis, history of stroke, orthostatic hypotension, dizziness, anemia, visual acuity, hearing assessment, extremity deformity/neuropathy, and carotid sinus hypersensitivity[70]. Finally, Lord et al. (2007) identified the following medical factors as associated with falls: impaired cognition, stroke, Parkinson's disease, depression, abnormal neurological signs, incontinence, arthritis, foot problems, dizziness, orthostatic hypotension, and vestibular disorders[71]. An updated review of the literature focused on evaluating the strength of association between various medical issues and fall risk would also be beneficial in refining the comorbidity questionnaire.

5.4.3 Construct validity of psychological measures

Under non-threatening conditions, greater levels of balance confidence were related to lesser ratings of state anxiety. Balance confidence and fear of falling were unrelated in either threatening or non-threatening conditions. Fear of falling and state anxiety were not significantly related under non-threatening conditions, but showed a moderate positive relationship under more threatening conditions, supporting the notion that anxiety and fear are on a continuum [22]. Examination of the correlation matrix as a whole showed that although some condition-specific psychological measures are related, the strength of associations are generally weak to moderate. This observation suggests that balance confidence, state anxiety, and fear of falling are independent constructs and that observed changes in one measure should not be used to infer changes in another.

Average ratings on the Activities-Specific Balance Confidence Scale (ABC) showed no relationship to condition-specific balance confidence or fear of falling measures under either non-threatening or threatening conditions. Higher ratings on the ABC were moderately associated with lower levels of state anxiety under threatening conditions. These results suggest that state-specific balance confidence, anxiety, and fear are different from balance confidence in activities of daily living. Higher ratings on the ABC were strongly associated with lower ratings on the general fear of falling questionnaire, although the magnitude of association would indicate that these too are related but distinct constructs.

It also is important to note that associations among psychological measures vary depending on the conditions in which they are measured. Previous reports have evaluated associations by correlating changes in one measure to changes in another as a result of some experimental manipulation (e.g. postural threat)[18-21,26,27,29]. However, in doing so, some relationships may have been hidden. For example, these data show that changes in fear of falling were unrelated to changes in state anxiety. However, under conditions of postural threat higher ratings of fear were associated with higher levels of anxiety.

Under both threatening and non-threatening conditions, higher levels of balance confidence were associated with better performance on the one-leg stance task. Under threatening conditions, lower levels of anxiety were related to better performance on one-leg stance tasks. More generalized measures of psychological constructs (ABC and general fear of falling) were unrelated to performance of either the One-Leg Stance or Functional Reach tasks.

In sum, when correlation and reliability analyses are considered together, it is recommended that relationships between and among psychological constructs and balance performance be evaluated in a within-condition (situation-specific) manner.

5.4.4 Internal consistency and dimensionality of the state anxiety questionnaire

This is the first report to examine the internal structure and consistency of the state anxiety questionnaire, which was contextually modified from a sport anxiety questionnaire and developed for use in studies of postural threat[26]. The intended factor structure addresses somatic, worry and concentration aspects of anxiety. Internal consistency, when evaluated using the intended structure, demonstrated acceptable levels with alpha values greater than 0.70 for each of the three elements. However, when corrections accounting for scale length were applied, the consistency of the concentration aspect fell below acceptable levels.

Factor analysis identified three components within the state anxiety questionnaire. Although many of the questions fell within expected categories (i.e. were grouped according to the intended factor structure) there were also clear departures.

Four of the six intended concentration items were grouped together under a "concentration" component, while the remaining two questions showed overlap with other components: examination of the item wording shows that item 5 (I was concerned about being able to concentrate) likely addresses both concentration and worry aspects of anxiety, while item 13 (thoughts of falling interfered with my concentration) appears to addresses worry and fear-related aspects of anxiety. This result is not surprising when anecdotal observations and participant comments are considered (e.g. regarding question 5: "I was not concerned about being able to concentrate, I just couldn't concentrate. So, how do I rate that question?"). When each item was eliminated individually, improvements in consistency values were shown for two questions within the concentration element and suggests that either or both of these items may need to be eliminated or reworded (concentration items 11 and 16).

A second component was strongly loaded by three somatic questions (items 10, 12 and 15); examination of the item wording suggests that these three questions differ from the others and are manifestations of higher levels of anxiety approaching fear and parallel fight or flight responses[22]. This result is supported by the internal consistency analysis where improvements in the alpha reliability values are seen when each of these questions in individually eliminated. This component may therefore be more aptly labeled expressions of "high anxiety". Two items were weakly loaded onto this component and showed overlap with the final component: items 13 (thoughts of falling interfered with my concentration) and 9 (I was worried about my personal safety) address notions related to fear, particularly a fear of falling, but also include terminology related to worry and ability to focus on the task requirements.

A third and final component was strongly loaded by items from both worry and somatic aspects of anxiety. Examination of item wording suggests that these items address signs or symptoms reflecting lower levels of anxiety in situations where threat or danger is less imminent[22]. This component may therefore be more aptly labeled indications of "low anxiety". This component accounted for the greatest amount of variability in scores.

Taken together, the consistency and dimensionality analysis suggest that the state anxiety questionnaire may be improved for future use by rewording or eliminating the items identified by analysis as ambiguous or contradictory. A recent study by Geh et al. (2011) using only the somatic and worry elements of the questionnaire found a high rating of internal consistency (alpha reliability of 0.86) and this 10-item modified scale was responsive to changes in testing conditions[72]. Huffman et al. (2009) also evaluated only the somatic and worry aspects of the questionnaire and found significant increases in anxiety with the introduction of postural threat[20]. A post-hoc analysis of the data from this dissertation evaluating a 9-item modified scale (using the same items as above) but also eliminating the ambiguous worry item 9 from the original scale), showed improved internal consistency (alpha of 0.87, 0.42 corrected for scale length) over both the original (alpha of 0.91, 0.39 corrected for scale length) and the 10-item scale (alpha of 0.86, 0.40 corrected for scale length). Moreover, when the internal consistency of each component (as identified by the factor analysis) within the 9-item scale was assessed, excellent internal consistency was achieved and improved as compared to the intended components; corrected reliability values were 0.54 and 0.56 for the low and high anxiety components respectively (see Appendix R). From a time-efficiency and clinical feasibility perspective therefore, it may be that the concentration aspect can be eliminated from the questionnaire and the remaining items will still be a reliable measure sensitive to changes in state anxiety.

5.4.5 Internal consistency and dimensionality of the ABC

Reports evaluating the measurement properties of the ABC have shown excellent ratings of internal consistency with alpha reliability values of 0.94-0.96[51,55,56]. The current data revealed an equally high rating of internal consistency (α=0.91). Previous reports evaluating the internal structure of the ABC identified two components[51] or groupings[9] where items were classified as being either "perceived low-risk" or "perceived high-risk/challenging" activities. Dimensionality evaluation of the current data identified three distinct components. The difference in the number of components identified is likely driven by sample population differences. The current results were derived from healthy, high-functioning older adults, as indicated by low comorbidity scores and high ABC scores (78% of sample with scores greater than 80)[73], respectively. In contrast, the aforementioned work where only 2 components were derived assessed patient populations (sufferers of Parkinson's disease and stroke); activities perceived as challenging for a patient suffering from neurological deficits (e.g. item 12 (walking in a crowded mall) or item 6 (standing on a chair to reach)) were perceived as low or moderate risk activities for healthy older individuals. Internal consistency analysis, where large improvements in the reliability values were seen when items were individually eliminated, identified activities which likely provide limited insight into fall-risk by posing little risk/challenge for this population (item 1 (walking around a house) and item 7 (sweeping the floor) and activities that provide great risk for even the most healthy active individuals (item 16 (walking on an icy sidewalk)). An avenue for future work will involve refining the ABC for use in healthy community-dwelling elderly with a focus on the identified moderate and/or high risk activities, and evaluating the measurement properties of this narrowed scale. Botner et al. (2005) and Peretz et al (2006) identified six items on the ABC (using factor analysis and mean score comparisons) that were more challenging for patient populations than the other items in the scale (items 5, 6, 13, 14, 15 and 16). The data presented in Chapter 5 of this dissertation show that 3 items were perceived as particularly challenging for a sample of healthy community-dwelling elderly (items 14, 15, 16), as indicated by lower scores (<75) and greater variability. These items therefore, might be useful for distinguishing between groups of individuals with different levels of confidence/fall-risk. Alternatively, 6 items were identified as being different from others in the scale (items 2, 5, 6, 14, 15, 16) by evaluation of mean scores (<90) and item loadings from factor analysis results (only those loaded on components 2 and/or 3). Therefore, a post-hoc analysis of the data presented here included calculating an ABC-6P (following the examples of Peretz et al. (2006) and Botner et al. (2005) in patient (P) populations) as well as an ABC-6H and ABC-3H (based on the findings in this dissertation in healthy (H) individuals). All refined scales showed an improved rating of internal consistency over the ABC-16 with the highest found for the ABC-3H, followed by the ABC-6H and then ABC-6P, with corrected alpha-reliability values of 0.547, 0.430 and 0.427, respectively (see Appendix R). It will be important for future work to evaluate the predictive validity of these refined scales, with respect to fall-risk.

5.5 Limitations

The dimensionality and internal consistency analysis of the state anxiety questionnaire and ABC found that refinement of the scales is in order. It is a common perception that factor analysis requires large sample sizes and it is recommended that a minimum of 300 cases is required for reliable results from factor analysis[45]. There is some evidence however, to suggest that solutions with high loading marker variables do not require such large sample sizes and in some cases 100 or even 50 cases are sufficient[45]. Moreover, tests of sampling adequacy supported factor analyses in these data. It is however recommended that the structure of these tools be evaluated/confirmed in larger sample populations.

5.6 Conclusions

This assessment of the validity and reliability of psychological measures supports the notion that more global emotions like fear, even when to narrowed to a specific fear (e.g. of falling), are distinct from mood states like anxiety[5,11,12,22] and not synonymous with balance confidence or perceived stability[5,23]. Moreover, these data hold to the supposition that psychological states are task or condition dependent[5,25]and are, at most, moderately related to average measures of confidence in activities of daily living. These date show that while generalized psychological measures do not correlate with balance performance, task-specific psychological measures do.

Task-specific tools originally developed for use in postural threat studies that evaluate balance confidence, perceived stability and state anxiety demonstrate fair to good test-retest reliability in community-dwelling older individuals. The state anxiety questionnaire and the ABC demonstrated strong internal consistency, although refinement for use in higher functioning older adults, with respect to assessing fall-risk, is an important path for investigation.

In sum, the tools used throughout this dissertation to assess task-specific balance confidence, state anxiety and perceived stability have demonstrated acceptable test-retest reliability in both young and older individuals. Because these tools measure distinct constructs, are context-dependent and are related to balance performance, it may be most clinically relevant/revealing to supplement balance assessments using multiple context-specific psychological measures or a composite thereof.

Chapter 6

General Discussion and Conclusions

When an older individual experiences a fall, the resultant injuries and loss of functional mobility can reduce independence and quality of life[1,2]. Moreover, it is typical for caregivers and family members to bear a great deal of the burden[3], and interpersonal relationships may be negatively and irreparably affected. Finally, the ensuing cost to public healthcare systems is considerable[4], and attempts to reduce the load are needed.

The multifactorial nature of both the risk factors and causes of falls[5] makes identification of those at risk exceptionally challenging. Clinical balance tests typically require little or no equipment, are quick and easy to perform, require little training to administer and can be employed in a wide variety of settings. These tools would therefore be useful measures to include in generalized fall-risk assessments. A review of the literature however shows standard clinical balance measures alone do not reliably predict fall risk in community-dwelling older individuals.

Fear of falling and low balance confidence are commonly reported in elderly individuals[2,6]. There is significant neurophysiological evidence demonstrating the correlates between emotional processing pathways, autonomic regulation centers and balance control circuitry[7-13]. Animal studies[14] and clinical observations in humans[15,16] also provide evidence of the concomitant nature of psychological and balance disorders. Studies in human participants that have attempted to empirically evaluate the relationship between psychological state and balance control typically have done so by manipulating levels of postural threat to induce increases in fear, anxiety and/or arousal. However, the majority of these studies have been restricted to the evaluation of simple quiet standing balance control[17-25] and as a result, little is known about the nature of the associations between psychological measures and balance performance under more challenging balance conditions, particularly in elderly populations.

Three studies were conducted with the global purpose of better understanding the influence of fear of falling on balance control in both young and elderly individuals. In order to extend appreciation of this relationship from simple quiet standing tasks to more ecologically valid circumstances, the focus was on tasks commonly used by clinicians to assess balance, evaluate changes in control or performance resulting from progression of disease and/or assess the efficacy of rehabilitation techniques. A significant driving force in the design of the studies was clinical utility with an interest in knowledge transfer from laboratory to clinical settings.

The first of these studies[26] evaluated this relationship in healthy young individuals only, to examine the influence of postural threat independent of aging effects on balance. Postural threat was manipulated by requiring the participants to perform several balance tasks while standing on a platform raised to 40cm and 140cm above the ground; the resultant changes in balance performance and psychological measures thought to be related to fear of falling were examined. Participants performed quiet stance (in order to confirm that experimental manipulations resulted in similar changes to those of previous reports) as well as maximal reach and one-leg stance tasks at these two levels of postural threat. Participants were exposed to this procedure on three separate occasions, and test-retest reliability of balance and psychological measures was assessed.

Decrements in balance control a result of natural aging processes have been implicate in fall-risk including psychological, neurological, mechanical, and physiological changes and well as cognitive impairments[27-38]. Fear of falling and cognitive processing limitations associated with advancing age[28] may further compromise balance control in the elderly, and few studies have examined the influence of these factors on performance of clinical balance tests. In more challenging postural tasks, the costs of reduced balance control are more severe and could lead to more grave consequences in elderly as compared to young populations . There is evidence to suggest that in more challenging balance and locomotor tasks, attentional capacity is taxed to a greater extent than in quiet standing, more so in older than younger adults[39,40], and therefore dual-tasking may have a more harmful effect to performance of clinical balance tasks.

The second study in this series examined the independent and combined influences of postural threat and cognitive loading on clinical balance performance in community-dwelling older adults. Participants performed quiet stance, functional reach, one-leg stance, tandem stance and sit-to-stand tasks on the ground and on an elevated surface 50cm above the ground, with or without the addition of a memory task. A second phase of this study examined fall prediction. Fall prediction models were derived using outcome measures from the experimental manipulation and fall data were collected on a weekly basis for a one-year period. Given the indisputable multifactorial nature of causes in falls and fall-risk, various models incorporating clinical balance, psychological affect and disease burden variables were evaluated for their ability to predict prospective fall status.

A third study focused on evaluating the reliability and validity of psychological measures related to fear of falling used in this dissertation work. This study was conducted employing a separate sample of community-dwelling elderly adults, using a protocol similar to that of the second study.

6.1 Summary of Findings

The first purpose of this dissertation work was to evaluate the influence of fear of falling on the performance of clinical measures of balance control. It was expected that fear of falling induced by postural threat would result in decrements to performance of clinical balance tasks. Results of the first study demonstrated that postural threat caused reductions in balance confidence and perceived stability as well as increases in state anxiety. These changes in psychological measures were significantly correlated to decrements in clinical balance performance in healthy young adults.

The first segment of the second study found similar effects in healthy community-dwelling older adults, with poorer performance of clinical tasks associated with increased fear of falling and reduced balance confidence as a result of increased postural threat. Dual-tasking, as manipulated in this study, did not affect clinical balance performance or increase fear of falling, but did result in reduced confidence and increased state anxiety ratings.

The second phase of the second study was focused on evaluating the ability of various univariate and multivariate models to predict falls in community-dwelling elderly individuals. Given the lack of success of existing clinical and laboratory models[41,42], many of which evaluate a solitary measure[42], it was hypothesised that more comprehensive models including clinical balance scores, psychological measures and general health estimates would better discriminate between fallers and non-fallers. Phase two of the second study showed that commonly used clinical assessments, including scores on functional reach, one-leg stance, tandem stance, and repeated sit-to-stands, could not predict falls in this population. However, a combination of the scores on functional reach, one-leg stance and repeated sit-to-stands tasks could significantly predicted prospective fall status. Furthermore, improved predictive precision resulted from having these tasks performed under combined postural threat and cognitive load. Finally, the addition of task-specific psychological measures and comorbidity scores resulted in further improvements to predictive precision, over that of balance scores alone. A most interesting finding was that task-specific psychological measures alone, when measured under combined postural threat and cognitive loading, could predict prospective fall status. All together, the results show that it is imperative for researchers and clinicians to account for the confounding influence of psychological factors on balance control and performance.

Literature reviews of psychological constructs related to fear of falling and the tools most typically used to measure them, highlight the need for measurement property evaluations[43,44]. Another purpose of this dissertation work was to assess the reliability and validity of psychological measures related to fear of falling. Task-specific tools developed for use in postural threat studies that evaluate balance confidence, perceived stability and state anxiety demonstrated fair to excellent test-retest reliability in both healthy young and community-dwelling older individuals. In older adults, ratings on these task-specific measures of psychological constructs however were only moderately related to average measures of confidence in activities of daily living. Correlation analyses revealed that psychological measures are distinct albeit related constructs and are task/condition-dependent. While task-specific psychological measures were related to clinical balance performance, more generalized measures of balance confidence and fear of falling were not. This supports assertions of specificity founded in well-accepted social-cognitive theory[45], and reveals the importance of evaluating and managing psychological state as it relates to balance performance in a context-dependent or situation-specific manner.

6.2 Future Work

With the notion of knowledge transfer in mind, these studies were designed to illustrate the influence of fear of falling on measures used in standard clinical practice by physiotherapists, occupational therapists and balance assessment specialists. Tools used throughout this dissertation to assess psychological measures and disease burden are easy to administer and interpret. However, evidence was put forth suggesting that refinement of these scales may be warranted.

This work shows that psychological measures, both generalized to activities of daily living and with respect to individual tasks, are associated with fear of falling but evaluate distinct constructs. This supports the work of Hotchiss et al. (2004)[46], and extends the findings to include task-specific measures. Moreover, relationships between psychological state and balance performance are task and condition dependent. Therefore, it may be particularly worthwhile for future research to develop a composite measure to evaluate state-specific anxiety, balance confidence or self-efficacy, and fear of falling together. It will also be necessary to evaluate the measurement properties of this scale, including test-retest reliability, predictive validity, and sensitivity to change in large representative samples of community dwelling older adults. It is expected that such a tool would prove to be a revealing and useful addition to the clinical repertoire, notably to supplement balance scores in fall-risk assessment.

This work showed also that standard clinical measures were not able to predict fall status in healthy community-dwelling elderly. However, a selection of three more challenging balance tasks (functional reach, one-leg stance, sit-to-stands), each taxing different aspects of balance control (limits of stability, reduced base of support, functional mobility), could together identify individuals at risk for future falls. This result has important clinical implications for predicting and thereby preventing falls in this population. It may be worthwhile for future research to create a composite measure of these scores, to use in generalized fall-risk screenings.

Moreover, the results of this dissertation clearly suggest that fall prevention interventions will be most successful when fear of falling is addressed with appropriate assessment tools and targeted 'treatments'. Because psychological state is task-dependent, and performance on varied balance tasks are not correlated, it will be important to determine the specific activities or circumstances that are particularly anxiety or fear-inducing for participants using an individualistic approach. Should higher levels of fear or anxiety be a result of poor balance or mobility, interventions targeting improved balance control in a specified context may be beneficial. Should activity avoidance be driven by affect, then cognitive-behavioural interventions targeted specifically at psychological state may be more appropriate. However, due to the interplay and mediating roles of multiple risk factors[47], it is most likely that multifactorial interventions will produce the greatest benefit. In their review of interventions to reduce fear of falling, Zijlstra et al. (2007) discovered that, although methodologically high-quality studies were few in number, consistent reductions in 'fear of falling' came from home-based exercise, fall-related multifactorial, and group tai chi programs.

Collaborative research between health care administrators, practicing clinicians, information technologists and researchers will be essential in determining the most cost-efficient and effective method to incorporate these findings into wide-spread clinical evaluations.

6.3 Significance of Findings and General Conclusions

The findings of this dissertation support previous research demonstrating that fear of falling and changes to related psychological measures, induced by postural threat, are related to changes in posturographic measures of standing balance control. The findings have also extended the field of study to include an appreciation of the relationship between fear of falling and related psychological measures with more challenging and commonly used clinical balance tests.

Furthermore, this work demonstrated that evaluating the balance ability of community-dwelling elderly individuals with commonly used clinical scales, such as the Berg Balance Scale and Timed-up-and-Go, could not predict future falls. Additionally, more generalized psychological measures as they relate to activities of daily living, such as the Activities-Specific Balance Confidence Scale and general fear of falling, could not predict future falls. These measures therefore, provide limited insight into fall-risk for healthy independent-living older adults.

However, significant and improved fall-risk estimates were found when using a selection of only three easily administered but more demanding clinical balance tasks. Moreover, when these tasks were performed under challenging conditions, combining postural threat with cognitive loading, further improvements in predictive precision were seen. It is likely that these more taxing circumstances better reflect everyday experiences in which a fall is likely to occur.

Incorporating easy-to-administer task-specific psychological evaluations and self-reported health estimates with balance assessments further improved the likelihood of correctly identifying individuals at risk for falls. Although considered preliminary, due to the small sample size and the associated large confidence interval bounds, these results provide a promising and important avenue for future confirmatory research.

Improved estimates of fall-risk, in combination with successful intervention programs, may lead to a reduction in the number of falls experienced by community-dwelling elderly individuals potentially reducing the burden of fall-related hospitalizations, treatments and rehabilitation on individuals, families and healthcare systems.

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Appendix A

Information Letters and Consent Forms

INFORMATION LETTER AND CONSENT FORM

Understanding the Influence of Fear of Falling on Balance Control Efforts in Fall Prediction and Prevention

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1. PARTICIPANT INFORMATION LETTER

1. INTRODUCTION AND BACKGROUND

Recent evidence has found that when people stand still, they experience an increase in instability along with increases in their fear of falling. However, there is little known about how this fear affects performance of activities of daily living.

You are being invited to take part in this research study because you are an adult, 65 years of age or over, and are living independently in the community.

2. YOUR PARTICIPATION IS VOLUNTARY

Your participation is entirely voluntary. Before you decide whether to participate, it is important that you are aware of what the research involves. This information letter will tell you about the study, why the research is being done, what will happen during the study, and the possible benefits, risks and discomforts.

If you wish to participate, you will be asked to sign the consent portion of this letter, in the presence of the investigator (i.e. at the University of Waterloo). If you decide to take part in this study, you are still free to withdraw at any time without giving any reasons for your decision.

If you do not wish to participate, you do not have to provide any reason for your decision not to participate.

3. WHERE IS THE STUDY BEING CONDUCTED?

The study is being conducted in the Human Performance Laboratory at the University of Waterloo (B.C. Matthews Hall (BMH) 1405)

4. WHAT IS THE PURPOSE OF THE STUDY?

The purpose of the study is to examine the influence of fear of falling on balance in older individuals.

5. WHO CAN PARTICIPATE IN THE STUDY?

Adults aged 65 or older and living independently, are being invited to participate.

A total of 100 volunteers will be enrolled in this study.

6. WHO SHOULD NOT PARTICIPATE IN THE STUDY?

If you meet any of the following criteria, you should not participate in this study:

- If you have been diagnosed with any cognitive impairment or disorders

- If you currently use a support device to walk/stand (e.g. cane, walker, wheelchair)

- If you cannot support your own weight and maintain an upright posture while standing or walking

- If you have a known allergy to rubbing alcohol

7. WHAT DOES THE STUDY INVOLVE?

If you agree to take part in this study, you will be asked to do the following:

Prior to the start of the balance experiment, you will be asked to complete two questionnaires about your fear of falling, balance confidence, and health status. Two small sticky pads will then be placed on the palm of one hand, to measure whether or not you experience any anxiety throughout the testing session. You will also be asked to put on an elastic belt that fits comfortably around your waist and is fastened using Velcro straps. On the back of the belt, there is a small box that contains sensors designed to detect any changes in your upper-body movement. The box is lightweight and will not disturb your natural movements in any way.

You will then be asked to complete two sets of tasks that are frequently used to measure balance. *The first set of tasks includes*:

1) Sitting in a chair
2) Rising to a standing position from a chair
3) Standing with feet comfortably apart, with eyes open (2 minutes)
4) Standing with feet comfortably apart, with eyes closed (10 seconds)
5) Turning on the spot, in a full circle one way and then a full circle the other way
6) Moving from a standing position to a sitting position
7) Transferring from one chair to another
8) Standing with feet together, with eyes open (1 minute)
9) Standing with feet heel to toe, with eyes open (30 seconds)
10) Standing on one leg, with eyes open (10 seconds)
11) With feet firmly on the floor, looking over each shoulder in turn
12) Bending to pick an object up off the floor
13) Placing each foot alternately on a step/stool, continuing until each foot has touched the step/stool four times.
14) With feet planted, reaching forward with an outstretched arm

The second set of tasks includes the following in series:

1) Rising to a standing position from a chair
2) Walking 3 meters
3) Turning around (180 degrees)
4) Walking back to the chair
5) Sitting down in the chair

Following this, you will be asked to complete 6 tasks under four conditions. During one condition, the balance tasks will be performed on the ground; during the second condition, the balance tasks will be performed on an elevated surface, of chair height (approximately 20” (50cm)); during the third condition the balance tasks will be performed on the ground, while also doing a memory task; during the fourth condition the balance tasks will be performed on an elevated surface, of chair height (approximately 20” (50cm)) while also doing a memory task. The balance tasks are the following:

1) Standing with feet comfortably apart, with eyes open (1 minute)
2) Standing with feet comfortably apart, with eyes closed (1 minute)
3) Standing heel to toe, with eyes open (30 seconds)
4) Standing on one leg, with eyes open (up to 30 seconds)
5) With feet planted, reaching forward with an outstretched arm
6) Repeated sit to stands (5 times)

There will always be two people standing next to you during your performance of these tasks to ensure that you do not lose your balance.

Following each of the four conditions, you will be asked to sit down and take a 10-minute rest. During this period, you will also be asked to complete two brief questionnaires: one regarding feelings of anxiety; and another regarding your perceived fear and stability during the time when the balance tasks were carried out.

For the follow-up period (6-12 months) you will be asked to complete one questionnaire per week, reporting any falls or near falls that you might experience during that time. A package of questionnaires and prepaid/addressed envelopes will be given to you, to take home to complete and mail back to the investigator.

If you participate in this study, it will take about 2 hours in the lab, plus the time to complete the weekly questionnaires (about 10 minutes each).

8. WHAT ARE THE POSSIBLE HARMS AND SIDE EFFECTS OF PARTICIPATING?

The balance tasks that you will perform are based on actions you would likely experience in your daily life, and are commonly used to assess normal balance. There will always be two people standing or walking next to you to ensure that you will not lose your balance and fall. Therefore, there are no anticipated risks associated with performing the balance and walking tasks.

Rubbing alcohol will be used to cleanse the skin prior to placing the small pads on your palm. If you have a known allergy to rubbing alcohol, it would be in your best interest not to participate.

9. WHAT ARE THE BENEFITS OF PARTICIPATING IN THIS STUDY?

You may not receive any direct benefit from participating in this study. However, the information obtained from this research has the potential to help understand how fear of falling plays a role in balance deficits, as well as to improve community fall prevention and rehabilitation programs.

10. WHAT IF NEW INFORMATION BECOMES AVAILABLE THAT MAY AFFECT MY DECISION TO PARTICIPATE?

You will be advised of any new information regarding the procedures or potential risks associated with this study that may influence your decision about participation.

11. WHAT HAPPENS IF I DECIDE TO WITHDRAW MY CONSENT TO PARTICIPATE?

Your participation in this research is entirely voluntary. You may withdraw from this study at any time, by advising the researcher. If you decide to enter the study and to withdraw at any time in the future, there will be no penalty. You may decline to answer any questions presented during the session of the study conducted in the lab or in the follow up questionnaires if you so wish.

12. CAN I BE ASKED TO LEAVE THE STUDY?

If you are not able to complete the balance tasks involved in the study the investigator may ask you to withdraw from the study.

13. AFTER THE STUDY IS FINISHED

The results of this study will be analyzed and published in a scientific journal and/or presented at scientific meetings. Should you wish to receive information regarding the outcome of the study, please inform the investigators. The study findings are expected to be available summer 2009.

14. WILL THERE BE ANY REMUNERATION TO PARTICIPANTS?

You will be provided a $10/hour honorarium for your participation. This remuneration will be given at the completion of the laboratory session. If you do not complete the laboratory session, the honorarium will be prorated according to your time in the study. You will also be provided with a $2 honorarium for each weekly questionnaire submitted during the follow-up period, which will be given at the end of the study.

15. WILL MY TAKING PART IN THIS STUDY BE KEPT CONFIDENTIAL?

Your confidentiality will be respected. No information that discloses your identity will be released or published without your specific consent to the disclosure. Data collected during this study will be retained indefinitely, in a locked office in the Department of Kinesiology at the University of Waterloo to which only researchers associated with this study have access.

16. WHO DO I CONTACT IF I HAVE QUESTIONS ABOUT THE STUDY DURING MY PARTICIPATION?

If you have any questions or desire further information about this study before or during participation, you can contact Laura Hauck at ljgrin@uwaterloo.ca, Dr Steve Prentice at (519) 888-4567 Ext 36830, or Dr Jim Frank at (519) 253-3000 Ext 2107

17. WHO DO I CONTACT IF I HAVE ANY QUESTIONS OR CONCERNS ABOUT MY RIGHTS AS A PARTICIPANT IN THE STUDY?

This study has been reviewed and received ethics clearance through the Office of Research Ethics at the University of Waterloo. However, the final decision about participation is yours. If you have any comments, concerns or questions resulting from your participation in this study, please contact Dr. Susan Sykes at this office at (519) 888-4567 Ext. 36005 or at ssykes@uwaterloo.ca.

PARTICIPANT CONSENT FORM

I have read the participant information letter.
I have had sufficient time to consider the information provided and to ask for advice if necessary.
I have had the opportunity to ask questions and have had satisfactory responses to my questions.
I understand that all of the information collected will be kept confidential and that the results will only be used for scientific objectives.
I understand that my participation in this study is voluntary and that I am free to refuse to participate or to withdraw from this study at any time.
I am aware that I do not waive my legal rights by signing this consent form.
I have read this form and I freely consent to participate in this study.
I have been told that I will receive a dated and signed copy of this form.

I have received a copy of this consent form for my own records.
I consent to participate in this study.

______________________	________________________	_____________
Participant Signature	Print Name	Date
______________________	________________________	_____________
Witness Signature	Print Name	Date

Appendix B

General Psychological Questionnaires

Part 1: Fear of Falling

Instructions: Please indicate *with an X on the scale below*, how fearful (on average) you are of falling or falling again. If you have any questions, please ask the administrator.

+++
0 10 20 30 40 50 60 70 80 90 100
never fearful always fearful

Part 2: Activities-Specific Balance Confidence (ABC)

Instructions: Please *indicate with a numerical value in the space next to the listed activity*, your level of confidence in doing the activity without losing your balance or becoming unsteady.
+++
0 10 20 30 40 50 60 70 80 90 100
no confidence completely confident

If you do not currently do the activity, try to imagine how confident you would be if you had to do the activity. If you normally use a walking aid or hold onto someone to do the activity, rate your confidence as if you were using these supports. If you have any questions, please ask the administrator.

How confident are you that you will **not** lose your balance or become unsteady when you do the following: ….

1… walk around the house? _____%
2. …walk up or down stairs? _____%
3. … bend over and pick a slipper up from the front of a closet floor? _____%
4. … reach for a small can off a shelf at eye level? _____%
5. … stand on your tiptoes and reach for something above your head? _____%
6. … stand on a chair and reach for something? _____%
7. … sweep the floor? _____%
8. … walk outside the house to a car parked in the driveway? _____%
9. … get in our out of a car? _____%
10. …walk across a parking lot to the mall? _____%
11. …walk up or down a ramp? ____%
12. …walk in a crowded mall where people rapidly walk past you? ____%
13. …are bumped into/by people as you walk through the mall? _____%
14. …step onto/off an escalator while holding onto a railing? _____%
15. …step onto/off an escalator while holding parcels (not railing)? _____%
16. …walk outside on icy sidewalks? _____%

Appendix C

Examples of Task-Specific Psychological Questionnaires

Note: You do not have to answer any question you are not comfortable answering.

Condition: No Challenge

Considering that no one is completely confident (100%) and no one completely lacks confidence (0%), please use the scale below to tell us the amount of confidence you have in your ability to maintain your balance while performing the six balancing tasks:

Standing: Eyes Open

+++										
0	10	20	30	40	50	60	70	80	90	100
No Confidence					Moderate Confidence					Complete Confidence

Standing: Eyes Closed

+++										
0	10	20	30	40	50	60	70	80	90	100
No Confidence					Moderate Confidence					Complete Confidence

Standing: Heel to Toe

+++										
0	10	20	30	40	50	60	70	80	90	100
No Confidence					Moderate Confidence					Complete Confidence

Standing: One Leg

+++										
0	10	20	30	40	50	60	70	80	90	100
No Confidence					Moderate Confidence					Complete Confidence

Standing: Feet Planted Forward Reach

+++										
0	10	20	30	40	50	60	70	80	90	100
No Confidence					Moderate Confidence					Complete Confidence

Repeated Sit to Stands

+++										
0	10	20	30	40	50	60	70	80	90	100
No Confidence					Moderate Confidence					Complete Confidence

Note: You do not have to answer any question you are not comfortable answering.

Condition: Postural Challenge (elevated surface)

Please answer the following questions about how you honestly feel just after completing the balance tasks in this condition using the following scale:

1	2	3	4	5	6	7	8	9
I do not feel this at all		I feel this moderately				I feel this extremely		

1. I felt nervous[S]
   1 2 3 4 5 6 7 8 9
2. I had lapses of concentration[C]
   1 2 3 4 5 6 7 8 9
3. I had self-doubts[W]
   1 2 3 4 5 6 7 8 9
4. I felt myself tense and shaking[S]
   1 2 3 4 5 6 7 8 9
5. I was concerned about being able to concentrate[C]
   1 2 3 4 5 6 7 8 9
6. I was concerned about doing the balance task correctly[W]
   1 2 3 4 5 6 7 8 9
7. My body was tense[S]
   1 2 3 4 5 6 7 8 9
8. I had difficulty focusing on what I had to do[C]
   1 2 3 4 5 6 7 8 9
9. I was worried about my personal safety[W]
   1 2 3 4 5 6 7 8 9
10. I felt my stomach sinking[S]
   1 2 3 4 5 6 7 8 9
11. I did not pay attention to the point on the wall all of the time[C]
   1 2 3 4 5 6 7 8 9
12. My heart was racing[S]
   1 2 3 4 5 6 7 8 9
13. Thoughts of falling interfered with my concentration[C]
   1 2 3 4 5 6 7 8 9
14. I was concerned that others would be disappointed with my performance[W]
   1 2 3 4 5 6 7 8 9
15. I found myself hyperventilating[S]
   1 2 3 4 5 6 7 8 9
16. I found myself thinking about things unrelated to doing the task[C]
   1 2 3 4 5 6 7 8 9

Intended Aspects of State Anxiety: [S]Somatic; [C]Concentration; [W]Worry

Note: You do not have to answer any question you are not comfortable answering.

Condition: Cognitive Challenge

Using the following scale, please rate how ***stable*** you felt when performing the six balance tasks **while performing the memory task**:

Standing: Eyes Open

+++
0 10 20 30 40 50 60 70 80 90 100
Not Stable At All | Moderately Stable | Completely Stable

Standing: Eyes Closed

+++
0 10 20 30 40 50 60 70 80 90 100
Not Stable At All | Moderately Stable | Completely Stable

Standing: Heel to Toe

+++
0 10 20 30 40 50 60 70 80 90 100
Not Stable At All | Moderately Stable | Completely Stable

Standing: One Leg

+++
0 10 20 30 40 50 60 70 80 90 100
Not Stable At All | Moderately Stable | Completely Stable

Standing: Feet Planted Forward Reach

+++
0 10 20 30 40 50 60 70 80 90 100
Not Stable At All | Moderately Stable | Completely Stable

Repeated Sit to Stands

+++
0 10 20 30 40 50 60 70 80 90 100
Not Stable At All | Moderately Stable | Completely Stable

Note: You do not have to answer any question you are not comfortable answering.

Condition: Postural and Cognitive Challenges

Using the following scale, please rate how ***fearful of falling*** you felt when performing the six balance tasks **<u>on the elevated surface AND while performing the memory task</u>**:

Standing: Eyes Open

+++
0 10 20 30 40 50 60 70 80 90 100
Not Fearful At All | Moderately Fearful | Completely Fearful

Standing: Eyes Closed

+++
0 10 20 30 40 50 60 70 80 90 100
Not Fearful At All | Moderately Fearful | Completely Fearful

Standing: Heel to Toe

+++
0 10 20 30 40 50 60 70 80 90 100
Not Fearful At All | Moderately Fearful | Completely Fearful

Standing: One Leg

+++
0 10 20 30 40 50 60 70 80 90 100
Not Fearful At All | Moderately Fearful | Completely Fearful

Standing: Feet Planted Forward Reach

+++
0 10 20 30 40 50 60 70 80 90 100
Not Fearful At All | Moderately Fearful | Completely Fearful

Repeated Sit to Stands

+++
0 10 20 30 40 50 60 70 80 90 100
Not Fearful At All | Moderately Fearful | Completely Fearful

Appendix D

Falls Information Questionnaire

Falls Questionnaire

Name ________________________ **Date _____________________**

Please answer the questions below by *circling* the appropriate answer. When you are finished, please use the return envelope to mail this questionnaire to the investigators.

1) Did you experience a fall or near fall this week? Yes No

If yes, continue with (2) If not, you are finished

2) If yes, where were you? Home Away from home

If at home, where? Kitchen Living Room Bathroom Bedroom

Outside Other ______________________________

If away from home, where? Sidewalk Park Parking Lot Mall/Store

Another Home Other ________________

3) What were you doing? Sitting Standing Getting up from a bed/chair

Walking Climbing Stairs Other _______________

4) How did you fall? Slip Trip Lost Balance Legs Gave Out Felt Faint/Dizzy

Not sure Other __________________________________

5) Were you carrying any items? If yes, were they… Heavy Light

6) Were you bumped or pushed? Yes No

7) Were you distracted by something/someone (talking, reading a sign)? Yes No

8) Did you suffer any injuries as a result of the fall? Yes No

If yes, continue with (9) If not, you are finished

9) What injuries did you suffer? Bruises Cuts/Grazes Broken wrist

Broken Hip Broken Ribs Back Pain

Other ________________________________

10) Did you go to the hospital for treatment of these injuries?

If yes, continue with (11) If not, you are finished

11) At the hospital, were you? Admitted for treatment Treated and sent home

12) What treatment did you receive?

____

____

Do you have any additional comments?

Appendix E

Comorbidity Questionnaire

Health Questionnaire

Name: Date:

Height: Weight: Age:

Instructions: The following is a list of common health problems. Please indicate if you currently have the problem in the first column – if you do not have the problem, skip to the next problem. If you do have the problem, please indicate in the second column, if you receive medications or some other type of treatment for the problem. In the third column indicate if the problem limits any of your activities. Finally, indicate all medical conditions that are not listed, under the "other medical problems" at the end of the page.

PROBLEM	Do/Did you have the problem?	Do you receive treatment for it?	Does it affect your activities?
Heart Failure	Y N	Y N	Y N
Heart Rhythm Irregularities	Y N	Y N	Y N
Heart Attack	Y N	Y N	Y N
Heart Valve	Y N	Y N	Y N
Lung Circulation	Y N	Y N	Y N
Leg/Arm Vein/Artery	Y N	Y N	Y N
Stroke or TIA	Y N	Y N	Y N
High Blood Pressure	Y N	Y N	Y N
Paralysis	Y N	Y N	Y N
Other Neurological	Y N	Y N	Y N
Lung Disease	Y N	Y N	Y N
Diabetes	Y N	Y N	Y N
Hypothyroidism	Y N	Y N	Y N
Kidney Disease/Failure	Y N	Y N	Y N
Liver Disease	Y N	Y N	Y N
Ulcers	Y N	Y N	Y N
AIDS/HIV	Y N	Y N	Y N
Cancer	Y N	Y N	Y N
Rheumatoid Arthritis	Y N	Y N	Y N
Blood Clotting Disorders	Y N	Y N	Y N
Unintended Weight Loss	Y N	Y N	Y N
Fluid/Electrolyte Disorders	Y N	Y N	Y N
Anemia	Y N	Y N	Y N
Alcohol Abuse	Y N	Y N	Y N
Drug Abuse	Y N	Y N	Y N
Mood Disorders	Y N	Y N	Y N
Depression	Y N	Y N	Y N
Dementia	Y N	Y N	Y N
Muscle Weakness	Y N	Y N	Y N
Balance/Walking/Mobility	Y N	Y N	Y N
Vision	Y N	Y N	Y N
Dizziness/Vertigo/Fainting	Y N	Y N	Y N
Overweight/Obese	Y N	Y N	Y N
Other	Y N	Y N	Y N
Other	Y N	Y N	Y N

Appendix F
Berg Balance Test

Berg Balance Scale

SITTING TO STANDING
INSTRUCTIONS: Please stand up. Try not to use your hand for support.
( ) 4 able to stand without using hands and stabilize independently
( ) 3 able to stand independently using hands
( ) 2 able to stand using hands after several tries
( ) 1 needs minimal aid to stand or stabilize
( ) 0 needs moderate or maximal assist to stand

STANDING UNSUPPORTED
INSTRUCTIONS: Please stand for two minutes without holding on.
( ) 4 able to stand safely for 2 minutes
( ) 3 able to stand 2 minutes with supervision
( ) 2 able to stand 30 seconds unsupported
( ) 1 needs several tries to stand 30 seconds unsupported
( ) 0 unable to stand 30 seconds unsupported

If a subject is able to stand 2 minutes unsupported, score full points for sitting unsupported. Proceed to item #4.

SITTING WITH BACK UNSUPPORTED BUT FEET SUPPORTED ON FLOOR OR ON A STOOL
INSTRUCTIONS: Please sit with arms folded for 2 minutes.
( ) 4 able to sit safely and securely for 2 minutes
( ) 3 able to sit 2 minutes under supervision
( ) 2 able to able to sit 30 seconds
( ) 1 able to sit 10 seconds
( ) 0 unable to sit without support 10 seconds

STANDING TO SITTING
INSTRUCTIONS: Please sit down.
( ) 4 sits safely with minimal use of hands
( ) 3 controls descent by using hands
( ) 2 uses back of legs against chair to control descent
( ) 1 sits independently but has uncontrolled descent
( ) 0 needs assist to sit

TRANSFERS
INSTRUCTIONS: Arrange chair(s) for pivot transfer. Ask subject to transfer one way toward a seat with armrests and one way toward a seat without armrests. You may use two chairs (one with and one without armrests) or a bed and a chair.
( ) 4 able to transfer safely with minor use of hands
( ) 3 able to transfer safely definite need of hands
( ) 2 able to transfer with verbal cuing and/or supervision
( ) 1 needs one person to assist
( ) 0 needs two people to assist or supervise to be safe

STANDING UNSUPPORTED WITH EYES CLOSED
INSTRUCTIONS: Please close your eyes and stand still for 10 seconds.
( ) 4 able to stand 10 seconds safely
( ) 3 able to stand 10 seconds with supervision
( ) 2 able to stand 3 seconds
( ) 1 unable to keep eyes closed 3 seconds but stays safely
( ) 0 needs help to keep from falling

STANDING UNSUPPORTED WITH FEET TOGETHER
INSTRUCTIONS: Place your feet together and stand without holding on.
( ) 4 able to place feet together independently and stand 1 minute safely
( ) 3 able to place feet together independently and stand 1 minute with supervision
( ) 2 able to place feet together independently but unable to hold for 30 seconds
( ) 1 needs help to attain position but able to stand 15 seconds feet together
( ) 0 needs help to attain position and unable to hold for 15 seconds

Berg Balance Scale continued…..

REACHING FORWARD WITH OUTSTRETCHED ARM WHILE STANDING
INSTRUCTIONS: Lift arm to 90 degrees. Stretch out your fingers and reach forward as far as you can. (Examiner places a ruler at the end of fingertips when arm is at 90 degrees. Fingers should not touch the ruler while reaching forward. The recorded measure is the distance forward that the fingers reach while the subject is in the most forward lean position. When possible, ask subject to use both arms when reaching to avoid rotation of the trunk.)
( ) 4 can reach forward confidently 25 cm (10 inches)
( ) 3 can reach forward 12 cm (5 inches)
( ) 2 can reach forward 5 cm (2 inches)
( ) 1 reaches forward but needs supervision
( ) 0 loses balance while trying/requires external support

PICK UP OBJECT FROM THE FLOOR FROM A STANDING POSITION
INSTRUCTIONS: Pick up the shoe/slipper, which is place in front of your feet.
( ) 4 able to pick up slipper safely and easily
( ) 3 able to pick up slipper but needs supervision
( ) 2 unable to pick up but reaches 2-5 cm(1-2 inches) from slipper and keeps balance independently
( ) 1 unable to pick up and needs supervision while trying
( ) 0 unable to try/needs assist to keep from losing balance or falling

TURNING TO LOOK BEHIND OVER LEFT AND RIGHT SHOULDERS WHILE STANDING
INSTRUCTIONS: Turn to look directly behind you over toward the left shoulder. Repeat to the right. Examiner may pick an object to look at directly behind the subject to encourage a better twist turn.
( ) 4 looks behind from both sides and weight shifts well
( ) 3 looks behind one side only other side shows less weight shift
( ) 2 turns sideways only but maintains balance
( ) 1 needs supervision when turning
( ) 0 needs assist to keep from losing balance or falling

TURN 360 DEGREES
INSTRUCTIONS: Turn completely around in a full circle. Pause. Then turn a full circle in the other direction.
( ) 4 able to turn 360 degrees safely in 4 seconds or less
( ) 3 able to turn 360 degrees safely one side only 4 seconds or less
( ) 2 able to turn 360 degrees safely but slowly
( ) 1 needs close supervision or verbal cuing
( ) 0 needs assistance while turning

PLACE ALTERNATE FOOT ON STEP OR STOOL WHILE STANDING UNSUPPORTED
INSTRUCTIONS: Place each foot alternately on the step/stool. Continue until each foot has touch the step/stool four times.
( ) 4 able to stand independently and safely and complete 8 steps in 20 seconds
( ) 3 able to stand independently and complete 8 steps in > 20 seconds
( ) 2 able to complete 4 steps without aid with supervision
( ) 1 able to complete > 2 steps needs minimal assist
( ) 0 needs assistance to keep from falling/unable to try

STANDING UNSUPPORTED ONE FOOT IN FRONT
INSTRUCTIONS: (DEMONSTRATE TO SUBJECT) Place one foot directly in front of the other. If you feel that you cannot place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot. (To score 3 points, the length of the step should exceed the length of the other foot and the width of the stance should approximate the subject's normal stride width.)
( ) 4 able to place foot tandem independently and hold 30 seconds
( ) 3 able to place foot ahead independently and hold 30 seconds
( ) 2 able to take small step independently and hold 30 seconds
( ) 1 needs help to step but can hold 15 seconds
( ) 0 loses balance while stepping or standing

STANDING ON ONE LEG
INSTRUCTIONS: Stand on one leg as long as you can without holding on.
( ) 4 able to lift leg independently and hold > 10 seconds
( ) 3 able to lift leg independently and hold 5-10 seconds
( ) 2 able to lift leg independently and hold ≥ 3 seconds
( ) 1 tries to lift leg unable to hold 3 seconds but remains standing independently.
( ) 0 unable to try of needs assist to prevent fall

Appendix G

Word Lists

Study 2 - Elderly cohort 1

List 1	List 2
ORANGES	JUICE
CHIPS	POP
ALMONDS	SAUSAGE
BANANA	STEAK
KIWI	WATER
CANDY	FISH
POPCORN	LAMB
APPLE	GATORADE
COOKIES	PORK
CHERRIES	TEA
PEANUTS	COFFEE
GRAPES	BACON

Study 3 - Elderly cohort 2

Week 1

List 1	List 2	List 3
ORANGES	JUICE	MILK
CHIPS	POP	YOGURT
ALMONDS	SAUSAGE	POTATOES
BANANA	STEAK	CARROTS
KIWI	WATER	CHEESE
CANDY	FISH	CELERY
POPCORN	LAMB	BROCCOLI
APPLE	GATORADE	ICE CREAM
COOKIES	PORK	LETTUCE
CHERRIES	TEA	BUTTER
PEANUTS	COFFEE	CREAM
GRAPES	BACON	BEANS

Week 2

List 4	List 5	List 6
BREAD	PEARS	PEPPERS
SALMON	TOMATOES	YAMS
MEATBALLS	PLUMS	RELISH
FLOUR	GRANOLA	MUSTARD
BAGELS	PUDDING	OLIVES
TURKEY	MELONS	TURNIPS
OATS	PEACHES	KETCHUP
BURGERS	APRICOTS	MAYO
CHICKEN	CRACKERS	PEAS
ROLLS	PRETZELS	PICKLES
ROAST	CASHEWS	SQUASH
CEREAL	RAISINS	ONIONS

Appendix H

Example of Falls Questionnaire Submission Guidelines

Weekly Questionnaire Completion and Submission Schedule
April 7th Participation

Week 1: Apr 14, 2008
Week 2: Apr 21, 2008
Week 3: Apr 28, 2008

Week 4: May 5, 2008
Week 5: May 12, 2008
Week 6: May 19, 2008
Week 7: May 26, 2008

Week 8: Jun 2, 2008
Week 9: Jun 9, 2008
Week 10: Jun 16, 2008
Week 11: Jun 23, 2008
Week 12: Jun 30, 2008

Week 13: Jul 7, 2008
Week 14: Jul 14, 2008
Week 15: Jul 21, 2008
Week 16: Jul 28, 2008

Week 17: Aug 4, 2008
Week 18: Aug 11, 2008
Week 19: Aug 18, 2008
Week 20: Aug 25, 2008

Week 21: Sep 1, 2008
Week 22: Sep 8, 2008
Week 23: Sep 15, 2008
Week 24: Sep 22, 2008
Week 25: Sep 29, 2008

Week 26: Oct 6, 2008
Week 27: Oct 13, 2008
Week 28: Oct 20, 2008
Week 29: Oct 27, 2008

Week 30: Nov 3, 2008
Week 31: Nov 10, 2008
Week 32: Nov 17, 2008
Week 33: Nov 24, 2008
Week 34: Dec 1, 2008

Week 35: Dec 8, 2008
Week 36: Dec 15, 2008
Week 37: Dec 22, 2008
Week 38: Dec 29, 2008

Week 39: Jan 5, 2009
Week 40: Jan 12, 2009
Week 41: Jan 19, 2009
Week 42: Jan 26, 2009

Week 43: Feb 2, 2009
Week 44: Feb 9, 2009
Week 45: Feb 16, 2009
Week 46: Feb 23, 2009
Week 47: Mar 2, 2009

Week 48: Mar 9, 2009
Week 49: Mar 16, 2009
Week 50: Mar 23, 2009
Week 51: Mar 30, 2009
Week 52: Apr 6, 2009

Instructions

Regular Post:

1) Complete one questionnaire every week, following the attached schedule.
2) Report on any falls or near falls for the week prior to the date(s) provided.
3) Mail 4-5 questionnaires together in one envelope, according to the groupings on the attached schedule using the pre-addressed and postage-paid envelopes.

Email:

1) Send one email every week, following the attached schedule.
2) Enter Week and Date in the subject line of each email.
For example: "Week ending April 14th, 2008"

3) Report on any falls or near falls for that week in the body of the email, using the questionnaire and the following examples as guides.

Example A: 1) Yes
2) Home, Bathroom
3) Climbing Stairs
4) Tripped
5) No
6) No
7) Yes – talking to my husband/wife
8) No

Example B: 1) No

Example C: 1) Yes
2) Away from home - Mall
3) Walking
4) Slipped – did not see the wet floor sign
5) Yes - light
6) No
7) No
8) Yes
9) Broken wrist – tried to catch myself
10) Yes
11) Treated and sent home
12) Cast was put on, sent home with some Tylenol

Appendix I

Comorbidity Results

COMORBIDITY	N (of 46)	Percent (%)
Heart Failure	1	2.17
Heart Rhythm Irregularities	9	19.57
Heart Attack	3	6.52
Heart Valve	3	6.52
Lung Circulation	1	2.17
Leg/Arm Vein/Artery	5	10.87
Stroke or TIA	6	13.04
High Blood Pressure	19	41.30
Paralysis	2	4.35
Other Neurological	5	10.87
Lung Disease	5	10.87
Diabetes	6	13.04
Hypothyroidism	6	13.04
Kidney Disease/Failure	6	13.04
Liver Disease	2	4.35
Ulcers	4	8.70
AIDS/HIV	0	0.00
Cancer	4	8.70
Rheumatoid Arthritis	15	32.61
Blood Clotting Disorders	3	6.52
Unintended Weight Loss	5	10.87
Fluid/Electrolyte Disorders	2	4.35
Anemia	3	6.52
Alcohol Abuse	3	6.52
Drug Abuse	0	0.00
Mood Disorders	1	2.17
Depression	10	21.74
Dementia	0	0.00
Muscle Weakness	6	13.04
Balance/Walking/Mobility	5	10.87
Vision	25	54.35
Dizziness/Vertigo/Fainting	17	36.96
Overweight/Obese	12	26.09
Other	7	15.22

Appendix J

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Appendix K
Summary of Chapter 2 Statistics

Summary of significant multivariate statistics

Task/Measure	Height	Task	F	df	p	Effect Size	Obs. Power
QS	λ=0.559	n/a	3.284	6,25	0.016	0.441*	0.885
Anxiety	λ=0.505		13.25	2,27	<0.0001	0.495*	0.995
		λ=0.411	15.40	4,110	<0.0001	0.359*	1.000
Efficacy	λ=0.203		18.870	5,24	<0.0001	0.797*	1.000
		λ=0.218	11.866	10,24	<0.0001	0.533*	1.000

*Large(0.35), # Medium-Large ES , +Medium ES (0.15) (Cohen, 1988)

Summary of significant univariate statistics

Task/Measure	Height	Task	F	df	p	Effect Size	Obs. Power
QS	AP-MP	n/a	5.857	1,30	0.022	0.163+	0.649
	AP-RMS		13.657	1,30	0.001	0.313ϕ	0.947
	AP-MPF		6.034	1,30	0.020	0.167+	0.662
MR	MaxReach	n/a	63.834	1,29	<0.0001	0.688*	1.000
OL	Time	n/a	4.058	1,30	0.05	0.119+	0.496
Psych	Efficacy		51.10	1,27	<0.0001	0.664*	1.000
	AF		28.03	1,27	<0.0001	0.520*	1.000
	MC		25.07	1,27	<0.0001	0.475*	0.998
	OW		39.55	1,27	<0.0001	0.608*	1.000
	RA		42.92	1,27	<0.0001	0.620*	1.000
		Efficacy	44.21	2,54	<0.0001	0.629*	1.000
		AF	50.15	2,54	<0.0001	0.653*	1.000
		MC	41.97	2,54	<0.0001	0.621*	1.000
		OW	33.80	2,54	<0.0001	0.566*	1.000
		RA	52.19	2,54	<0.0001	0.658*	1.000
	Stability		18.13	1,27	<0.0001	0.402*	0.984
		Stability	43.78	2,54	<0.0001	0.619*	1.000
	Anxiety		10.28	1,28	0.003	0.268#	0.872
	GSR		23.85	1,28	<0.0001	0.460*	0.997
		Anxiety	13.08	2,56	<0.0001	0.318ϕ	0.996
		GSR	25.14	2,56	<0.0001	0.473*	1.000

*Large ES (0.4), ϕMedium-Large, # Medium ES (0.25), +Small ES (0.10) (Cohen, 1992)

References

Cohen J. Statistical Power Analysis for the Behavioral Sciences Second ed., Hillsdale, New Jersey: Lawrence Erlbaum Associates, Inc.; 1988, p. 481

Cohen J. A Power Primer. Psychological Bulletin (1992). 112(1);155-159.

Dependent Variable Correlations within MANOVAs

Quiet Standing

	AP-RMS	AP-MPF	ML-MP	ML-RMS	ML-MPF
AP-MP	0.208 (0.262)	-0.245 (0.184)	-0.608 (<0.0001)	0.070 (0.708)	-0.101 (0.589)
AP-RMS		-0.519 (0.003)	0.060 (0.749)	0.309 (0.091)	-0.064 (0.731)
AP-MPF			0.195 (0.294)	0.074 (0.691)	-0.043 (0.819)
ML-MP				-0.094 (0.617)	0.022 (0.905)
ML-RMS					-0.533 (0.002)

Psychological Measures

	AF	MC	OW	RA
Overall Confidence	0.860 (<0.0001)	0.725 (<0.0001)	0.735 (<0.0001)	0.607 (<0.0001)
AF		0.877 (<0.0001)	0.829 (<0.0001)	0.747 (<0.0001)
MC			0.837 (<0.0001)	0.753 (<0.0001)
OW				0.881 (<0.0001)

	GSR
Anxiety	0.049 (0.800)

Appendix L

Summary of Chapter 3 Statistics

Summary of significant multivariate statistics

Task	Threat	Load	F	df	p	Effect Size	Obs. Power
QSEO		λ=0.757	3.776	4,47	0.010	0.243#	0.857
OL	λ=0.775		3.958	3,41	0.014	0.225#	0.795
STS	λ=0.712		6.213	3,46	0.001	0.288#	0.949
TS	λ=0.851		3.109	2,46	0.050	0.119+	0.570
Psych	λ=0.589		5.302	5,38	0.001	0.411*	0.975
		λ=0.623	4.591	5,38	0.002	0.377*	0.951
Anxiety	λ=0.728		5.983	3,48	0.002	0.272#	0.942
		λ=0.667	8.004	3,48	<0.0001	0.333*	0.985

*Large(0.35), # Medium-Large ES , +Medium ES (0.15) (Cohen, 1988)

Summary of significant univariate statistics

Task	Threat	Load	F	df	p	Effect Size	Obs. Power
QSEO		Roll Vel	6.673	1,50	0.013	0.118+	0.717
		PitchVel	5.463	1,50	0.023	0.099+	0.630
FR	Reach		85.580	1,48	<0.0001	0.641*	1.000
OL	Time		12.098	1,43	0.001	0.220#	0.925
STS	Pitch Vel		10.146	1,48	0.003	0.174+	0.887
	Time		5.185	1,48	0.027	0.097+	0.607
TS	Roll Ang		5.970	1,47	0.018	0.113+	0.668
Psych	Conf		14.727	1,42	<0.0001	0.260#	0.963
	Stab		11.689	1,42	0.001	0.218#	0.916
	Fear		13.233	1,42	0.001	0.240#	0.944
	Anx		11.226	1,42	0.002	0.211#	0.905
		Conf	9.042	1,42	0.004	0.177+	0.836
		Anx	10.863	1,42	0.002	0.205#	0.896
Anxiety	Somatic		14.829	1,50	<0.0001	0.229#	0.965
	Conc		12.773	1,50	0.001	0.203#	0.939
	Worry		7.502	1,50	0.009	0.130+	0.766
		Conc	24.121	1,50	<0.0001	0.325*#	0.998

*Large ES (0.4), # Medium ES (0.25), +Small ES (0.10) (Cohen, 1992)

References

Cohen J. Statistical Power Analysis for the Behavioral Sciences Second ed., Hillsdale, New Jersey: Lawrence Erlbaum Associates, Inc.; 1988, p. 481

Cohen J. A Power Primer. Psychological Bulletin (1992). 112(1);155-159.

Dependent Variable Correlations within MANOVAs

Quiet Standing Eyes Closed

	Roll Velocity	Pitch Angle	Pitch Velocity
Roll Angle	0.781 (<0.0001)	0.435 (0.001)	0.468 (0.001)
Roll Velocity		0.510 (<0.0001)	0.587 (<0.0001)
Pitch Angle			0.580 (<0.0001)

Quiet Standing Eyes Open

	Roll Velocity	Pitch Angle	Pitch Velocity
Roll Angle	0.710 (<0.0001)	0.489 (<0.0001)	0.568 (<0.0001)
Roll Velocity		0.452 (0.001)	0.790 (<0.0001)
Pitch Angle			0.581 (<0.0001)

One-Leg Stance

	Roll Velocity	Time
Roll Angle	0.793 (<0.0001)	-0.041 (0.790)
Roll Velocity		-0.271 (0.076)

Sit-to-Stand

	Pitch Velocity	Time
Pitch Angle	0.175 (0.229)	0.532 (<0.0001)
Pitch Velocity		-0.489 (<0.0001)

Tandem Stance

	Roll Velocity
Roll Angle	0.814 (<0.0001)

Psychological Measures

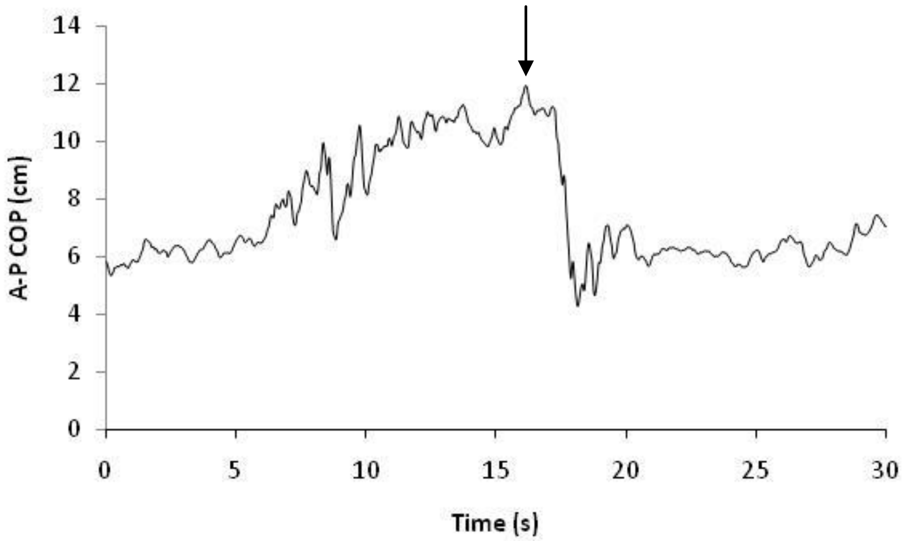
	Stability	Fear	Anxiety	Arousal
Confidence	0.842 (<0.0001)	-0.587 (<0.0001)	-0.480 (0.001)	-0.061 (0.690)
Stability		-0.686 (<0.0001)	-0.613 (<0.0001)	0.186 (0.205)
Fear			0.658 (<0.0001)	-0.207 (0.167)
Anxiety				-0.106 (0.474)

Anxiety components

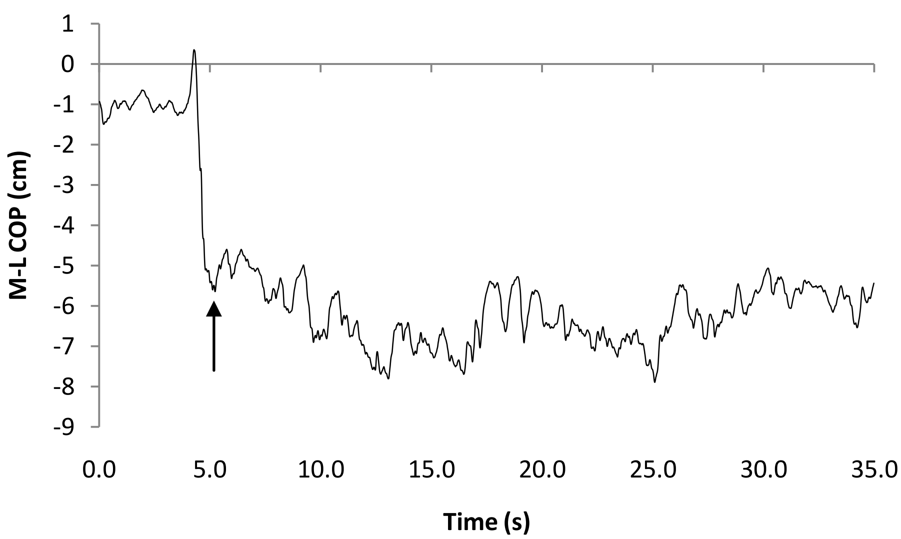
	Concentration	Worry
Somatic	0.585 (<0.0001)	0.641 (<0.0001)
Concentration		0.734 (<0.0001)

Appendix M
Study 1: Centre of Pressure Measures

Anterior-Posterior COP displacement during MR trial: The arrow indicates the maxreach for the trial. Displacement was calculated as the maxreach less the COP at the beginning of the trial.



Medial-Lateral COP displacement during OL trial: The arrow indicates onset of one leg stance (zero reference point). Time-held was calculated from this point until the end of the trial (maximum of 30s) or until the COP returned to baseline (indicating a return to bipedal stance/loss of balance).



Appendix N

Effect Measures for Various Binary Logistic Models

Measure	OR	95% C.I.	AUC	95% C.I.	Cox-Snell	Nagelkerke
BBS	0.80	0.53-1.21	0.58	0.41-0.75	0.025	0.034
TUG	0.99	0.76-1.29	0.50	0.32-0.68	0.000	0.000
Reach NC	0.72	0.42-1.12	0.62	0.45-0.78	0.033	0.045
Reach CC	0.81	0.49-1.34	0.53	0.35-0.71	0.016	0.022
Reach PC	0.65	0.35-1.20	0.62	0.45-0.80	0.044	0.061
Reach P+CC	0.72	0.42-1.23	0.63	0.46-0.80	0.033	0.045
Time OL NC	1.03	0.95-1.10	0.57	0.39-0.74	0.011	0.014
Time OL CC	1.02	0.95-1.10	0.54	0.36-0.72	0.008	0.010
Time OL PC	1.03	0.96-1.09	0.58	0.40-0.76	0.014	0.019
Time OL P+CC	1.03	0.96-1.10	0.56	0.38-0.74	0.012	0.017
Time STS NC	1.08	0.92-1.27	0.57	0.40-0.74	0.021	0.029
Time STS CC	1.14	0.96-1.35	0.60	0.43-0.77	0.061	0.082
Time STS PC	1.08	0.93-1.25	0.56	0.39-0.74	0.022	0.030
Time STS P+CC	1.09	0.95-1.26	0.61	0.44-0.79	0.036	0.049
Time TS NC	1.11	0.87-1.41	0.50	0.42-0.57	0.020	0.027
Time TS CC	1.00	0.82-1.21	0.48	0.39-0.57	0.000	0.000
Time TS PC	0.99	0.90-1.09	0.42	0.29-0.54	0.001	0.001
Time TS P+CC	1.03	0.92-1.15	0.55	0.45-0.66	0.006	0.008

Measure	AUC	95% C.I.	Cox-Snell	Nagelkerke
FR-OL-STS NC*	0.74	0.58-0.90	0.107	0.145
FR-OL-STS CC*	0.70	0.53-0.87	0.129	0.174
FR-OL-STS PC*	0.73	0.56-0.89	0.155	0.211
FR-OL-STS P+CC*	0.76	0.60-0.91	0.151	0.206

Measure	**OR**	**95% C.I.**	**AUC**	**95% C.I.**	**Cox-Snell**	**Nagelkerke**
ABC	0.96	0.88-1.04	0.61	0.43-0.79	0.026	0.035
GFoF	1.02	0.99-1.06	0.57	0.42-0.74	0.034	0.047
Confidence NC	0.96	0.92-1.01	0.64	0.47-0.80	0.068	0.093
Confidence CC	0.99	0.96-1.02	0.57	0.38-0.77	0.025	0.034
Confidence PC	0.99	0.96-1.03	0.54	0.35-0.73	0.005	0.007
Confidence P+CC	0.97*	0.94-0.99	0.69*	0.53-0.84	0.108	0.147
Stability NC	0.97	0.92-1.01	0.62	0.46-0.79	0.032	0.044
Stability CC	0.98	0.95-1.03	0.54	0.36-0.73	0.016	0.022
Stability PC	0.97	0.93-1.01	0.61	0.45-0.78	0.059	0.080
Stability P+CC	0.97	0.93-1.01	0.64	0.48-0.81	0.084	0.115
Anxiety NC	1.01	0.93-1.09	0.57	0.39-0.74	0.002	0.003
Anxiety CC	1.02	0.97-1.08	0.63	0.45-0.81	0.023	0.031
Anxiety PC	1.03	0.98-1.08	0.60	0.42-0.77	0.028	0.038
Anxiety P+CC	1.07*	1.01-1.14	0.72*	0.56-0.88	0.137	0.187
Fear NC	1.02	0.96-1.07	0.55	0.38-0.72	0.007	0.009
Fear CC	1.01	0.96-1.07	0.51	0.34-0.68	0.007	0.010
Fear PC	1.04	0.99-1.10	0.59	0.43-0.76	0.072	0.097
Fear P+CC	1.04	0.99-1.09	0.61	0.44-0.77	0.033	0.045

Measure	**AUC**	**95% C.I.**	**Cox-Snell**	**Nagelkerke**
BBS + ABC	0.62	0.45-0.79	0.042	0.058
BBS + ABC + Como	0.61	0.44-0.78	0.047	0.064
BBS + GFoF	0.57	0.40-0.74	0.045	0.061
BBS + GFoF + Como	0.59	0.42-0.76	0.046	0.063
TUG + ABC	0.62	0.44-0.80	0.024	0.032
TUG + ABC + Como	0.60	0.42-0.78	0.026	0.036
TUG + GFoF	0.61	0.44-0.78	0.044	0.059
TUG + GFoF + Como	0.61	0.44-0.78	0.044	0.060

Measure	**AUC**	**95% C.I.**	**Sens/Spec**	**Cox-Snell**	**Nagelkerke**
Reach Distance	0.63	0.46-0.80	0.75/0.46	0.033	0.045
Reach Confidence	0.73*	0.58-0.88	0.75/0.55	0.166	0.227
Reach + Confidence	0.72*	0.57-0.87	0.75/0.50	0.154	0.211
Reach + Confidence + comorbidity	0.74*	0.59-0.88	0.75/0.50	0.154	0.211
One-leg Time	0.56	0.38-0.75	0.75/0.31	0.012	0.017
One-leg Confidence	0.54	0.36-0.73	0.75/0.35	0.010	0.014
One-leg + Confidence	0.60	0.41-0.78	0.75/0.50	0.027	0.036
One-leg + Confidence + comorbidity	0.62	0.43-0.80	0.75/0.44	0.038	0.052

Appendix O

Characteristics of Single-fall events

Sub ID					
1	Away, Inside	Exercise Class	Lost Balance	None	Dizzy, up too fast
6	**Away, Outside**	**Riding Bike**	**Lost Balance**	**Scraped knee**	**First time in 60years**
21	Home, Outside	Stairs	Slip on Ice	Sore knees and bottom	
25	Away, Outside	Sidewalk	Trip on Uneven	Bruises, Grazes	Boots too big
28	Home, Outside	Garden	Lost Balance	FOOSH, hurt shoulder	Pounding in Stake
31	Away, Outside	Sidewalk	Slip on Ice	None	
37	Home, Outside	Garden	Slip	None	
39	Home, Inside	Stairs	Carrying box	None	
43	Home, Outside	Garage	?	Broken Patella	Taking out garbage
44	Away, Inside	Stairs	Slip	None	Not fully on Step
46	**Away, Outside**	**Stairs**	**Slip**	**None**	**Sailboat, wet stairs**
48	Home, Outside	Garden	Lost Balance	None	Dizzy, pulling weeds
49	Away, Outside	Sidewalk	Trip	None	

Appendix P

Confidence Ratings

(Across Tasks - Day 1 vs. Day 2)

	Day1			Day2			Day1	Day2	
ID	ConfNC	ConfPC	% change	ConfNC	ConfPC	% change	Direction of Variance		Consistent
53	25	15	-40%	20	20	0%	Down	Same	No
54	90	50	-44%	90	85	-6%	Down	Down	Yes
55	100	85	-15%	100	100	0%	Down	Same	No
56	85	75	-12%	60	68	13%	Down	Up	No
57	68	55	-19%	90	90	0%	Down	Same	No
58	65	45	-31%	30	30	0%	Down	Same	No
59	90	40	-56%	100	100	0%	Down	Same	No
60	70	65	-7%	80	85	6%	Down	Up	No
61	75	1	-99%	90	95	6%	Down	Up	No
62	.	35	.	65	55	-15%	.	Down	No
63	93	73	-22%	93	94	1%	Down	Up	No
64	63	65	3%	65	60	-8%	Up	Down	No
66	100	35	-65%	85	90	6%	Down	Up	No
67	55	45	-18%	75	60	-20%	Down	Down	Yes
68	100	90	-10%	95	90	-5%	Down	Down	Yes
69	65	65	0%	.	35	.	Same	.	No
70	75	60	-20%	75	60	-20%	Down	Down	Yes
71	68	65	-4%	95	90	-5%	Down	Down	Yes
72	90	80	-11%	80	70	-13%	Down	Down	Yes
74	55	35	-36%	55	50	-9%	Down	Down	Yes
75	100	100	0%	100	100	0%	Same	Same	Yes
76	60	45	-25%	60	65	8%	Down	Up	No
77	95	65	-32%	60	50	-17%	Down	Down	Yes
78	55	15	-73%	85	95	12%	Down	Up	No
79	50	.	.	55	60	9%	.	Up	No
80	70	70	0%	80	45	-44%	Same	Down	No
81	75	75	0%	60	60	0%	Same	Same	Yes
82	70	63	-10%	95	80	-16%	Down	Down	Yes
83	85	50	-41%	60	70	17%	Down	Up	No
84	55	43	-22%	35	30	-14%	Down	Down	Yes
85	20	1	-95%	70	50	-29%	Down	Down	Yes
86	75	75	0%	85	75	-12%	Same	Down	No
		Reduced	75%		Reduced	47%		Consistent	41%
		Same	16%		Same	22%			
		Increased	3%		Increased	28%			
		Mean Increase	2%		Mean Increase	8%			

Note 1: On Day 1, 75% of individuals demonstrate reduced confidence under threat. However, on Day 2, only 47% individuals demonstrate reduced confidence under threat. Only 41% of individuals were consistent in the direction of change of confidence ratings (as a change from NC to PC). This causes negative covariance, which violates assumptions for the calculation of reliability using intraclass correlations, resulting in negative ICC values. (Covariance=mean[(Xi-Xmean)(Yi-Ymean)] - mean value of each product pair)

Note 2: Poor reliability of confidence ratings under postural threat is likely a manifestation of the testing/habituation effect. Confidence must be estimated prior to task performance, and participants are unfamiliar with the testing conditions on Day 1. On Day 2 however, they have been exposed to procedures.

	Day1	Day2	50%
Sub	% change	% change	Consistency
53	77%	-81%	no
54	0%	0%	same
55	-7%	-24%	yes
56	0%	0%	same
57	-77%	-31%	yes
58	-51%	-48%	yes
59	0%	0%	same
60	-29%	0%	no
61	-24%	-37%	yes
62	-84%	-35%	yes
63	-34%	-60%	yes
64	92%	-50%	no
66	-28%	-12%	yes
67	26%	41%	yes
68	20%	0%	no
69	-11%	-26%	yes
70	0%	0%	same
71	11%	-35%	no
72	0%	0%	same
74	-8%	-26%	yes
75	0%	0%	same
76	-83%	-77%	yes
77	-89%	0%	no
78	-75%	83%	no
79	-61%	22%	no
80	-21%	-66%	yes
81	-7%	-59%	yes
82	0%	0%	same
83	-4%	0%	no
84	-62%	-81%	yes
85	-65%	-84%	yes
86	-76%	-30%	yes
Reduced	63%	56%	
Same	22%	34%	
Increased	16%	9%	
Mean Increase	45%	37%	

Note 1: On Day 1, 63% of individuals demonstrated reduced one-leg stance times under threat. However, on Day 2, only 56% individuals demonstrated reduced one-leg stance times under threat. Only 50% of individuals were consistent in the direction of change of one-leg stance times (as a change from NC to PC).

Appendix Q

Comparison of Study 2 and 3 participants

Dependent Measure	Study 2 (N=52)	Study 3 (N=32)	p
Age	75.23, 5.61	73.09, 6.18	0.107
Sex†	M=20 F=32	M=7 F=25	0.114
	Prospective	Retrospective	
Fallers†	0=20 1^{+}=32	0=22 1^{+}=10	0.007*
General Balance, Mobility, Health and Psychological Measures			
BBS#	53.56,1.55	53.31, 2.35	0.814
TUG	10.74, 2.33	8.57,1.43	0.0001*
GFOF#	22.92,19.21	26.41, 21.49	0.464
ABC#	88.24, 8.53	87.18, 11.85	0.941
Como#	7.21,4.16	4.91, 2.84	0.013*
Memory Task Performance			
Memory CC	7.52, 2.10	7.06, 1.81	0.312
Memory PCC	7.00, 2.02	7.34, 1.68	0.422
Clinical Balance Performance Measures			
NC OL	21.50, 8.75	22.39, 9.57	0.667
NC FR	13.24, 3.47	12.64, 2.73	0.403
CC OL	21.85, 8.79	21.87, 10.21	0.990
CC FR	12.95, 3.40	12.06, 3.22	0.241
PC OL	19.26, 10.02	18.25, 12.03	0.694
PC FR	10.99, 3.01	11.25, 2.95	0.705
PCC OL	17.88, 9.67	18.87, 11.37	0.679
PCC FR	10.46, 3.16	10.72, 2.76	0.703
PC-NC %change OL#	-71.94, 120.81	-107.98, 195.55	0.145
PC-NC %change FR#	-23.62, 24.76	-17.43, 25.90	0.099
Task-specific Psychological Measures			
NC OL conf	56.63, 27.61	61.29, 27.29	0.459
NC FR conf#	81.27, 17.48	83.23, 19.30	0.210
CC OL conf	50.20, 25.92	50.00, 25.30	0.973
CC FR conf#	70.56, 25.28	70.78, 22.90	0.973
PC OL conf	49.86, 26.62	46.77, 28.00	0.619
PC FR conf	69.41, 24.27	61.45, 28.67	0.183
PCC OL conf	43.47, 26.30	37.65, 27.53	0.339
PCC FR conf	65.25, 26.92	55.16, 25.73	0.095
PC-NC %change OL#	-147.68, 701.03	-329.73, 1016.70	0.299
PC-NC %change FR#	-43.56, 120.81	-410.17, 1801.23	0.211
NC OL stab	51.44, 26.07	50.78, 21.85	0.901
NC FR stab#	85.38, 17.17	78.13, 23.48	0.111
CC OL stab	51.90, 26.12	47.50, 23.24	0.438
CC FR stab#	77.73, 23.93	79.38, 21.09	0.966
PC OL stab	45.35, 27.70	42.81, 24.39	0.672
PC FR stab#	78.50, 20.91	76.25, 21.55	0.588
PCC OL stab	44.33, 26.40	43.75, 26.34	0.923
PCC FR stab	76.13, 21.96	74.06, 20.73	0.669
NC OL fear#	18.43, 24.44	5.06, 8.00	0.025*
NC FR fear#	6.67, 13.95	6.41, 17.33	0.682
CC OL fear#	19.31, 27.02	6.56, 14.05	0.020*
CC FR fear#	7.25, 13.58	4.06, 10.43	0.141
PC OL fear#	26.53, 28.71	12.19, 15.60	0.048*
PC FR fear#	9.02, 16.52	12.50, 26.03	1.000
PCC OL fear#	30.09, 27.90	11.56, 16.68	0.001*

PCC FR fear#	13.75, 19.15	10.62, 20.78	0.254
PC-NC %change OL#	-67.14, 447.32	-31.39, 344.09	0.632
PC-NC %change FR#	-65.92, 325.06	-39.52, 227.94	0.231
Condition-specific Psychological Measures (averaged across tasks)			
NC conf	68.95, 19.75	71.26, 20.30	0.469
CC conf	60.38, 23.17	60.39, 21.41	0.998
PC conf	59.64, 22.22	54.11, 24.66	0.298
PCC conf	54.36, 23.97	46.41, 23.22	0.140
NC stab	68.41, 17.51	64.45, 19.04	0.333
CC stab	64.81, 21.83	63.44, 19.23	0.771
PC stab	61.92, 20.79	59.53, 17.56	0.589
PCC stab	60.23, 20.58	58.91, 20.34	0.774
NC anx#	24.67, 9.13	25.70, 9.10	0.574
CC anx#	29.90, 13.23	29.41, 12.64	0.899
PC anx#	30.25, 15.29	29.91, 9.45	0.269
PCC anx#	33.54, 14.62	34.12, 11.36	0.531
NC fear#	12.55, 16.95	5.73, 11.72	0.045*
CC fear#	13.29, 17.52	5.31, 10.31	0.028*
PC fear#	17.77, 20.26	12.34, 19.76	0.195
PCC fear#	21.83, 21.36	11.09, 17.68	0.009*

Values presented are means, standard deviations
† Chi-squared comparison, #Independent-samples Mann-Whitney U test, *significant at 0.05
BBS=Berg Balance Scale
TUG=Timed up and Go Mobility test
GFOF=General Fear of Falling
ABC=Activities-Specific Balance Confidence Scale
Como=Comorbidity/Health Score
NC=No challenge
CC=Cognitive Challenge/Loading
PC=Postural Challenge/Threat
PCC=Combined Postural Threat and Cognitive Loading
OL=One-Leg stance
FR=Functional Reach
conf= Balance Confidence
stab= Perceived Stability
anx=State Anxiety
fear=fear of falling

Appendix R

Modified State Anxiety and ABC scales

Anxiety-9 - Refined based on findings presented in this dissertations

Low Anxiety Component (alpha reliability 0.875, 0.538 when corrected for scale length)
W6: I was concerned about doing the balance task correctly
W3: I had self-doubts
S7: My body was tense
S1:I felt nervous
W14: I was concerned that others would be disappointed with my performance
S4: I felt myself tense and shaking
High Anxiety Component (alpha reliability 0.791, 0.558 when corrected for scale length)
S10: I felt my stomach sinking
S15: I found myself hyperventilating
S12: My heart was racing
State-Anxiety-9 overall (alpha reliability 0.868, 0.422 when corrected for scale length)

Refined Anxiety (Anxiety-9) for predicting prospective falls - binary logistic regression

	AUC	CI Lower	CI Upper	CI Range
AnxNC	0.4615	0.2814	0.6415	0.3601
AnxCC	0.5669	0.3892	0.7447	0.3555
AnxPC	0.5081	0.3311	0.6851	0.3540
AnxPCC	0.6298	0.4629	0.7968	0.3339

Refined Anxiety (Anxiety-9) for predicting retrospective falls - binary logistic regression

	AUC	CI Lower	CI Upper	CI Range
AnxNC	0.6977	0.4814	0.9141	0.4327
AnxCC	0.6091	0.4048	0.8133	0.4085
AnxPC	0.5568	0.3286	0.7851	0.4565
AnxPCC	0.5000	0.2888	0.7112	0.4224

ABC-6P - Following example of Peretz et al. (2006) and Botner et al. (2005)

How confident are you that you will not lose your balance or become unsteady when you do the following:....
6 items (alpha reliability 0.817, 0.427 when corrected for scale length)
5....stand on your tiptoes and reach for something above your head
6.....stand on a chair and reach for something
13....are bumped into by people as you walk through the mall
14.....step onto/off an escalator while holding onto a railing
15.....step onto/off an escalator while holding parcels (not railing)
16.....walk outside on icy sidewalk

ABC-6H - Based on findings presented in this dissertation

How confident are you that you will not lose your balance or become unsteady when you do the following:....
6 items (alpha reliability 0.819, 0.430 when corrected for scale length)
2....walk up or down stairs
5....stand on your tiptoes and reach for something above your head
6.....stand on a chair and reach for something
14.....step onto/off an escalator while holding onto a railing
15.....step onto/off an escalator while holding parcels (not railing)
16.....walk outside on icy sidewalk

ABC-3H - Based on findings presented in this dissertation

How confident are you that you will not lose your balance or become unsteady when you do the following:....
3 items (alpha reliability 0.784, 0.547 when corrected for scale length)
14.....step onto/off an escalator while holding onto a railing
15.....step onto/off an escalator while holding parcels (not railing)
16.....walk outside on icy sidewalk

Refined ABC for predicting prospective falls - binary logistic regression

	AUC	CI Lower	CI Upper	CI Range
ABC-16	0.6156	0.4377	0.7936	0.3559
ABC-6P	0.6643	0.4849	0.8437	0.3588
ABC-6H	0.6501	0.4722	0.828	0.3558
ABC-3H	0.6126	0.4303	0.7948	0.3645

Refined ABC for predicting retrospective falls - binary logistic regression

	AUC	CI Lower	CI Upper	CI Range
ABC-16	0.4023	0.1458	0.6587	0.5129
ABC-6P	0.4273	0.1763	0.6783	0.5020
ABC-6H	0.4364	0.1890	0.6838	0.4948
ABC-3H	0.4864	0.2531	0.7197	0.4666

Appendix S

Correlations among psychological measures: Study 3

	Perceived Stability	State Anxiety	Fear of Falling
Balance Confidence			
No Challenge (NC)	0.499 (p=0.004)**	-0.404 (p=0.024)*	-0.026 (p=0.889)
Cognitive Load (CC)	0.634 (p<0.0001)**	-0.429 (p=0.014)*	-0.163 (p=0.372)
Postural Threat (PC)	0.403 (p=0.025)*	-0.267 (p=0.146)	-0.209 (p=0.260)
Threat and Load (PCC)	0.699 (p<0.0001)**	-0.607 (p<0.0001)*	-0.434 (p=0.013)*
Perceived Stability			
No Challenge (NC)	1.0	-0.639 (p<0.0001)**	-0.312 (p=0.082)
Cognitive Load (CC)		-0.648 (p<0.0001)**	-0.338 (p=0.059)
Postural Threat (PC)	1.0	-0.673 (p<0.0001)**	-0.387 (p=0.029)*
Threat and Load (PCC)		-0.540 (p=0.001)**	-0.501 (p=0.003)**
State Anxiety			
No Challenge (NC)	-0.639 (p<0.0001)**	1.0	0.344 (p=0.054)
Cognitive Load (CC)			0.470 (p=0.007)**
Postural Threat (PC)	-0.673 (p<0.0001)**	1.0	0.481 (p=0.005)**
Threat and Load (PCC)			0.478 (p=0.006)**

	ABC - 16 items		ABC - chair reach
Balance Confidence		FR-Balance Confidence	
No Challenge (NC)	0.078 (p=0.675)	No Challenge	0.136 (p=0.466)
Cognitive Load (CC)	0.586 (p<0.0001)**	Cognitive Load (CC)	-0.082 (p=0.655)
Postural Threat (PC)	0.241 (p=0.192)	Postural Threat (PC)	0.056 (p=0.764)
Threat and Load (PCC)	0.399 (p=0.024)*	Threat and Load (PCC)	-0.119 (p=0.516)
Perceived Stability		FR-Perceived Stability	
No Challenge (NC)	0.372 (p=0.036)*	No Challenge (NC)	0.266 (p=0.141)
Cognitive Load (CC)	0.345 (p=0.053)	Cognitive Load (CC)	-0.075 (p=0.685)
Postural Threat (PC)	0.558 (p=0.001)**	Postural Threat (PC)	0.039 (p=0.830)
Threat and Load (PCC)	0.378 (p=0.033)*	Threat and Load (PCC)	0.034 (p=0.855)
State Anxiety		FR - State Anxiety	
No Challenge (NC)	-0.312 (p=0.082)	No Challenge	-0.051 (p=0.780)
Cognitive Load (CC)	-0.209 (p=0.251)	Cognitive Load (CC)	-0.075 (p=0.685)
Postural Threat (PC)	-0.561 (p=0.001)**	Postural Threat (PC)	-0.107 (p=0.561)
Threat and Load (PCC)	-0.309 (p=0.085)	Threat and Load (PCC)	-0.034 (p=0.854)
Fear of Falling		FR - Fear of Falling	
No Challenge (NC)	-0.336 (p=0.060)	No Challenge	0.166 (p=0.363)
Cognitive Load (CC)	-0.264 (p=0.144)	Cognitive Load (CC)	0.120 (p=0.514)
Postural Threat (PC)	-0.201 (p=0.269)	Postural Threat (PC)	-0.038 (p=0.835)
Threat and Load (PCC)	-0.279 (p=0.121)	Threat and Load (PCC)	0.001 (p=0.997)

Appendix T

Intraclass Correlation Coefficients

Comparison of conventions: Studies 1 and 3

Reliability (ICC) values in young (study 1): average (3,k), and individual (3,1) measures; percent change (%) and absolute change (abs); quiet stance (QS), Maximal Reach (MR) and One-Leg Stance (OL)

	QS (%)		QS (abs)		MR (%)		MR (abs)		OL (%)		OL (abs)	
	3,k	3,1	3,k	3,1	3,k	3,1	3,k	3,1	3,k	3,1	3,k	3,1
AP-RMS	0.42	0.20	0.48	0.23	-	-	-	-	-	-	-	-
AP-MPF	0.60	0.33	0.65	0.39	-	-	-	-	-	-	-	-
AP-MP	0.70	0.44	0.74	0.49	-	-	-	-	-	-	-	-
Time-held	-	-	-	-	-	-	-	-	0.09	0.03	0.31	*0.13*
Max-reach	-	-	-	-	0.32	0.14	0.85	*0.66*	-	-	-	-
Overall Confidence	0.73	0.47	0.74	0.49	0.82	0.60	0.79	0.56	0.79	0.56	0.74	0.49
AF Confidence	0.78	0.53	0.79	0.56	0.41	0.19	0.40	0.18	0.81	0.59	0.79	0.56
MC Confidence	0.11	0.04	0.40	0.18	0.81	0.58	0.81	0.59	0.71	0.45	0.64	0.38
OW Confidence	0.61	0.34	0.61	0.35	0.61	0.34	0.57	0.31	0.80	0.56	0.77	0.53
RA Confidence	0.40	0.18	0.44	0.21	0.61	0.34	0.59	0.32	0.65	0.38	0.66	0.39
Stability	0.76	0.51	0.79	0.56	0.77	0.53	0.80	0.57	0.42	0.19	0.79	0.56
Physiological Anxiety	0.54	0.28	0.58	0.32	0.69	0.43	0.65	0.38	0.73	0.47	0.71	0.45
State Anxiety	0.71	0.45	0.80	0.57	0.87	0.68	0.84	0.64	0.79	0.56	0.82	0.60

Question 1: Is it better to use measures as a percent change or absolute change? (i.e. which are more reliable?)

Makes little difference. When looking at 3,k values, all are comparable with the exception of max-reach (percent ICC 0.322 (-0.256 to 0.659); absolute ICC 0.851 (0.724-0.925) and stability in OL (percent ICC 0.417 (-0.093-0.711); absolute ICC 0.790 (0.607-0.896).

Question 2: Is it more appropriate to present (3,k) or (3,1) values?

No consensus in literature. Average (k) measures will generally be higher than individual (1) measures. May be more appropriate to use average, to negate/attenuate learning/day effects - better evaluation of reliability of measure/tool itself. Alternatively, Weir (2005) suggests evaluating reliability when plateau in outcome is seen.

Reliability (ICC) values in young within condition: average (3,k), and individual (3,1) measures; quiet stance (QS), Maximal Reach (MR) and One-Leg Stance (OL)

	Low Postural Threat						High Postural threat					
	QS		MR		OL		QS		MR		OL	
	3,k	3,1	3,k	3,1	3,k	3,1	3,k	3,1	3,k	3,1	3,k	3,1
AP-RMS	0.52	0.26	-	-	-	-	0.63	0.36	-	-	-	-
AP-MPF	0.47	0.26	-	-	-	-	0.63	0.36	-	-	-	-
AP-MP	0.70	0.44	-	-	-	-	0.41	0.19	-	-	-	-
Time-held	-	-	-	-	0.83	0.62	-	-	-	-	0.82	0.61
Max-reach	-	-	0.76	0.52	-	-	-	-	0.85	0.66	-	-
Overall Confidence	0.71	0.44	0.45	0.21	0.80	0.57	0.76	0.51	0.88	0.71	0.87	0.69
AF Confidence	0.42	0.19	0.63	0.36	0.83	0.62	0.78	0.54	0.78	0.54	0.88	0.71
MC Confidence	0.65	0.39	0.68	0.41	0.66	0.39	0.38	0.17	0.83	0.62	0.86	0.66
OW Confidence	0.56	0.30	0.70	0.43	0.79	0.55	0.66	0.40	0.79	0.59	0.88	0.70
RA Confidence	0.83	0.61	0.72	0.46	0.79	0.56	0.68	0.42	0.80	0.57	0.78	0.55
Stability	0.70	0.43	0.79	0.55	0.80	0.58	0.75	0.50	0.81	0.59	0.88	0.70
Physiological Anxiety	0.87	0.69	0.87	0.69	0.87	0.69	0.89	0.73	0.87	0.69	0.86	0.67
State Anxiety	0.64	0.37	0.72	0.46	0.73	0.47	0.89	0.73	0.90	0.74	0.81	0.69

Reliability (ICC) values in young, average of conditions: average (3,k), and individual (3,1) measures; quiet stance (QS), Maximal Reach (MR) and One-Leg Stance (OL); 3,k measures as an average across conditions equivalent to ICC values derived from mean squares from ANOVA (bolded, published values)

	Average of Low and High Threat					
	QS		MR		OL	
	3,k	3,1	**3,k**	3,1	**3,k**	3,1
AP-RMS	**0.65**	0.38	**-**	-	**-**	-
AP-MPF	**0.50**	0.23	**-**	-	**-**	-
AP-MP	**0.89**	0.42	**-**	-	**-**	-
Time-held	**-**	-	**-**	-	**0.91**	0.77
Max-reach	**-**	-	**0.81**	0.60	**-**	-
Overall Confidence	**0.67**	0.50	**0.67**	0.58	**0.86**	0.68
AF Confidence	**0.68**	0.39	**0.79**	0.56	**0.81**	0.70
MC Confidence	**0.60**	0.34	**0.77**	0.53	**0.85**	0.61
OW Confidence	**0.59**	0.37	**0.78**	0.57	**0.82**	0.67
RA Confidence	**0.77**	0.54	**0.78**	0.56	**0.78**	0.59
Stability	**0.63**	0.47	**0.79**	0.59	**0.88**	0.67
Physiological Anxiety	**0.88**	0.73	**0.87**	0.69	**0.87**	0.69
State Anxiety	**0.83**	0.68	**0.86**	0.71	**0.85**	0.66

Question 3: Should reliability be evaluated within condition or as an average of conditions?

More tools/measures with point estimates of reliability greater under high threat conditions.

Reliability (ICC) values in elderly for balance measures: within conditions; absolute and % change; bolded values those included/presented in chapter.

Condition	OL (s)		FR (cm)	
	3,k	**3,1**	3,k	**3,1**
NC	0.84, 0.50-0.85	**0.72, 0.50-0.85**	0.77, 0.52-0.89	**0.62, 0.36-0.80**
CC	0.80, 0.58-0.90	**0.66, 0.41-0.82**	0.85, 0.68-0.92	**0.73, 0.52-0.86**
PC	0.76, 0.50-0.88	**0.61, 0.34-0.79**	0.80, 0.59-0.90	**0.67, 0.42-0.82**
PCC	0.72, 0.42-0.86	**0.60, 0.27-0.76**	0.76, 0.50-0.88	**0.61, 0.33-0.79**
Average NC-PC	0.87, 0.73-0.94	0.77, 0.57-0.88	0.82, 0.63-0.91	0.69, 0.46-0.84
Abs NC to PC	-0.05, -1.14, 0.49	**-0.02, -0.36-0.32**	0.27, -0.50-0.48	**0.16, -0.20-0.48**
Per NC to PC	-0.00, -1.06-0.51	**-0.00, -0.45-0.34**	0.20, -0.64-0.61	**0.11, -0.24-0.44**

Reliability ($ICC_{3,1}$) values in elderly for psychological measures: within conditions; % and absolute change; bolded values those included/presented in chapter.

Condition	Balance Confidence	Perceived Stability	State Anxiety	Fear of Falling
NC	**0.57, 0.27-0.77**	**0.60, 0.32-0.78**	**0.54, 0.24-0.74**	**0.78, 0.59-0.89**
CC	**0.61, 0.34-0.79**	**0.76, 0.56-0.88**	**0.48, 0.17-0.71**	**0.69, 0.46-0.84**
PC	**0.24, -0.12-0.54**	**0.65, 0.39-0.81**	**0.72, 0.50-0.85**	**0.74, 0.54-0.87**
PCC	**0.60, 0.32-0.78**	**0.70, 0.47-0.84**	**0.60, 0.32-0.78**	**0.50, 0.18-0.72**
Average NC-PC	0.48, 0.14-0.72	0.68, 0.44-0.83	0.75, 0.54-0.87	0.81, 0.64-0.90
Abs NC to PC	**-0.31, -0.61-0.05[#]**	**0.17, -0.19-0.49**	**0.17, -0.19-0.48**	**0.55, 0.25-0.75**
Per NC to PC	**-0.13, -0.47-0.24**	**-0.03, -037-0.31**	**0.09, -0.27-0.42**	**0.62, 0.35-0.79**

Reliability ($ICC_{3,k}$) values in elderly for psychological measures: within conditions; % and absolute change

Condition	Balance Confidence	Perceived Stability	State Anxiety	Fear of Falling
NC	0.73, 0.43-0.87	0.75, 0.48-0.88	0.70, 0.38-0.85	0.88, 0.75-0.94
CC	0.76, 0.50-0.88	0.86, 0.72-0.93	0.65, 0.29-0.83	0.82, 0.63-0.91
PC	0.39, -0.27-0.70	0.79, 0.56-0.90	0.84, 0.67-0.92	0.85, 0.70-0.93
PCC	0.75, 0.48-0.88	0.83, 0.64-0.92	0.75, 0.48-0.88	0.66, 0.31-0.84
Average NC-PC	0.65, 0.25-0.83	0.81, 0.62-0.91	0.85, 0.70-0.93	0.89, 0.78-0.95
Abs NC to PC	-0.92, -3.08-0.10	0.29, -0.45-0.65	0.29, -0.47-0.65	0.71, 0.40-0.86
Per NC to PC	-0.30, -1.77-0.39	-0.07, -1.19-0.48	0.16, -0.72-0.59	0.77, 0.52-0.89

Appendix U

Intraclass Correlation Coefficients

Population/study comparisons

Populations comparisons: 3,k values and 95% confidence intervals; psych measures averaged across tasks

	Balance Confidence	Perceived Stability	State Anxiety	Fear of Falling
Elderly Average NC-PC (2)	0.65, 0.25-0.83	0.81, 0.62-0.91	0.85, 0.70-0.93	0.89, 0.78-0.95
Young Average NC-PC (2)	0.84, 0.68-0.93	0.84, 0.67-0.93	0.84, 0.68-0.93	-
Young Average NC-PC (3)	0.86, 0.74-0.93	0.86, 0.73-0.93	0.88, 0.77-0.94	-
Elderly Abs Δ NC to PC (2)	-0.92, -3.08-0.10	0.29, -0.45-0.65	0.29, -0.47-0.65	0.71, 0.40-0.86
Young Abs Δ NC to PC (2)	0.66, 0.29-0.83	0.82, 0.62-0.91	0.74, 0.50-0.87	-
Young Abs Δ NC to PC (3)	0.82, 0.66-0.91	0.85, 0.71-0.92	0.88, 0.77-0.94	-

Populations comparisons: 3,1 values and 95% confidence intervals; psych measures averaged across tasks; bolded values were those presented in respective chapters

	Balance Confidence	Perceived Stability	State Anxiety	Fear of Falling
Average of threat conditions				
Elderly (2 sessions)	0.48, 0.14-0.72	0.68, 0.44-0.83	0.75, 0.54-0.87	0.81, 0.64-0.90
Young (2 sessions)	0.73, 0.51-0.86	0.73, 0.80-0.86	0.73, 0.51-0.86	-
Young (3 sessions)	0.67, 0.48-0.81	0.66, 0.47-0.81	0.70, 0.53-0.83	-
Individual threat conditions				
Elderly No Threat (2 sessions)	**0.57, 0.27-0.77**	**0.60, 0.32-0.78**	**0.54, 0.24-0.74**	**0.78, 0.59-0.89**
Young Low Threat (2 sessions)	0.56, 0.29-0.76	0.54, 0.22-0.75	0.53, 0.22-0.74	-
Elderly Low Threat (2 sessions)	**0.24, -0.12-0.54**	**0.65, 0.39-0.81**	**0.72, 0.50-0.85**	**0.74, 0.54-0.87**
Young High Threat (2 sessions)	0.73, 0.52-0.86	0.79, 0.61-0.90	0.85, 0.69-0.93	-
Absolute Change due to threat				
Elderly (2 sessions)	**-0.31, -0.61-0.05**	**0.17, -0.19-0.49**	**0.17, -0.19-0.48**	**0.55, 0.25-0.75**
Young (2 sessions)	0.49, 0.17-0.72	0.69, 0.44-0.84	0.59, 0.30-0.78	-
Young (3 sessions)	0.60, 0.40-0.77	0.65, 0.45-0.80	0.70, 0.53-0.83	-

Populations comparisons: 3,k and 3,1 values and 95% confidence intervals; balance measures; bolded values were those presented in respective chapters

	OL (s)		FR (cm)	
	3,k	3,1	3,k	3,1
Elderly Average NC-PC (2)	0.87, 0.73-0.94	0.77, 0.57-0.88	0.82, 0.63-0.91	0.69, 0.46-0.84
Young Average NC-PC (2)	0.87, 0.73-0.94	0.77, 0.57-0.88	0.70, 0.37-0.85	0.54, 0.23-0.75
Young Average NC-PC (3)	**0.91, 0.83-0.95**	0.77, 0.62-0.87	**0.81, 0.66-0.91**	0.60, 0.40-0.77
Elderly Abs Δ NC to PC (2)	-0.05, -1.14, 0.49	**-0.02, -0.36-0.32**	0.27, -0.50-0.48	**0.16, -0.20-0.48**
Young Abs Δ NC to PC (2)	0.42, -0.21-0.72	0.26, -0.09-0.56	0.75, 0.49-0.88	0.61, 0.33-0.79
Young Abs Δ NC to PC (3)	0.31, -0.29-0.65	0.13, -0.08-0.38	0.85, 0.72-0.93	0.66, 0.47-0.81

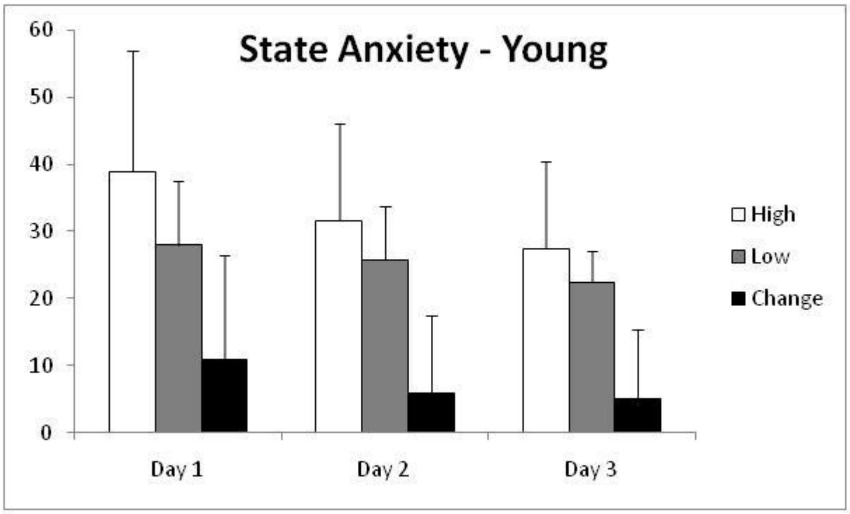
Caveats/Cautions:

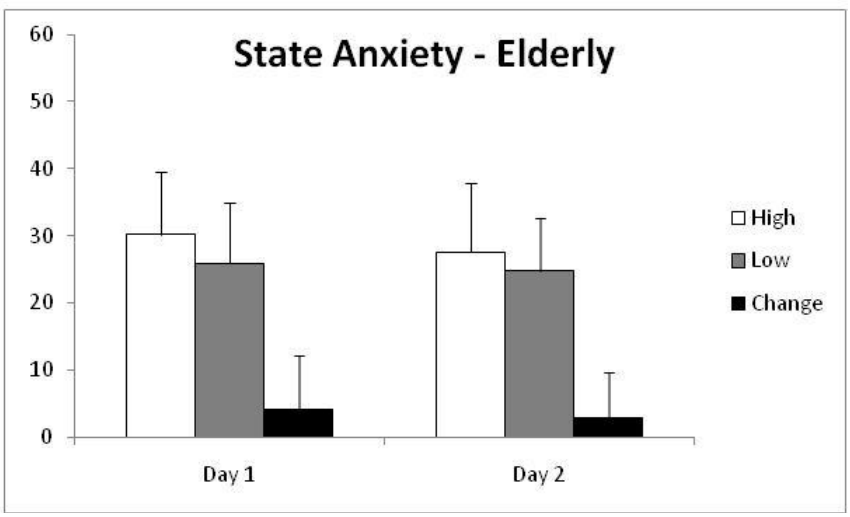
Balance measures in young derived from FP data; in elderly derived from stopwatch/ruler

Postural threat in young average of low and high; in elderly average of none and low

Populations comparisons of change in state anxiety: 3,1 values and 95% confidence intervals; Between and Within subject variance; SEM as per Weir 2005, normalized SEM as per Smoglia 2010

	ICC	BS Variance	WS Variance	absSEM	Normalized SEM
Elderly Abs Δ NC to PC (Day 1-Day 2)	0.17, -0.19-0.48	64.55	46.18	6.80	0.78
Young Abs Δ NC to PC (Day 1 - Day 2)	0.59, 0.30-0.78	299.97	78.32	8.85	1.05
Young Abs Δ NC to PC (Day 2 - Day 3)	0.83, 0.67-0.92	230.30	21.55	4.64	0.82





In young, change from day 1 to day 2 significantly different (t30=2.25, p=0.032)
In young, change from day 2 to day 3 not significantly different (t28=1.103, p=0.279)
In elderly, change from day 1 to day 2 not significantly different (t31=0.773, p=0.446)

Weir (2005) Quantifying test-retest reliability using the intraclass correlation coefficient and theSEM. Journal of Strength and conditioning research. 19(1),231-40
Smoglia et al. (2010) Reliability and precision of EMG in leg, torso, and arm muscles during running. Journal of Electromyography and Kinesiology. 20 e1-e9

Appendix V

Addendum to Chapter 2: Study 1

Participants were recruited from an undergraduate kinesiology course and were provided with bonus marks in that course for their participation in the study. The sample may therefore be considered one of convenience, which may limit the generalisability of results.

No formal sample size calculation was completed. The aim was to have 30 participants, consistent with published literature (similar test-retest reliability evaluations (Bilney 2003; Henriksen 2004; Menz 2004; Curtis 2006)); 31 undergraduate students volunteered to participate and 29 completed all three testing sessions.

Low reliability of MPF measures during quiet stance may have attenuated associations between this and psychological measures. It is possible therefore that significant relationships may have been missed. However, the focus of the study was on measures of clinical balance performance; the measures of time held for one-leg stance and max-reach for the reaching task demonstrated strong reliability (0.92 and 0.81 respectively).

Predictive validity, where changes in psychological measures may used to predict performance on balance tasks, can be addressed for the measure of balance confidence only; this is the only psychological construct evaluated prior to task performance. Associations between other psychological measures (anxiety and stability) and balance performance however support the notion that psychological state may affect performance; changes to balance performance on clinical tests may be wrongly attributed to physiological issues or disease, when the changes may in fact be driven by psychological manifestations.

<u>References</u>

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Henriksen M, Lund H, Moe-Nilssen R, Bliddal H, Danneskiod-Samsoe B. Test-retest reliability of trunk accelerometric gait analysis. Gait and Posture (2004). 19;288-97.

Menz HB, Latt MD, Tiedemann A, Mun San Kwan M, Lord SR. Reliability of the GAITRite walkway ssystem for the quantification of temporo-spatial parameters of gait in young and older people. Gait and Posture (2004). 20;20-5.

Curtis T, Roush JR. The lateral Scapular slide test: a reliability study of males with and without shoulder pathology. North American Journal of Sports Physical Therapy (2006). 1(3);140-6.

Appendix W
Waterloo Research in Aging Participant Pool (WRAP)

Waterloo Research in Aging Participant Pool (WRAP)
University of Waterloo
200 University Avenue West
519.888.4567 ext. 37776
wrap@healthy.uwaterloo.ca

Dear RESEARCHER:

We would like to introduce you to the Waterloo Research in Aging Participant Pool (WRAP). The database contains names and other details provided by healthy local seniors aged 60 years or older who are interested in taking part in research, and are a source of potential participants for researchers whose interest is in the area of aging. We have advertised this initiative to the K-W community, through newspaper ads, posters and flyers, and have received many phone calls from interested seniors. The database includes names, contact details and some medical history on each interested senior.

Researchers whose studies involve participants over the age of 60, and have received ethics clearance through University of Waterloo's Office of Research Ethics, are eligible to have access to the WRAP database. You can contact the WRAP Coordinator whenever you need senior participants, and she will give you the names and contact information of interested seniors, within 1 week from receipt of the Request Form. Enclosed is a sample form that you would need to complete, when requesting a list of potential participants from WRAP. Please feel free to copy this form as required. Please note that in order to cover the administrative costs associated with maintenance of the WRAP pool, recruitment, and participant coordinator duties; Faculty researchers pay an annual usage fee of $300 for their own access and that of their students to potential participants' information from the WRAP database.

Also included is a copy of the background questionnaire completed by all interested participants in the database. You can use this questionnaire to guide your inclusion/exclusion criteria request, to obtain a list of participant names of seniors who best fit with the needs of your study.

If your project also makes use of the SONA/REG pool at UW, you can submit 2 copies of your ORE forms to the SONA, and simultaneously submit a copy of your forms to Susan Sykes, Director, ORE, to obtain clearance for use of the WRAP pool.

You will also find enclosed in this package a copy of the WRAP policies and procedures manual. We ask that you read over these policies in order to be aware of the established protocol that has received full ethics clearance from the ORE. If students under your supervision are going to be using the pool, they must read the policies and procedures **AND complete full training with the WRAP Coordinator** before gaining access to any participant information.

Sincerely,

Myra Fernandes and Eric Roy
Co-Directors of WRAP

Michelle Manios
WRAP Co-coordinator

WATERLOO RESEARCH IN AGING PARTICIPANT POOL (WRAP) POLICIES AND PROCEDURES

Section Number		Section Description
1.0		**Preamble**
2.0		**Job Descriptions – WRAP Coordinator and WRAP Administrative Team**
	2.1	The WRAP Coordinator will manage the day-to-day operations of the WRAP pool as outlined below
	2.2	The WRAP Administrative Team will oversee the operation of the WRAP
3.0		**Recruitment of healthy elderly participants**
	3.1	The WRAP Coordinator will recruit healthy elderly participants under the supervision of the WRAP Administrative Team for participation in research with WRAP
	3.2	The WRAP Coordinator will maintain and administer a database of healthy elderly participants for participation in research
	3.3	The WRAP Coordinator will manage access to the WRAP's healthy elderly participant database
4.0		**General Testing Guidelines**
	4.1	Access to participants (by WRAP-approved Psychology or Kinesiology researchers or their students) will be managed by the WRAP Coordinator
	4.2	The WRAP Coordinator is responsible for managing all requests for participants
	4.3	The WRAP Coordinator must use the following protocol to administer the WRAP participant pool
	4.4	Behavior towards participants
	4.5	Students currently being supervised by a WRAP researcher and the WRAP Coordinator will have access to the WRAP participant pool
	4.6	Investigators have a moral responsibility to follow up on abnormal findings
	4.7	Investigators will offer participants a debriefing
	4.8	Participants are entitled to reimbursement of direct out-of-pocket expenses for those activities directly related to their participation in the study and, in some cases, nominal remuneration for their time
5.0		**Policies, Legislation, and Codes of ethics**

The following guidelines outline the policies and procedures that will govern the day-to-day operations of the WRAP participant pool. They are derived from policies in existence at a research institution affiliated with and approved by the University of Toronto.
Any reference to "researchers" in this document implies that these researchers have been approved to have access to participant information stored in the WRAP, in accordance with the policies and procedures outlined in this document.

1. PREAMBLE

Chapter 7 These guidelines are for participant recruitment and testing activities in the WRAP and apply to all Research staff, including scientists, postdoctoral fellows, students, and research assistants drawing from the WRAP participant pool. In addition, researchers collaborating from external agencies with members of WRAP will adhere to these guidelines.

Chapter 8 The purpose of the guidelines is to centralize and operationalize recruitment and testing practices. This should improve the efficiency of research operations and provide continuity for participants who volunteer for research. The guidelines are implemented by the WRAP Coordinator, who reports to the WRAP Administrative Team.

The Canadian federal and provincial policies and legislation listed in Section 5.0 pertain to testing of participants. The current guidelines are viewed as being supplemental to the policies and legislation. A number of codes of ethics are also listed in this appendix.

2.0 JOB DESCRIPTIONS - WRAP COORDINATOR AND WRAP ADMINISTRATIVE TEAM

2.1 The WRAP COORDINATOR will manage the day-to-day operations of the WRAP participant pool as outlined below.

a) The WRAP Coordinator will work in the WRAP Administrative Office (PAS 4236) for approximately 5 hours/week.

b) The following are tasks that the WRAP Coordinator will be responsible for during the course of employment:

i) Placing advertisements for participants (as directed by the WRAP Administrative Team) with local organizations (radio stations, newspapers, magazines, doctor's offices, etc.) and acting as the liaison between these organizations and the WRAP. He/she will be responsible for filling out the required paperwork (for approval by the WRAP Administrative Team) to ensure that the community organizations are paid for their services and will look after documenting any advertising expenditures in the WRAP budget.

ii) Creating and maintaining the WRAP participant pool database accordingly and documenting any changes that are made to the database in the WRAP participant pool documentation manual and the WRAP participant pool user's manual.

iii) Updating participant profiles as necessary (based on feedback from researchers)

iv) Answering and returning phone calls from potential participants

v) Completing initial screening questionnaire over the phone with the potential participants and entering this data into the database and ensuring that any formal documentation is mailed to the new potential participants no later than **two days** after the telephone screening interview was conducted.

vi) Acting as the liaison between the WRAP Administrative Team and the researchers (ie. the researchers should contact the WRAP Coordinator who will process his/her request in due course). Should there be a conflict, the WRAP Coordinator will contact a member of the WRAP Administrative Team for assistance in resolving the conflict.

vii) Tracking progress of ongoing research initiatives and participant involvement. If a potential participant declines participation in any given study, the participant can be contacted the next time a study for which she/he may be eligible is identified unless the participant has otherwise indicated. The WRAP Coordinator will ensure that the researchers have completed the proper documentation at each stage of their research projects.

viii) Creating and distributing the WRAP newsletter to the individuals included in the WRAP participant pool. This newsletter will be created once every year and will include updates about members of the WRAP and details about individual research studies that are ongoing.

2.2 The WRAP Administrative Team will oversee the operation of the WRAP participant pool

a) The WRAP Administrative Team consists of Drs. Myra Fernandes (Department of Psychology) and Eric Roy (Departments of Kinesiology and Psychology) at the University of Waterloo. While the WRAP Coordinator reports directly to the WRAP Administrative team, it is ultimately their responsibility to ensure that the WRAP participant pool and all its procedures run in an effective and ethically sound manner. They are responsible for assisting in any conflict resolution between the WRAP Coordinator and individual researchers, but will not be directly involved in participant recruitment/contact or in the distribution of participant information to individual researchers.

b) The WRAP Administrative Team will approve any documentation that is being distributed to members of the community/potential participants or to the other members of WRAP.

c) The WRAP Administrative Team will have to abide by the same regulations as other researchers when requesting participants from the WRAP participant pool for use in their own research initiatives.

3.0 RECRUITMENT OF HEALTHY OLD PARTICIPANTS

3.1 The WRAP Coordinator will recruit healthy elderly participants under the supervision of the WRAP Administrative Team for participation in research with WRAP.

a) Participants will be recruited through newspaper and radio ads, postings, talks, community events and other activities. Use of media will follow public relations guidelines as established by the University of Waterloo. The Office of Research Ethics will approve all advertisements before they are distributed to community organizations.

b) Participant recruitment will be ongoing, to provide a constant flow for use by all WRAP-approved researchers. For certain studies with special needs not met by the existing database (e.g., participants in a certain age group), the WRAP Coordinator and the relevant Investigator will make a directed effort towards recruitment of those participants. All recruitment efforts will be approved by the Office of Research Ethics prior to being implemented.

c) All investigators will recruit participants according to the guidelines established by the WRAP and approved by the Office of Research Ethics, with the help of the WRAP Coordinator, at any occasion possible (e.g., public talks).

d) Potential participants will either give permission to be contacted by the WRAP Coordinator (by completing an individual contact card distributed at a public lecture/event), or will call the WRAP Coordinator (e.g., by responding to an advertisement).

e) A brief phone interview will be conducted using a standard form, including identifying and background information, general health, medications, history of neurological illness, language background, and years of education.

f) If participants are considered suitable for inclusion in the participant pool, informed consent will be obtained prior to their data being entered into the database by way of an information letter and consent form that would be mailed to the individual to be signed and returned. A package will be sent to them containing answers to frequently asked questions. These will also be read over the phone. Once the participant's information has been entered into the database, they will be sent copies of all subsequent mailings, including newsletters and other pertinent information that may arise. Each newsletter will contain the following statement: "By virtue of receiving this newsletter, you are on our participant database, if you would like your name to be removed, please contact..."

The WRAP Coordinator will provide continuity by being the primary contact person for healthy elderly participants registered with WRAP.

3.2 The WRAP Coordinator will maintain and administer a database of healthy elderly participants for participation in research

a) The WRAP has only one database for all participants. Individual labs should not maintain their own database to facilitate recruitment and tracking of participation levels.

b) The database will contain the following:

- i) Identifying and background information from the screening interview
- ii) Comments from screening interview (if any)
- iii) Research information: dates of prior research participation, researchers and study Coordinator.

c) The database will be updated according to new information received from Investigators or participants (e.g., participant has developed a neurological disease). It is the Investigators' responsibility to communicate this information to the WRAP Coordinator, as soon as possible, and no later than upon the return of the list of names to the subject coordinator.

d) The database will be backed up regularly. Monthly back-ups will be stored in the WRAP Administrative Office.

3.3 The WRAP Coordinator will manage access to the WRAP's healthy elderly participant database.

a) The WRAP Coordinator will consolidate information concerning ongoing WRAP studies involving human participants.

- i) Investigators who wish to access the database will return a form that includes the following information to the WRAP Coordinator (see also Appendix D):
    - Name of principal Investigator, collaborators, and anyone involved in data collection (e.g., R.A.'s)
    - Type of participants required (e.g., age range, educational level)
    - Number of participants required
    - Anticipated duration of study
    - Funding source
    - ORE Approval number
    - Testing requirements (time, number of sessions, type of testing)
    - Exclusion criteria
- ii) WRAP Researchers should treat all information obtained about participants as confidential (see confidentiality statement on the request form)

b) The WRAP Coordinator will determine access to the database.

- i) The database is for members of WRAP and their collaborators/students (see list of collaborators on the ORE application form 101).
- ii) If the requested participants are not already in the database, the Investigator and the WRAP Coordinator will co-ordinate recruitment to be carried out by the WRAP Coordinator under the supervision of the WRAP Administrative Team.
- iii) When two or more Investigators seek access to the same participants, priority will be determined by the WRAP Coordinator, according to the following criteria. Prior to making this judgment, the WRAP Coordinator could be in touch with the researchers in question, in order to explain the problem. At that time, the individual researchers would have the opportunity to solve the problem independently. Should the need arise for the WRAP Coordinator to make a decision, the following criteria would be used:
    - <u>Seniority</u>: WRAP researchers will have priority over postdoctoral fellows, who have priority over graduate students
    - <u>Urgency</u>: For example, staff members whose appointment is ending and require participants to complete a study; Investigators responding to reviewer's requests for additional testing.
    - <u>Timing</u>: Priority will be given to Investigators who submitted their request first.
    - <u>Prior contact</u>: Investigators who made initial contact with the participants will have priority for follow-up testing (i.e., turning one's participants over to the database should not restrict access to those participants in the future). Follow-up contact will be handled through the WRAP Coordinator.
    - Appeals of the Coordinator's decision will be reviewed by the WRAP Administrative Team

c) The WRAP Coordinator will select participants to meet approved requests.

- i) The WRAP Coordinator will provide a list of names in response to requests, with the number of names determined by availability.

ii) Participants may be invited to participate in studies as frequently as they have requested, but only to the extent that their frequency of participation does not affect research data.

iv) While the WRAP Coordinator will seek to apply the inclusion/exclusion criteria specified by the Investigator, it is ultimately the Investigator's responsibility to ensure that the participants are appropriate.

d) All participants will be identified by a Research participant ID number. While investigators may assign their own participant numbers, they will maintain the Research participant ID number in their records for the sake of continuity across studies.

e) When WRAP-approved researchers contact potential participants to be included in their study, the following paragraph should be included for the researcher to inform the participant of where they received their contact information:

> "I am a researcher involved with the Waterloo Research in Aging Participant Pool. I received your contact information from the Coordinator of the Participant Pool who determined that you were eligible to participate in my study. Thank you for being involved in the participant pool. The study I am working on right now …"

4.0 GENERAL TESTING GUIDELINES

4.1 Access to patients (by WRAP-approved Psychology or Kinesiology researchers or their students) will be managed by the WRAP Coordinator.

a) Requests for patients will be made using the form described above (see 3.3 ai) for healthy older participants.

b) Determination of access to patients will depend upon how the patient was initially recruited.

i) The WRAP Coordinator will determine access to patients referred to the WRAP, or recruited directly by the WRAP Coordinator following the same guidelines as specified above for healthy young and old adults.

4.2 The WRAP Coordinator is responsible for managing all requests for participants.

a) All research projects must have received full ethics clearance from the Office of Research Ethics prior to the researcher requesting access to participants through WRAP.

b) The principal investigator is responsible for ensuring that all proper documentation (ie. Request for Participants Summary form) has been completed and submitted to the WRAP Coordinator before expecting to have access to participants from the WRAP participant pool and no research project using participants from the WRAP participant pool will be permitted to start until this documentation has been received and processed by the WRAP Coordinator. Copies of this form are available to individual researchers by contacting the WRAP Coordinator. In addition, an email copy of the given study's Certificate of Full Ethics Clearance must be received by the Coordinator from the ORE

c) Access to WRAP participants will be monitored by the WRAP Coordinator.

d) In order to have access to WRAP participants, the Principal Investigator (PI) must be a member of WRAP or be a researcher/student collaborating on a project with a member of the WRAP.

e) Where deemed advisable, requests for participants may be refused on the grounds that particular patients:

i) have recently been involved in another project

ii) have already been involved in a number of projects over a period of time

iii) are considered particularly vulnerable

f) The WRAP Coordinator will provide the PI with contact information of potential participants as **soon as possible, and will endeavour to provide this information within one week after receiving the Request for Participants Summary form.** Should this not be possible, it is the responsibility of the WRAP Coordinator to provide the PI with written documentation explaining the reason why the request cannot be completed (this will be done via email and saved in the WRAP email account for permanent documentation).

g) The Request for Participants Summary form will be kept as a formal record of the research that has been completed along with personal information (ie. Research participant ID number) of the participants contacted and used in the study.

4.3 The WRAP Coordinator must use the following protocol to administer the WRAP participant pool.

a) After the research project has received full ethics clearance from the Office of Research Ethics at the University of Waterloo, the PI must complete a Request for Participants Summary form (refer to page 54) which he/she then sends to the WRAP Coordinator via email.

b) Upon receiving the Request for Participants Summary form, the WRAP Coordinator will search the database for participants who meet the criteria identified in the form. The Request for Participants Summary form require that details be given of the proposed participant population in terms of University department, location of testing, and number of participants required.

c) Individual requests for participants may be refused by any member of the WRAP Administrative team.

d) The WRAP Coordinator will send an email message to the PI as soon as possible after receiving the request for participants containing the information required for the PI to be in touch with the potential participants. This data will be password protected, and each PI will be assigned a password which they will be responsible for keeping confidential. The WRAP Coordinator will be the only other individual with access to this password for each PI.

e) Should a PI feel that their research is being unduly held up by the WRAP Coordinator, he/she should contact a member of the WRAP Administrative Team who will deal with the problem in short order.

f) Once the PI has received all documentation about contacting the participants, it is the responsibility of the PI or a member of his/her research team to contact the participants on the list and establish appropriate testing times and meeting locations. It is understood that the PI may only contact each participant on the list for the specific study for which the PI has registered and requested participants.

g) If, upon contact with the potential participant, the researcher discovers that there has been a change in the participant's status, he/she must communicate this change in status to the WRAP Coordinator via email, as soon as possible, and at the latest upon return of participant names to the Coordinator. The WRAP Coordinator will then update the database to reflect this change in participant status.

h) Should the PI require additional participants at any point in the testing process, he should submit another Request for Participants Summary form, indicating that he/she is requesting additional participants. As with the original request for participants, the WRAP Coordinator will return additional participant names to the PI as soon as possible.

i) Once the PI has finished collecting data for the study, he/she must inform the WRAP Coordinator via email as soon after the completion of testing as possible. Any delays in conveying this information ultimately impede progress of other research projects.

4.4 Behaviour towards participants

a) Testing of participants will be in accord with current ethical guidelines and standards as specified by the Canadian Psychological Association/American Psychological Association.

b) **Before being able to communicate with potential participants by phone, all researchers/students must undergo a phone screening training/information session with the WRAP Coordinator.** During this session, general procedures and protocols will be outlined to the researcher/student, and he/she will have the opportunity to ask questions about what to expect when communicating with the potential participant over the phone. Researchers/students will also be given guidelines to follow should they attempt to contact a participant whose condition has changed (including death), and how he/she should provide written notification to the WRAP Coordinator of this change .

c) It is the responsibility of the WRAP Coordinator (NOT the individual researcher/student) to contact the family of the individual whose condition has changed (not including death) in order to invite them to transfer the participant's personal information to the patient database.

d) Any complaints or questions from participants concerning their research participation should be directed to the researcher running the study or to the ORE.

e) When a participant indicates she/he will drive her/his own vehicle to the University of Waterloo, the researcher/student should arrange to meet the participant in a designed parking area; or a pre-arranged area, if participant is coming by taxi or being dropped off. When testing phase is completed the researcher/student should accompany the participant back to their vehicle or the pre-arranged area to be picked up.

f) When the testing area is on a different floor from where participants enter the building the researcher/student should escort participants to and from the testing area VIA AN ELEVATOR. Participants should not use the stairs, unless the senior insists, to avoid the chance of a fall.

4.5 Students currently being supervised by a WRAP researcher and the WRAP Coordinator will have access to the WRAP participant pool.

a) Students requesting access to participants through the WRAP participant pool must be working under the direct supervision of a member of WRAP and must indicate their status on the Request for Participants Summary form.

b) Any student working under the supervision of a WRAP researcher can gain access to the WRAP database provided the study has received full ethics clearance from the ORE.

c) The WRAP Coordinator reports to the WRAP Administrative Team and works with the members of WRAP to assist in participant recruitment and distribution of participant information. If the WRAP Coordinator wishes to conduct a research study, he/she must follow the same guidelines as any other researcher requesting access to participant information.

d) All students requesting access to participant information, or students working on projects under the supervision of a member of WRAP where participant information from the WRAP participant pool will be available to them must read a copy of the WRAP Policies and Procedures manual, and agree to follow the guidelines outlined therein.

4.6 Investigators have a moral responsibility to follow up on abnormal findings as a result of testing.

a) Even though project being conducted by the WRAP are not clinical in nature, researchers have a moral responsibility to take appropriate action if clinically significant abnormal findings are uncovered while testing normal participants.

b) The Principal Investigator involved with the study (or a student's faculty supervisor) will contact the participant to inform them that medical consultation is warranted. The individuals involved with WRAP have no further obligation to treat the participant should the abnormal finding turn out to be clinically significant. If the PI suspects that the abnormal finding is due to abuse, he/she is obligated to inform the WRAP Coordinator of this suspicion. The WRAP Coordinator is then required to report this suspicion to the ORE and follow any guidelines offered from that department.

If the WRAP Coordinator suspects that one of the researchers has been abusive toward any participant, he/she is also obligated to inform the ORE of this suspicion, and that researcher will have his/her WRAP privileges revoked until such a time as the conflict has been resolved. If the researcher is found to be innocent, he/she will again have access to WRAP resources. If, however, the researcher is found to be guilty, he/she will be permanently removed from the list of WRAP-approved researchers, and disciplinary action through the ORE will ensue.

c) In the event that clinically significant abnormal findings are obtained, permission will be sought from the participant to communicate the information to his/her family physician.

4.7 Investigators will offer participants a debriefing.

a) The debriefing will provide information on the goals and methods of the study.

b) Participants will be informed about published research through the Volunteer Newsletter published every two years.

4.8 Participants are entitled to reimbursement of direct out-of-pocket expenses for those activities directly related to their participation in the study, and in some cases, nominal remuneration payment in recognition of their time.

There are two kinds of remuneration that can be made to volunteer research participants.

a) **Reimbursement of out-of-pocket expenses**. Participants are entitled to reimbursement of direct out-of-pocket expenses for:

- **Local travel** – specifically GRT fare or parking at the University of Waterloo (in unusual cases, taxi fare may be reimbursed).
- **Lunch** – if testing time exceeds 4 hours or can only be scheduled over a lunch period.

b) **Nominal remuneration in recognition of time commitment.** While volunteerism is encouraged, the Tri-Council Policy acknowledges that nominal remuneration in recognition of participant time may sometimes be appropriate. **This does *not* imply that all volunteer participants must receive payment for participation in research studies. The following guidelines are intended to provide general guidance to researchers on the remuneration of volunteer research participants.** They are designed to promote consistency, both internally and in relation to other area institutions. The following factors were taken into consideration in developing these guidelines.

- ***Participants are entitled to reimbursement of direct out-of-pocket expenses.***
- ***Remuneration in recognition of time commitment must not constitute undue inducement to participate.*** Such offers of remuneration must not provide unreasonable inducement to participant, particularly in cases where volunteer participants may be in economic need. It is also recognized that some participants may receive other benefits such as clinically useful information for some patients.
- ***Remuneration in recognition of time may be offered in certain circumstances.*** Examples of when this may be appropriate include situations where:
  - Participants undergo many hours of testing
  - Participants have to make multiple return visits
  - Participant populations are hard to recruit
  - There is competition for research participants from other institutions which do offer remuneration.
- ***Remuneration in recognition of time should be internally consistent.*** Research in different University of Waterloo laboratories with similar demands on participants should offer similar remuneration.
- ***Remuneration in recognition of time should be consistent with other institutions.***
- ***There is diversity in remuneration expectations.*** Some populations, such as healthy elderly adults, include large numbers of participants who routinely volunteer their time with no expectation of payment. Participation for its own sake is often more beneficial to patients than to healthy controls. The following guidelines are therefore flexible in their approach to this diversity.

Guidelines

(A) REIMBURSEMENT OF OUT-OF-POCKET EXPENSES

Local Travel: GRT fare or University of Waterloo parking will be reimbursed at the current rates. Where taxi or long distance travel (ie. gas or mileage costs) are involved, arrangements must be approved beforehand by the PI.

Lunch: A maximum of $10 will be provided, if testing exceeds 4 hours or can only be scheduled over a lunch period.

(B) NOMINAL REMUNERATION IN RECOGNITION OF TIME

Note: This does *not* imply that volunteer participants must be paid for their time. In cases where payment is appropriate, the following suggested rates subsume all out-of-pocket expenses.

Suggested Rates

Cognitive and psychomotor studies (5 – 8 hours)	$60.00
Cognitive and psychomotor studies (3 – 4 hours)	$30.00
Cognitive and psychomotor studies (1 hour)	$10.00

Exceptions

- Participants who elect to waive payment may be offered the option of donating the amount concerned to the University of Waterloo to be included in an internal scholarship fund for students interested in pursuing a career in age-related research.

(C) PROCESSING OF REMUNERATION

1. Out-of-pocket expenses will be reimbursed in cash on the day on which they are incurred.
2. Payments in recognition of time will be paid in cash at the completion of each participant's time commitment. In cases where a participant withdraws from a study, payment may be pro-rated according to the amount of time completed (minimum of $5.00).
3. It is the responsibility of the researcher to pay participants from his/her own research grants.
4. Where appropriate, reimbursement of expenses or nominal payment for initial testing and information gathering may be drawn from centrally-held funds (ie. a group grant).

5.0 POLICIES, LEGISLATION, AND CODES OF ETHICS

5.1 National Policy

Tri-Council Policy on Ethical Conduct for Research Involving Humans,
CIHR, NSERC, SSHRC, August 1998 *http://www.ncehr-cnerh.org/english/code_2/*

5.2 Ontario Legislation

Freedom of Information and Protection of Privacy Act
http://www.qp.gov.bc.ca/statreg/stat/F/96165_01.htm

Mental Health Act
http://www.qp.gov.bc.ca/statreg/stat/M/96288_01.htm

Regulated Health Professions Act, 1991
http://192.75.156.68/DBLaws/Statutes/English/91r18_e.htm

Substitute Decisions Act, 1992
http://192.75.156.68/DBLaws/Statutes/English/92s30_e.htm

5.3 Codes of Ethics

Canadian Code of Ethics for Psychologists (Canadian Psychological Association)
http://www.cpa.ca/ethics2000.html

Ethical principles for Psychologists (American Psychological Association)
http://www.apa.org/ethics/code2002.html

Ethical principles in the Conduct of Research with Human Participants (American Psychological Association)
http://scolar.vsc.edu:8005/VSCCAT/AAT-6703

WRAP
Participant Information Booklet

Participant Name:

____

Recruited from which Source?

____

Date Contacted:

____

Questionnaire Completed By:

____

Data Entered (Date):

____

Participant Identification Code:

____

GENERAL INFORMATION

Name: ______________________________

Address: ______________________________
____
____

Telephone: ______________________________

Email: ______________________________

Gender: ______________________________

D.O.B.: ______________________________

First Language (if not English, how old were you when you learned English?)
____

Total Education (in years): ______________________________

Handedness: ______________________________

If UW staff/faculty member, please indicate which department you work/worked in:
____

MEDICAL INFORMATION

1. *Please describe your general health.*

   ____
   ____
   ____

2. *Have you ever had any neurological problems (ie. strokes, seizures)?*

   Yes No

   If yes, please describe:
   ____
   ____
   ____

3. *Have you ever been unconscious for any length of time (ie. head injury, black-outs)?*

   Yes No

   If yes, please describe:
   ____
   ____
   ____

4. *Have you ever been diagnosed with any medical conditions or illnesses?*

   Yes No

   If yes, please describe:

5. *Have you ever had any surgeries?*

Yes No

If yes, please describe:

6. *Do you drink alcohol?*

Yes No

If yes: How many times per week/month?
How many drinks would you consume on the average occasion?
Preference: Beer Wine Liquor
Has it ever been a problem for you?
If yes: Did you receive treatment?

If no, did you ever drink? Yes No
How many times per week/month?
How many drinks would you consume on the average occasion?
Preference: Beer Wine Liquor
Has it ever been a problem for you?
If yes: Did you receive treatment?

7. *Do you, or have you used recreational drugs including marijuana?*

Yes No

If yes: Are you currently or was it in the past?
How often per week or per month?
Which drug or drugs?
How long have you been/were you using this drug for?
Did you ever receive treatment for it?

8. *Have you ever been treated for anxiety, depression, or any other psychological problem?*

Yes No

If yes: What were you treated for?
When did you begin receiving treatment?
How long did the treatment last?
What type of treatment did you receive?
Were you ever prescribed any medication?
What were you prescribed to take?
How long did you take that medication for?
Were you ever hospitalized?

9. *Are you currently taking any medications?*

Yes No

Drug	Dosage	Reason
1.		
2.		
3.		
4.		
5.		

10. *Is your current weight over 200 lbs?*

Yes No

What is your height? __________

11. *Do you wear glasses or contact lenses?*

Yes No

If yes: For reading or distance?

12. *Do you have any difficulty with your hearing?*

Yes No

If yes: Do you wear a hearing aid?

13. *Have you ever had a stroke or a T.I.A? (Transient Ischemic Attack)?*

Yes No

14. *Have you been seen by a neurologist or a neurosurgeon?*

Yes No

If yes: Was this for a back or neck problem?

If yes: Was this for a tension headache?

15. *Have you had cancer other than skin cancer diagnosed within the last three years?*

Yes No

16. *Do you have shortness of breath when sitting?*

Yes No

17. *Do you use home oxygen?*

Yes No

18. *Do you have difficulty understanding conversations because of your hearing even if you wear a hearing aid?*

Yes No

19. *Do you have trouble with your vision that prevents you from reading ordinary print even if you have glasses on?*

Yes No

20. *Have you had heart surgery?*

Yes No

21. *Have you ever been resuscitated?*

Yes No

22. *Do you have diabetes that requires insulin to control?*

Yes No

23. *Do you have hypertension that is not well controlled?*

Yes No

24. *Have you had a head injury with loss of consciousness greater than five minutes?*

Yes No

25. *Have you ever been unconscious for more than one hour other than during surgery?*
Yes No
26. *Have you ever required overnight hospitalization because of a head injury?*
Yes No
27. *Have you had encephalitis or meningitis?*
Yes No
28. *Have you ever had a heart attack?*
Yes No
If yes: Did you have any change in your memory, ability to talk or solve problems 24 hours after your heart attack?
29. *Are you currently taking medications for mental or emotional problems?*
Yes No
30. *Have you been hospitalized for mental or emotional problems in the past five years?*
Yes No
31. *Have you ever had seizures?*
Yes No
32. *Do you have Parkinson's disease?*
Yes No
33. *Have you ever had brain surgery?*
Yes No
34. *Have you ever undergone surgery to clear arteries to the brain?*
Yes No
35. *Have you ever had any illness that caused a permanent decrease in memory or other mental functions?*
Yes No
36. *Have you ever received electroshock therapy?*
Yes No
37. *Have you ever been diagnosed as learning disabled?*
Yes No
38. *Were you placed in special classes in school because of learning problems?*
Yes No
39. *Have you ever been diagnosed as having a brain tumour?*
Yes No
40. *Do you have difficulty using your hands?*
Yes No
41. *Have you ever had major surgery with anaesthesia?*
Yes No
If yes: Did you have any change in your memory, ability to talk or solve problems one week after surgery?
42. *Do you have multiple sclerosis, cerebral palsy, or Huntington's disease?*
Yes No
43. *Are you receiving kidney dialysis?*
Yes No
44. *Do you have liver disease?*
Yes No
45. *Do you have lupus?*
Yes No

Appendix X

Sample size calculations for Study 2

Sample size was calculated for the regression/prediction component of study 2 following the formula:

$N \geq (8/f^2) + (m-1)$ (Tabachnick, 2007)
where $f^2 = 0.02$, 0.15, and 0.35 for small, medium, and large effects, respectively
where m = number of independent variables in predictive model.

Medium to large effects sizes were seen for similar dependent measures in Study 1.
Number of IV in predictive models was to range from 1 (balance only) to 3 (balance, psych, health)
Therefore sample sizes required was estimated to range from:
Smallest N=(8/0.35)+(1-1)=22.86 **(23)** to Largest N=(8/0.15)+(3-1)=55.33 **(55)**

The WRAP coordinator provided the names of 108 potential participants; of these, 52 were able to participate in the period of time during which data collection was to take place.

References

Tabachnick BG and Fidell LS. Using multivariate statistics. (Fifth ed.) Pearson Education, Inc; 2007.