The relationship between movement reinvestment, balance confidence, and clinical balance performance in older adults

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Abstract

Movement reinvestment is a personality trait that may confound clinical balance performance. It is assessed using the Movement Specific Reinvestment Scale (MSRS) which has a conscious motor processing (CMP) subscale (tendency to consciously attend to and control movement) and a movement self-consciousness (MSC) subscale (tendency to be self-conscious about movement). The thesis objectives were to 1) explore relationships between movement reinvestment, balance confidence, and clinical balance outcomes, and 2) determine whether movement reinvestment explained variation in clinical balance performance over and above that of other established predictors of balance like age and balance confidence. Two hundred and forty-three older adults living independently in the community (173 females, mean (SD) age = 66.79 (7.31) years) completed the MSRS, Activities-Specific Balance Confidence (ABC) scale, and three trials (best trial taken) of a single leg stance (SLS) test (duration), timed-up-and-go (TUG) test (duration), functional reach (FR) test (distance), and obstacle course (OC) test (duration + error). First, bivariate correlations were conducted among all measures. Next, four separate hierarchical linear regressions were performed to predict clinical balance outcomes. In all regressions, age, sex, fall status, health status, and balance confidence were entered simultaneously on the first step, followed by CMP and MSC together on the second step. The results showed that higher CMP and MSC were associated with lower balance confidence. Higher MSC was associated with poorer clinical balance performance including shorter SLS durations, longer TUG durations, and higher OC scores. CMP was unrelated to clinical balance outcomes. Age and balance confidence were significant predictors of clinical balance outcomes. However, only the final regression model predicting OC score showed significant change from the initial model (R^2 change of .018). MSC and not CMP was significantly positively related to

OC score on the final step, after controlling for demographic variables and balance confidence. The results provide novel evidence of a relationship between greater self consciousness concerning movement style and poorer clinical balance outcomes in community-living adults over the age of 55 years of age. MSC can provide added insight into performance on a challenging obstacle course over and above that of other commonly used predictors including age, sex, fall status, health status and balance confidence. The results suggest that trait movement reinvestment and specifically MSC may be important to consider in clinical balance assessment protocols especially for complex adaptive gait tasks.

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Chapter 1: Literature Review

1.1. Falls in older adults

A fall is widely considered an unexpected event in which an individual inadvertently comes to rest on the ground, floor, or lower level (Montero-Odasso et al., 2022). Falls are a common occurrence in older adults; it is estimated that approximately 30% of adults aged 65 years and older fall each year (Montero-Odasso et al., 2022). Considering this statistic and population aging (Peel, 2011), falls represent a significant health care problem. For example, falls can have physical (i.e., bone fractures), psychological (i.e., fear or concerns related to falling) and behavioural (i.e., activity restriction) consequences, and are associated with other negative outcomes including institutionalization and increased mortality (Stinchcombe et al., 2014). Falls also have significant social and economic costs (Stinchcombe et al., 2014).

Falls in older adults most often result from a complex interaction between biological (e.g., balance deficit, muscle weakness), behavioural (e.g., fear of falling, lack of exercise, inappropriate footwear), socioeconomic (e.g., low income, living alone), and environmental (e.g., uneven flooring, stairs, obstacles) risk factors (Stinchcombe et al., 2014). This interaction makes it difficult to predict falls in older adults. However, as the number of older adults in Canada and the world is rapidly growing (Peel, 2011; Stinchcombe et al., 2014), it is important to be able to identify older adults at risk of falling and to find better ways to reduce fall risk in older adults (Montero-Odasso et al., 2022).

1.2. Age-related changes in postural control

Postural control or the ability to control the body's position in space has two main goals: postural orientation and postural equilibrium (Horak, 2006). Postural orientation or posture refers to the ability of the central nervous system (CNS) to align the individual body parts to each other and orient the body to the environment (Horak, 2006). Postural equilibrium or balance refers to the ability of the CNS to control the body's centre of mass within a stationary base-of-support (e.g., quietly standing on 1 leg) or moving base-of-support (e.g., walking; Horak et al., 2006). Postural control is considered a complex sensorimotor skill that requires integration of sensory information from various sources (i.e., visual, vestibular, somatosensory inputs) to produce appropriate motor responses to control the posture and balance of the body (Horak, 2006; Pollock et al., 2000). It has been suggested that postural control is a fundamental skill with a skill being something that is learned by the CNS and becomes more effective with practice over time (Pollock et al., 2000). Cognitive influences (i.e., attention) and emotional factors (i.e., anxiety, fear) have been shown to influence postural control (Adkin & Carpenter, 2018; Ellmers et al., 2023; Hall et al., 2023; Shumway-Cook & Woollacott, 2002). In addition to the sensory and motor systems needed for postural control, this research suggests that the cognitive and emotional systems play an important role in the control of posture and balance depending on task and environmental challenges.

A great deal of research effort has been directed toward understanding age-related changes in postural control (Maki & McIlroy, 1996; Osoba et al., 2019; Sturnieks et al., 2008). As we age, we often experience declines in the sensory, motor, and cognitive systems which can impact balance across a range of postural tasks from quiet standing to walking over obstacles. For example, sensory inputs necessary for balance may degrade with age; changes in vision (e.g., reduced visual acuity, depth perception and contrast sensitivity), somatosensory (e.g., higher thresholds for detecting movement), and vestibular (e.g., loss of vestibular sensitivity) information can have a negative effect on balance control. These effects are pronounced in situations where the availability, integration and weighting of sensory information is critical to task success like walking on a thick carpet in the dark, detecting a balance perturbation, or navigating obstacles (Horak, 2006). In addition to these sensory changes, there are often motor changes that happen as a result of the aging process. For instance, the human body will naturally start to lose lean body and skeletal mass beginning from the mid to late 20's and will continue to progress until old age (Sturnieks et al., 2008). As the quadricep muscles are significantly impacted from atrophy, older adults will typically have decreased leg strength, as well as less hip, knee and ankle torque needed for walking, stepping over obstacles and recovering from perturbations (Sturnieks et al., 2008). Additionally, changes in cognition including reduced information processing speed and reduced ability to divide attention between cognitive tasks when balancing are observed with aging (Woollacott & Shumway-Cook, 2002).

Normal aging is also associated with decreased ability to maintain balance while quietly standing. As quiet standing requires an appropriate amount of peripheral sensation from the feet, body sway can appear larger indicating impaired redundancy in balance in those who are older or who have sensory issues (Sturnieks et al., 2008). Other sensory inputs such as vision, proprioception and vestibular senses are also an area of concern as proper movement generally requires a clear visual field, a well functioning somatosensory system in the muscles, joints and tendons as well as the ability to locate proper position and movement of the head in order to complete tasks without a fall. Of these, the most common factor that most people notice is that eyesight generally starts to worsen over time making it harder for people to assess what is in front of them and how fast it is moving towards them, a requirement needed to avoid an obstacle. Furthermore, aging also impacts walking and the natural gait pattern. Current literature shows that as one ages, they tend to walk with slower velocity, shorter step length, produce wider steps and increased time in the double support phase (Sturnieks et al., 2008). This further supports the need for understanding age related changes as daily life includes many different styles of obstacles making it difficult to avoid them quickly or step over them high and wide enough (Sturnieks et al., 2008).

Clinical balance assessment tools are commonly used to assess one's balance performance or lack thereof as they prove to be useful for diagnostic and therapeutic reasons in clinical settings (Mancini & Horak, 2010). Some of the most common clinical tests currently used are the single leg stance test, timed-up-and-go (TUG) test, and Berg Balance Scale (Sibley et al., 2015). However, many times a mix of clinical balance tests is used to fully assess the functioning of the balance control system (Horak, 2006). Typically, performance on these tests declines with age, and age and sex normative values have been established in the literature for many clinical balance tests. The TUG test measures the duration required by an individual to stand up from a chair, walk a distance of 3 meters, turn, walk back to the chair and sit down (Podsiadlo & Richardson, 1991). Bohannon has shown that the mean and 95% confidence intervals for the duration in seconds to complete the TUG test differed for 60–69-year-olds (8.1; 7.1-9.0), 70-79-year olds (9.2; 8.2-10.2) and 80-99-year olds (11.3; 10.0-12.7; Bohannon, 2006). Despite the use of clinical balance tests, there remains a need to improve clinical balance assessment protocols to better identify balance issues and fall risk (Mancini & Horak, 2010).

1.3. Psychological Influences on Balance

Fear of falling, low fall-related efficacy and low balance confidence are commonly reported in older adults (Hadjistavropoulos et al., 2011; Letgers, 2002; Staab et al., 2013). For example, Scheffer and colleagues reported that prevalence of fear of falling in older adults ranged from 21 to 85% (Scheffer et al., 2008). These prevalence rates are important as fear of falling in older adults is associated with a wide range of behavioural changes, including balance and gait deficits and increased risk of falls (Cumming et al., 2000; Friedman et al., 2002; Li et al., 2003). Ultimately, fear of falling can lead to physical and social activity restriction, decline in physical functioning, loss of independence, and reduced quality of life (Letgers, 2002).

Research has consistently shown that psychological factors (e.g., fear of falling, fall-related efficacy, balance confidence, etc.) can modify balance control (Adkin & Carpenter, 2018; Hadjistavropoulos et al., 2011; Staab et al., 2013). For example, individuals reporting low balance confidence, low falls-related efficacy or fear of falling have been shown to have increased postural sway on quiet standing tasks, reduced limits of stability, slower gait velocity, reduced step length and cadence, and greater step width (Binda et al., 2003; Chamberlin et al., 2005; Maki, 1997; Maki et al., 1991; McAuley et al., 1997; Myers et al., 1996; Reelick et al., 2009; Rochat et al., 2010; Rosengren et al., 1998). Lamarche and colleagues examined trunk sway during clinical balance tests in older adults who reported high balance confidence compared to older adults who reported low balance confidence (Lamarche et al., 2013). Their results showed that older adults with low balance confidence had greater trunk pitch and roll sway on standing tasks and less trunk roll sway on gait tasks. From a clinical balance assessment and experimental design perspective, this work has been important to show that psychological factors can confound balance assessment.

The psychological influences on balance control and daily activities are typically assessed through trait like questionnaires. Fear of falling is assessed by having older adults answer yes or no to the question “Are you afraid of falling”. Fall-related efficacy and balance confidence are also common constructs used to identify the psychological influences on balance control (Legters, 2002). The Falls Efficacy Scale (FES) was initially developed to assess falls related efficacy for different activities of daily living (Tinetti et al., 1990). The Activities-

Specific Balance Confidence Scale (ABC) was developed to assess general balance confidence across a range of daily activities in more highly functioning older adults (Powell & Myers, 1995). The ABC scale is a questionnaire that consists of 16 activities for which individuals rate their level of confidence on a scale from 0% (not at all confident) to 100% (fully confident) in being able to complete the activity without losing their balance. Thus, the scale assesses the degree of belief in one's ability to avoid a loss of balance during daily activities.

A relationship between balance confidence and clinical balance performance is well established (Schepens et al., 2012). Scores on the ABC scale have been used to identify fall risk in community living older adults with older adult fallers reporting lower scores on the ABC scale compared to older adult non-fallers (Lajoie & Gallagher, 2004). ABC scores have also been shown to be associated with performance outcomes on a variety of clinical balance tests such as one leg stance duration, TUG duration, and functional reach distance (Cho et al., 2004; Hatch et al., 2003; Schepens et al., 2010). For example, scores on the ABC scale have shown to be negatively correlated with TUG duration in older adults; those older adults reporting lower confidence took longer to complete the task (Cho et al., 2004; Schepens et al., 2010). Cho and colleagues found a positive correlation between ABC scores and timed single leg stance in community-dwelling older adults aged 65 and older; lower scores on the ABC scale were associated with shorter single leg stance durations (Cho et al., 2004). Schepens and colleagues found that functional reach distance was positively correlated with ABC scores in a group of older adults 65 years and older; lower balance confidence was associated with shorter reach distances (Schepens et al., 2010).

1.4. Psychomotor Influences on Balance

1.4.1. Movement Reinvestment and Its Measurement

Reinvestment in movement is a psychomotor factor that may influence balance control in older adults. Movement reinvestment has been described as a personality trait that reflects an individuals' propensity or tendency to attempt to control and/or monitor their movements (Masters & Maxwell, 2008). As such, the amount and type of reinvestment in movement and its potential to modify balance may differ depending on whether an older adult has a higher or lower propensity to reinvest in movement. The tendency for movement reinvestment is generally considered to be undesirable, especially for well learned movements (Masters & Maxwell, 2008). It is thought that attempts to consciously control and monitor movement interferes with automatic movement processes resulting in less efficient movement and ultimately poorer performance outcomes (Masters & Maxwell, 2008). This explanation is similar to that of the constrained action hypothesis which explains the advantage of adopting an external attention focus (i.e., direct attention to the effects of an action on the environment) over an internal attention focus (i.e., direct attention to the specific movements needed to produce the action; Wulf, 2013). Focusing externally facilitates performance as it promotes a more automatic control of movement while focusing internally results in a more conscious control of movement, subsequently constraining or interfering with normal automatic control processes (Wulf, 2013). Thus, understanding the relationship between movement reinvestment and perceived and actual balance performance may assist in explaining fall risk, the results of balance assessment, and direct efforts for training balance in older adults.

The Movement Specific Reinvestment Scale (MSRS) was designed to assess trait levels of movement reinvestment (Appendix C). Participants answer questions about their tendency to reinvest in their movements on a six-point Likert scale from strongly disagree to strongly agree. The scale includes ten total questions with two subscales, with each subscale including five questions. The two subscales are conscious motor processing (CMP) and movement self-consciousness (MSC; Masters & Maxwell, 2008). CMP reflects an individual's tendency to consciously control processes associated with their movement. One question on the CMP subscale is "I try to think about my movements when I carry them out". Movement self-consciousness (MSC) reflects an individual's concern for their style of their movement. One question from the MSC subscale is "I am concerned about my style of moving". Researchers have used the overall MSRS score (score range 10-60) or they have examined the CMP (score range 5-30) and MSC (score range 5-30) subscales separately.

1.4.2. Movement Reinvestment in Older Adults

Masters and Maxwell highlighted contingencies for movement reinvestment which included situations that involved psychological pressure, high levels of motivation, anxiety, fear, movement difficulties and falls (Masters & Maxwell, 2008). For an older adult, an awareness or concern about balance may prompt reinvestment in movement especially for daily tasks that challenge balance or for situations or environments in which balance is evaluated (e.g., when balance is observed or assessed by others). In these cases, an older adult may attempt to consciously control movement processes or monitor movement style in an attempt to perform well and present a favourable impression to others. Despite efforts to employ these strategies to better maintain balance, consciously controlling movement processes or monitoring movement style is theorized to have negative consequences for balance performance (Masters & Maxwell, 2008). Despite this theory and evidence to support it, recent work has suggested that in high anxiety situations consciously processing balance may in fact act to mitigate anxiety-induced balance changes (Ellmers et al., 2021; Fischer et al., 2023). A better understanding of the relationship between movement reinvestment and balance performance may provide insight into whether movement reinvestment is a protective or maladaptive strategy (Ellmers et al., 2023)

Relevant to the current thesis, Wong and colleagues first reported differences in movement reinvestment (as assessed with the MSRS) between older adult fallers and non-fallers (Wong et al., 2008). The results of this study showed that older adult fallers reinvested more in their movements (i.e., higher CMP and MSC scores) compared to older adult non-fallers. It was also revealed in this study that CMP emerged as the only significant discriminator between older adult fallers and non-fallers, among other common predictors such as age, gender, cognitive status and balance performance (Wong et al., 2008). Higher movement reinvestment scores in older adult fallers compared to older adult non-fallers have been subsequently confirmed (Musculus et al., 2021; Wong et al., 2009). However, no differences in movement reinvestment between older adult fallers compared to non-fallers have also been reported (de-Melker Worms et al., 2017; Uiga et al., 2018). Differences in movement reinvestment have also been reported between people with Parkinson's disease and healthy controls (Masters et al., 2007) and people with stroke and healthy controls (Orrell et al., 2009); individuals with balance or movement difficulties reported reinvesting more in their movements (i.e., higher CMP and MSC).

Although a relationship between movement reinvestment and concerns about falling (e.g., fear of falling, low falls related efficacy, low balance confidence) would be expected, there is limited empirical evidence to support this view. Chu and Wong compared falls efficacy, as assessed with the FES-Chinese version, between a group of older adults who reported low movement reinvestment and those who reported high movement reinvestment (Chu & Wong, 2019). These authors showed lower fall efficacy in the high compared to low movement reinvestment group. However, no relationship between movement reinvestment and balance confidence, as assessed with the ABC scale, has also been reported (Uiga et al., 2020a).

After these initial studies showed a relationship between movement reinvestment and falls, concerns about falling and movement difficulties, several studies have been conducted in older adults that provided evidence for a relationship between movement reinvestment and balance and gait control, with higher levels of reinvestment associated with poorer outcomes. These studies have also probed how movement reinvestment influences allocation of attention during the performance of balance and walking tasks. The results of these studies are outlined next.

After identifying a relationship between movement reinvestment and falls, Wong and colleagues probed attention focus in older adult fallers and non-fallers during a walking task (Wong et al., 2009). They had older adults walk for three metres while carrying 1) a full cup of water (with instructions to not spill any water), 2) an empty cup weighted to match the full cup of water, and 3) no cup. Nine walking trials were performed for each condition. Markers were positioned along the walking pathway and during each walk an auditory tone was presented. After each walking trial, older adults were asked an internal focus question (e.g., which foot was in front when you heard the tone), external focus question (e.g., was your body in front of or behind the marker), or an irrelevant focus question. Movement reinvestment was also assessed using the Chinese version of the MSRS. The results showed that CMP and MSC were higher in older adult fallers compared to older adult non-fallers. When walking in the most challenging task condition (i.e., carrying the full cup of water), fallers were more accurate responding to the internal focus question compared to non-fallers. However, both fallers and non-fallers were highly accurate when answering the external focus question. The authors argued that the fallers, who also reported higher movement reinvestment, were more likely to divide their attention between their own movements and the external environment.

Uiga and colleagues examined the ability to allocate attention during a stepping accuracy task in 56 older adults 65 years of age and over with no reported fall history (Uiga et al., 2015). Two groups were compared based on the tendency to reinvest in movement; 28 older adults had high levels of movement reinvestment while 28 older adults had low levels of movement reinvestment. The older adults completed a walking task that required them to accurately step onto a target located in their travel path and continue walking between two obstacles. While walking, a tone sounded at random times. After completing the walk, older adults answered a body awareness or awareness of the external environment question. The questions were designed to assess internal focus (e.g., was your left foot on the ground when you heard the tone?), body location (e.g., were you past the target when you heard the tone?) or external focus (e.g., was the light at the end of the walkway switched on when you heard the tone?) awareness. The results of the study showed that older adults who had higher movement reinvestment scores were more aware of their limb movements and less aware of the external environment. In contrast, those older adults who had lower movement reinvestment scores were more aware of the external environment and less aware of their movements.

Uiga and colleagues also studied the relationship between overall movement reinvestment and performance on a visuomotor walking task in 92 older adults who were 65 years of age or older (Uiga et al., 2020a). Participants completed the MSRS as well as ten walking trials during which they walked and stepped as accurately as possible on a target located on the travel path and continued to walk between two obstacles. The results showed a relationship between movement reinvestment and specific walking outcomes. Older adults who reported higher overall movement reinvestment scores took more time to plan their step onto the target and were less accurate in placing their foot on the target.

Young and colleagues had 24 older adults perform an adaptive gait task (Young et al., 2016). This task involved walking over a six by four grid that included 16 black and 8 white wooden blocks. The white blocks were arranged to form a path and participants were to follow the path from one end of the grid to the other end while avoiding stepping on any of the black blocks. There was a no threat and threat condition performed. In the no threat condition, participants were shown that the black blocks were stable and would not collapse if stepped on. In the threat condition, it was demonstrated that the black blocks may collapse if stepped on. During a random trial, participants were asked a question while walking and it was noted if the participant had to or did not have to stop walking while answering the question. Based on the responses observed, 12 older adults were assigned to a stop walking while talking group and 12 older adults were assigned to a non-stop walking while talking group. The older adults who stopped walking while talking had higher CMP but not MSC scores (as obtained from the MSRS) and also were more accurate on a test of external awareness when walking.

Musculus and colleagues employed a longitudinal design to determine if movement reinvestment could predict future movement errors (i.e., falls, stumbles) in older adults who were 65 years of age or older (Musculus et al., 2021). In their study, movement reinvestment (as measured with the MSRS) and clinical balance performance (as assessed with the Short Physical Performance Battery) was obtained at an initial testing session in 21 older adults (17 with a history of falls). Over the next two months, the older adults completed a daily movement diary. This involved monitoring their movements and identifying and assigning any movement problems that they had that day into one of four categories: falls including injuries, falls, stumbling, and nothing happened. Movement reinvestment and clinical balance performance were then reassessed at a second testing session. The results revealed that CMP but not MSC was higher in the older adult fallers compared to non-fallers. No differences were observed in clinical balance performance between the fallers and non-fallers. The results also showed that CMP was able to assist in predicting future movement errors (i.e., falls).

The results of the studies presented above provide evidence of a relationship between movement reinvestment and specific outcomes on gait tasks (interpreted as maladaptive) and future falls. However, other research has not revealed a relationship between movement reinvestment and balance outcomes for both static and dynamic balance tasks. Uiga and colleagues examined static balance performance in single (quiet standing) and dual task (quiet standing while monitoring and reporting the number of times a high-pitch tone occurred) conditions in young adults and older adult fallers and non-fallers (Uiga et al., 2018). Movement reinvestment was also assessed using the MSRS. The key results of the study showed that young adults had higher movement reinvestment scores compared to the older fallers and non-fallers, with no differences observed between the fallers and non-fallers. However, relationships between movement reinvestment scores and balance outcomes were only significant for young adults in the single task condition; higher levels of movement reinvestment were associated with larger sway amplitude and less complex balance in the medial-lateral direction. No associations between movement reinvestment and balance outcomes were observed for the older fallers and non-fallers. Uiga and colleagues investigated the role of conscious processing of movements during balance which utilized a verbalization intervention including both young and older adults (Uiga et al., 2020b). Participants, who were also divided into either a low or high reinvestor group by the MSRS, were randomly assigned to a verbalization or non-verbalization condition.

The groups stood quietly on a force plate for one minute and then they either were asked to a) think back to their performance and stated everything they thought of (verbalization) or b) list as many animals as possible during the task (non-verbalization). The results showed that only young adults were affected by the verbalization task: high reinvestors showed increased medial-lateral entropy (i.e., a more complex or less regular postural control strategy) after the verbalization task, while low reinvestors showed an increased area of sway and medial-lateral sway variability suggesting overall poorer balance after the verbalization task. Older adults showed no change in balance performance after the verbalization task. Furthermore, reinvestment-related verbal instructions from Mak and colleagues were the first attempt at examining the effects of verbal instructions (i.e., instructions to allocate attention internally or externally) on gait in older adults with varying reinvestment tendencies, however, no changes in balance performance and sway were found (Mak et al., 2020). This further highlights a gap in the literature and a need for further studies trying to alter one's attention with verbal instructions.

Other research has also showed no relationship between movement reinvestment and gait control. De-Melker Worms and colleagues had older adults walk on a treadmill for five minutes during which transient mechanical perturbations occurred (de-Melker Worms et al., 2017). The walking task was performed under three conditions: internal attention focus instructions (i.e., focus on the movement of legs), external attention focus instructions (i.e., focus on the movement of the treadmill belt) or no attention focus instructions. The results showed no differences between the attention focus instruction conditions and no relationship between any of the gait measures and CMP or MSC. Although other work described above showed relationships between attention focus, movement reinvestment and gait, this study revealed no effects of these psychomotor factors on gait behaviour.

As there are mixed results supporting the relationship between movement reinvestment and balance and gait control in older adults, there is a need for future work to explore this relationship.

1.4.3. Movement Reinvestment in Anxiety Conditions

According to Masters and Maxwell, performing in anxiety-inducing situations may prompt movement reinvestment (Masters & Maxwell, 2008). Anxiety is an emotional state that is triggered by a feeling of uncertaintity or a potentially harmful event that may or may not happen (Ellmers et al., 2023). A large body of research has examined the influence of anxiety on balance control in healthy young and older adults (Adkin & Carpenter, 2018). This work increases anxiety by increasing the surface height at which individuals stand or by altering the expectation of receiving a postural disturbance. In the context of the postural threat, feelings of anxiety arise primarily due to the "what if" thought about the potential consequences of falling (Ellmers et al., 2023).This work has revealed anxiety-induced changes in static, anticipatory and reactive balance control as well as normal and adaptive gait control (Adkin & Carpenter, 2018). Researchers have also investigated whether movement reinvestment increases in these anxiety-inducing conditions in both healthy young and older adults (Adkin & Carpenter, 2018; Ellmers et al., 2023). In this research, a modified state measure of the movement reinvestment scale has been employed, or specific questions probing attention focus to balance or conscious control of balance have been used to assess changes in these measures in anxiety-inducing situations. For example, Huffman and colleagues showed that healthy young adults reported higher CMP and MSC when standing at the edge of a high compared to low platform (Huffman et al., 2009). Balance changes including leaning back farther away from the platform edge and increased sway frequency were also observed when standing at the edge of the high platform. This study also examined the relationship between changes in CMP and MSC and changes in balance measures; changes in movement reinvestment were associated with changes in leaning behaviour but not sway amplitude or frequency; healthy young adults who reported greater changes in CMP and MSC leaned farther away from the platform edge (Huffman et al., 2009). The work of Zaback and colleagues reinforced these findings as healthy young adults reported higher CMP and MSC scores when quietly standing as well as when performing an anticipatory postural task (i.e., rising to the toes) at the edge of a high compared to lower platform (Zaback et al., 2015). Research has also showed that individuals report more attention to balance or conscious control of balance in anxiety-inducing conditions in both healthy young and older adult groups (Ellmers et al., 2021; Fischer et al., 2023; Johnson et al., 2019a; Johnson et al., 2019b, Johnson et al., 2020; Zaback et al., 2019; Zaback et al., 2016; Zaback et al., 2021) with these changes in attention to balance related to sway amplitude and frequency. This body of research shows that increases in state movement reinvestment, attention to balance, or conscious control of balance are consistently observed when performing balance tasks in anxiety-inducing situations with these changes associated with specific changes in balance control.

One scenario that may increase anxiety and prompt movement reinvestment in older adults is the clinical assessment of balance. Geh and colleagues examined performance on static and dynamic clinical balance tests in young and older women while being assessed by an expert or non-expert (i.e., white coat effects; Geh et al., 2011). The assessment by the expert was used to manipulate social anxiety (i.e., increased anxiety when being observed by an expert on balance) to study the effects of this change on balance. Geh and colleagues defined social anxiety as a fear of performance in situations where one is exposed to new people or a new situation where the possibility of judgment by other people may occur (Geh et al., 2011). The results showed that younger and older women increased their anxiety when their balance was being assessed by the expert compared to non-expert. Changes in performance on the clinical balance tests were also observed when being assessed by the expert, but mainly in the older women. Older women had increased sway frequency in the anterior-posterior direction and increased sway amplitude in the medial-lateral direction when standing quietly on two legs with eyes closed and shorter stance durations when standing on one leg with eyes open. Both young and older women had increased maximum centre of pressure displacement when performing the functional reach test and being assessed by the expert. Although movement reinvestment was not measured in this study, it may be a factor that could assist in explaining the changes in performance in response to the "white-coat effect". Lamarche and colleagues showed a relationship between self-presentational concerns and performance on a clinical balance test in older women (Lamarche et al., 2014). Self-presentational concerns (i.e., measured as how confident individuals were that they could present themselves as someone who had physical coordination and stamina, and who was fit, healthy, and exercised regularly) assisted in predicting the variation in TUG duration, over and above that of balance confidence and other predictors such as age, fall history, and muscle strength. Lower self-presentation efficacy was associated with longer times to complete the TUG test. Although not measured, it is possible that movement reinvestment may have assisted in explaining variation in clinical balance performance providing improved accuracy of clinical balance assessments. Thus, the results of these studies suggest situations in which balance is being evaluated induces anxiety or self-presentational concerns which has the potential to influence balance assessment outcomes. As other research has linked changes in movement reinvestment and specifically changes in CMP to changes in balance control, there is a need to determine if movement reinvestment can explain variations in balance performance over and above that of other physiological or psychological measures.

Chapter 2: Rationale, Purpose, and Hypotheses

2.1. Rationale

Falls are common in older adults. Research has identified age-related sensory, motor, and cognitive changes that can have a detrimental effect on balance control increasing fall risk (Sturnieks et al., 2008). Clinical balance tests like the Berg Balance Scale and TUG are often used by clinicians and researchers when assessing balance in older adults to provide insight into static and dynamic balance control, mobility status or fall risk, or to monitor changes in these outcomes in response to balance training programs (Mancini & Horak, 2010; Sibley et al., 2015). Thus, an accurate assessment of balance is critical to better identify at-risk older adults and to evaluate the effectiveness of balance interventions.

The ability to identify different factors that may influence or confound performance on clinical balance tests is key to accurately assessing balance in older adults. It is well established that psychological influences like fear of falling, fall-related efficacy, and balance confidence can modify balance in older adults across a wide range of postural tasks, including clinical tests of balance (Ellmers et al., 2023; Staab et al., 2013). Based on this work, many clinical balance assessment protocols have adopted the use of fear of falling, fall-related efficacy, and/or balance confidence questionnaires. These tools are used to assess psychological status in older adults and how it might impact their daily life as well as potentially confound balance assessment.

Less understood is how trait movement reinvestment modifies balance control in older adults. Fewer studies have been conducted to explore this relationship, but work in this area has highlighted that trait levels of CMP and MSC are higher in older adult fallers compared to non-fallers (Musculus et al., 2021; Wong et al., 2008; Wong et al., 2009) and individuals with movement difficulties (i.e., Parkinson's disease, stroke) compared to healthy controls (Masters et al., 2007; Orrell et al., 2009). Furthermore, older adults who stopped walking while talking when performing an adaptive gait task had higher CMP compared to those older adults who did not stop walking while talking (Young et al., 2016). Research has also shown that CMP is linked to future movement errors such as falls and stumbles (Musculus et al., 2021). Studies have also shown a relationship between movement reinvestment and specific measures of gait on a stepping accuracy task in older adults (Uiga et al., 2015; Uiga et al., 2020a). However, other studies have not supported a relationship between movement reinvestment and performance indicators on static balance (Uiga et al., 2018) and treadmill walking tasks (de-Melker Worms et al., 2017) in older adults. In addition, other studies have shown that movement reinvestment generates changes in the allocation of attention when walking in older adults. In general, those older adults who report higher levels of trait reinvestment are more accurate in answering questions concerning their body awareness and less accurate when answering questions about the external environment (Uiga et al., 2015). Taken together, this body of research shows that higher levels of movement reinvestment are associated with poorer outcomes like falls and that it has the potential to influence performance when navigating complex environments potentially through changes in attention allocation. However, based on the limited and mixed results stemming from this research, it is necessary to further explore the relationship between trait levels of movement reinvestment and outcomes on clinical balance tests to recommend the inclusion of a movement reinvestment measure in clinical balance assessment protocols.

The relationship between movement reinvestment and balance control is stronger in situations designed to evoke anxiety. Typically, in these studies, movement reinvestment is assessed as a state measure with increases in conscious motor processing, movement self-consciousness, and attention focus to balance reported in anxious compared to non-anxious conditions (Fischer et al., 2023; Huffman et al., 2009; Johnson et al., 2019a; Johnson et al., 2020; Zaback et al., 2015; Zaback et al., 2016). Most of this work has been conducted in healthy young adults but there is also evidence of these effects in older adults (Ellmers et al., 2021; Johnson et al., 2019b). These increases in state movement reinvestment and attention to balance have also been shown to be associated with specific anxiety-induced changes in balance control (Adkin & Carpenter, 2018). For older adults, clinical balance assessment is a situation that can increase anxiety and white-coat effects (i.e., increased social anxiety when assessed by a balance expert compared to non-expert) on clinical balance assessment outcomes have been identified in the literature (Geh et al., 2011). In addition, self-presentational concerns have been shown to predict performance on a clinical balance test (i.e., TUG durations) over and above that of other more established measures including balance confidence (Lamarche et al., 2014). One limitation of these latter two studies is that movement reinvestment was not assessed. It is possible that changes in clinical balance performance observed in older adults in these studies may be further explained through individuals adopting a more conscious control of balance and/or being more self-conscious of their balance when assessed in a clinical setting.

There is limited evidence of a relationship between movement reinvestment and perceived balance outcomes (i.e., fall-related efficacy, balance confidence). One study has shown that scores on the MSRS were associated with scores on the FES; those who reported lower falls efficacy reported higher levels of movement reinvestment (Chu & Wong, 2019). Other studies have not supported this relationship. Uiga and colleagues showed no relationship between movement reinvestment and balance confidence as assessed with the ABC scale (Uiga et al., 2020a). Given the acceptance of fall-related efficacy and balance confidence measures in clinical balance protocols and the possible relationship between movement reinvestment and these psychological outcome measures, it is important to determine the unique contribution of movement reinvestment in explaining performance on clinical balance test performance over and above that of fall-related efficacy or balance confidence (Lamarche et al., 2014)

An accurate assessment of balance is critical in older adults as it can detect fall risk, identify mobility issues, and provide direction for balance training programs. As such it is important to explore the relationship between movement reinvestment and performance on clinical balance tests. By establishing a relationship between movement reinvestment and clinical balance outcomes, insight may be gained into whether movement reinvestment can confound balance assessment. This information can provide a recommendation for the addition of a measure of movement reinvestment to balance assessment protocols.

2.2. Purpose and Hypotheses

The first purpose of this thesis was to explore the relationship between the two dimensions of movement reinvestment (i.e., CMP, MSC) and balance-related outcomes in healthy older adults. It was hypothesized that a relationship between movement reinvestment and perceived and actual balance outcomes would be observed; greater CMP and MSC would be associated with more falls, lower balance confidence, and poorer performance on clinical balance tests (Geh et al., 2011; Lamarche et al., 2014, Wong et al., 2008, Wong et al., 2009).

The second purpose of this thesis was to determine whether CMP and MSC could explain variation in balance performance in healthy older adults over and above that of balance confidence and other more commonly used predictors of balance performance including age, sex, fall status, and health status. It was expected that CMP and MSC would assist in providing additional information to predict performance on clinical balance tests (Geh et al., 2011; Lamarche et al., 2014, Uiga et al., 2020a; Young et al., 2016).

Chapter 3: Methods

3.1. Overview

A secondary data analysis was conducted for this thesis. Data were obtained from a study that examined the effects of a 12-week exercise and balance training program on social, cognitive, and behavioural (e.g., balance) measures in community-dwelling older adults (REB File Number: 11-267). Specifically, this thesis received ethics clearance to explore relationships between balance confidence, movement-specific reinvestment, and clinical balance test results taken from the initial or baseline testing session from this larger study (REB File Number: 23-293; Appendix A).

3.2. Participants

Two-hundred and forty-three participants from the original study were included in this thesis. Participants had to be 55 years of age or older and living independently within the community. People with Parkinson's Disease, Multiple Sclerosis, or a recent history of knee or hip replacement surgery (i.e., within 2 years of testing) were excluded. People with diabetes, osteoporosis, or history of knee or hip replacement surgery (i.e., beyond 2 years from testing) were included. This decision was made to maintain an adequate sample size for statistical analyses. However, as these conditions may influence balance, a dichotomous health status variable (i.e., absence, 0 or presence, 1 of one or more of these conditions) was created to account for this possibility in the statistical analyses. People who reported a history of cardiovascular disease, respiratory problems, cancer, or arthritis were also included in this thesis. In addition, participants anticipated and were cleared for the possibility of joining an exercise and balance training program.

The mean ± standard deviation age of the participants was 66.79 ± 7.31 years, with ages ranging from 55 to 86 years. Of the 243 participants, 173 or 71.2% were female and 70 or 28.8% were male. There were 72 participants who reported a fall within the past year (29.6%) while 171 participants did not self-report a fall (70.4%). Sixty-three or 25.9% of the participants reported diabetes, osteoporosis, or history of knee or hip replacement surgery (i.e., beyond 2 years from baseline testing) while 180 or 74.1% did not report any of these conditions.

3.3. Procedures

In the study from which the data for this thesis was obtained, participants provided informed consent to participate in the study. First, participants completed a demographic and health questionnaire (Appendix B; e.g., sex, age, known health conditions, medications, fall history, etc.) as well as a series of questionnaires assessing psychological outcomes and balance and movement outcomes (e.g., balance confidence and movement reinvestment). Second, participants had anthropometric data (e.g., height, weight, etc.) collected and were asked to perform clinical balance tests as well as fitness, strength, and flexibility tests. Although participants were scheduled to be tested at three different time points in this original study, only data collected during the initial or baseline testing session (i.e., prior to the start of the exercise and balance training program) was examined in this thesis. Only select demographic and anthropometric measures, balance confidence and movement reinvestment reports, and performance on clinical balance tests were used.

3.4. Dependent Measures

3.4.1 Demographic and Anthropometric Measures

Demographic and health information collected included age, sex, known health conditions (e.g., stroke, Parkinson's Disease, Multiple Sclerosis, diabetes, osteoporosis, knee or hip joint replacement, etc.), and fall history (i.e., the number of falls reported within the past year). Anthropometric data that was collected included height (cm) and weight (kg).

3.4.2. Balance Confidence

The Activities-specific Balance Confidence (ABC) scale was used to assess balance confidence (Appendix C; Powell & Myers, 1995). For this scale, participants rated their confidence in the ability to perform 16 daily activities without falling on a scale ranging from 0% (no confidence) to 100% (complete confidence). Examples of activities on this scale included walking up and down stairs, standing and reaching for an object, and walking on an icy sidewalk. The mean ABC score for the 16 activities was calculated with lower scores indicating less balance confidence. Internal consistency (i.e., a measure of scale reliability, or how well the items on a scale are related to each other, Tavakol & Dennick, 2011) was considered satisfactory for the ABC scale (α=.92) in this thesis (Field, 2018).

3.4.3. Movement-Specific Reinvestment

The Movement Specific Reinvestment Scale (MSRS) was used to assess trait movement reinvestment or the tendency for individuals to direct attention toward their movements (Appendix D; Masters & Maxwell, 2008). This scale has 10 items that are rated on a 6-point Likert scale ranging from strongly disagree (1) to strongly agree (6). The scale has two 5-item subscales. The conscious motor processing (CMP) subscale assesses an individual's tendency to consciously attend to and control their movements. An example item from this subscale is "I am always trying to think about my movements when I carry them out". The movement self-consciousness (MSC) subscale assesses an individual's concern about their style of movement or how their movements look to others. An example item from this subscale is "I am concerned what people might think about me when I am moving". The sum of the 5 items for the CMP and

MSC subscales was calculated with scores for each subscale ranging from 5 to 30. Higher scores reflected greater CMP and MSC. Internal consistency was considered satisfactory for both the CMP (α=.80) and MSC (α=.85) subscales in this thesis.

3.4.4. Clinical Balance Tests

The clinical balance tests included: single leg stance (SLS), timed-up-and-go (TUG), functional reach (FR) and obstacle course (OC) tests (Table 1). The SLS, FR, and TUG tests are common clinical tests used to assess balance (Mancini & Horak, 2010; Sibley et al., 2015). The OC test is novel to the study from which the data for this thesis was obtained. The course was specifically designed to assess multiple balance components or resources (Horak 2006) and was adapted from the work of Means and colleagues (Means et al., 1996a; Means et al., 1996b, Means et al., 2005) and Elliott and colleagues (Elliott et al., 2000). For each test, the best of three trials was taken; this approach has been used in research studies (e.g., Benavent-Caballer et al., 2016; Springer et al., 2007) and clinical practice (Horak et al., 2009; Mancini & Horak, 2010).

Table 1. Clinical balance tests and associated outcome measures.

Balance Test	Trials	Outcome Measure
Single Leg Stance (SLS)	3	Duration (s); Best Trial Used
Timed-Up-and-Go (TUG)	3	Duration (s); Best Trial Used
Functional Reach (FR)	3	Reach Distance (cm); Best Trial Used
Obstacle Course (OC)	3	Duration (s) + Errors (#); Best Trial Used

Single Leg Stance (SLS) Test

A SLS test was used to assess standing balance (Mancini & Horak, 2010; Sibley et al., 2015). Participants were instructed to stand on one leg with their eyes open focused on a target located at their eye level, 2.18 m in front of them for a maximum duration of 30 seconds. Participants were able to select the leg on which they preferred to stand. Participants were instructed to maintain a 90-degree angle with their raised leg and to stand for as long as they could. The test began when the participant either raise their leg or let go of support from the spotter. The task was stopped if the participant touched the ground or the stance leg with the raised leg or needed support from the spotter. Duration (s) was used to quantify performance with longer durations reflecting better standing balance performance. Three trials of the SLS test were performed with the best trial used for statistical analyses.

Functional Reach (FR) Test

The FR test was used to assess the ability to maintain dynamic balance during a reaching task (Duncan et al., 1990). Using their preferred arm, participants stood parallel to a wall, with their arm positioned at 90 degrees of shoulder flexion and the hand fisted, keeping their shoulders squared towards the wall. A measuring tape pinned to the wall was used to standardize the starting position of the third metacarpal head (e.g., 0 cm). Participants were told to reach as far forward as you can without taking a step. The test was repeated if the participant's heels lifted from the ground or if the participant required assistance. The maximum forward distance of the third metacarpal that was reached was recorded. Forward reach distance (cm), calculated as the distance from the initial to final position of the third metacarpal, was used to assess performance. Smaller reach distances reflected poorer performance, with a score of 6 inches (15.24 cm) or less considered at risk for falling in older adults (Mancini & Horak, 2010). Three trials of the FR test were completed with the best trial used for statistical analyses.

Timed-Up-and-Go (TUG) Test

The TUG test was used to assess functional mobility (Mancini & Horak, 2010; Sibley et al., 2015). Participants were instructed to stand up from a seated position, walk 3 meters, turn around, walk back to the chair, and sit down. The participant was told to complete the test as fast as possible following a "ready, set, go" command. Duration was recorded from the go signal until the participant was seated back in the chair. Duration (s) was used to quantify performance on the TUG test with longer durations reflecting poorer performance. Three trials of the TUG test were completed with the best trial selected for statistical analyses. The TUG test is a commonly used clinical balance test that is strongly correlated to level of functional mobility in older adults (Podsiadla & Richardson, 1991; Shumway-Cook et al., 2000). Longer durations on the TUG test (e.g., 13 s or greater) are associated lower levels of functional mobility (i.e., less independent performing normal daily activities; Podsiadla & Richardson, 1999). A duration of 13.5 seconds or greater is considered a high risk for falling although it is suggested lower durations (e.g., 11-12 seconds) may identify a risk for falling (Mancini & Horak, 2010).

Obstacle Course (OC) Test

The OC test was used to assess multiple resources needed for optimal balance control (Horak, 2006; Sibley et al., 2015). Figure 1 presents a layout of the OC test. The obstacle course was 15 m in length and involved five distinct challenges. These challenges included 1) stepping on to and walking in tandem steps across a foam surface that was 3 m in length, 2) adjusting steps to target nine specific foot placements positioned to require changes in step length and width, 3) avoiding four on-ground obstacles of different sizes (height range: 5 cm to 30 cm) and two hanging obstacles, 4) weaving around four barriers that were 1 m high and placed 1 m apart, and 5) ascending three steps and then descending three steps. The obstacle course was designed to provide challenges that may be experienced in everyday activities and required sensory re-weighting, scanning and integration of visual information, adaptive gait strategies, anticipatory or predictive control, and potentially reactive control strategies.

Participants were instructed to navigate the obstacle course as fast as possible while making as few errors as possible. Total duration (s) taken to complete the obstacle course and the number of errors made (frequency) were recorded. Errors included any loss of balance that required assistance from the spotter, not being able to adjust to target the foot placements, and any contact with the obstacles or barriers. As participants were required to navigate the course as fast as possible making as few errors as possible, a summary measure adding duration and the number of errors made together was calculated to account for possible speed/accuracy trade-offs following the example of Reed-Jones and colleagues (Reed-Jones et al., 2012). After a familiarization or practice trial, participants performed three trials of the OC test and the best trial was used for statistical analyses.

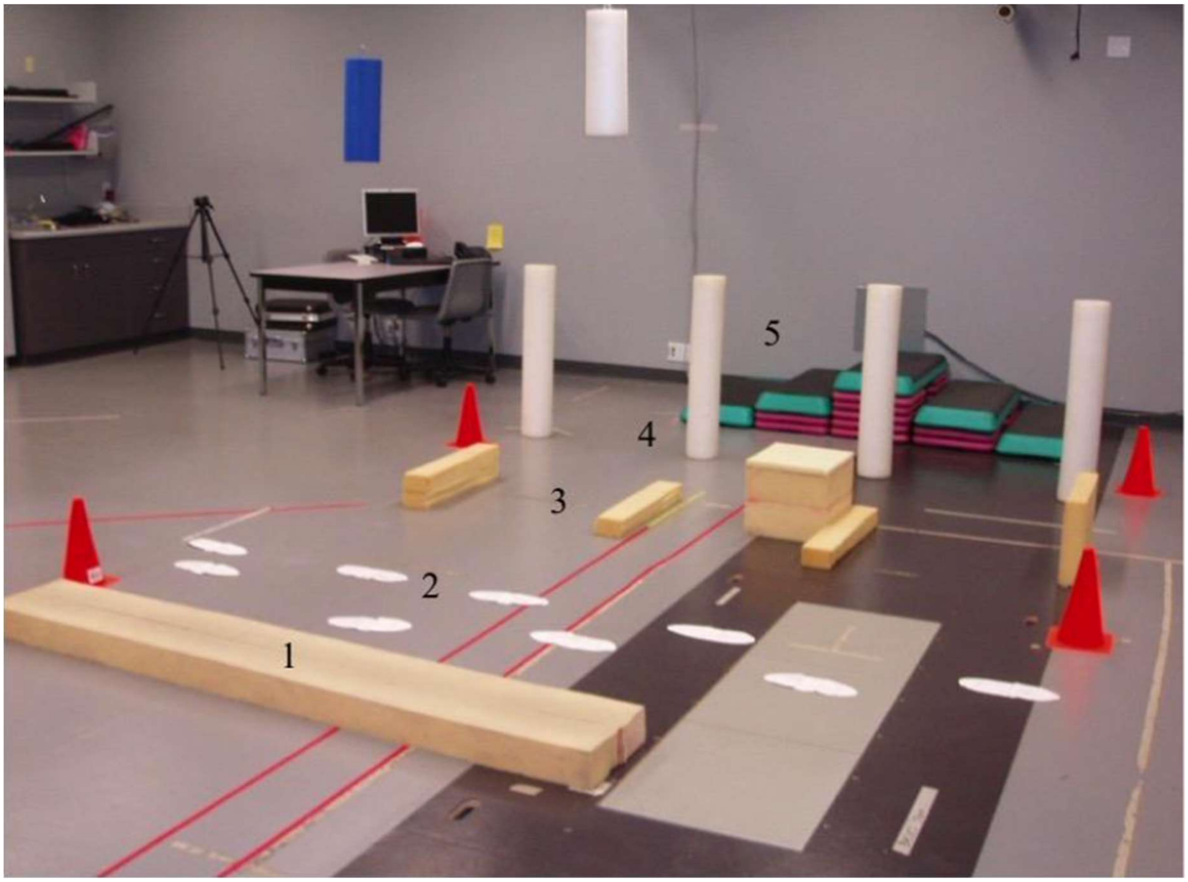

Figure 1. Layout of the obstacle course. Participants completed a tandem walk on foam support surface (Section 1), adjusted step width and length to target footprints placed on the floor (Section 2), avoided on ground and above ground obstacles (Section 3), navigated or steered around four barriers (Section 4) and walked up and down three stairs (Section 5).

3.5. Statistical Analysis

First, data screening was conducted, and normality assessed. Descriptive statistics were calculated for all dependent measures. Next, all dependent measures were screened for univariate outliers. To screen for univariate outliers, data was converted to standardized z-scores. A converted z-score greater than 3.29 or less than -3.29 was considered as an outlier. Any variable that met this set condition was visually inspected to determine if it should be replaced with the next closest value in the dataset not identified as an outlier. Following any replacements for the outlying variable, data were screened again, and any new outlying variables were replaced using this procedure until there were no remaining outliers (Tabachnick & Fidell, 2013). Following outlier replacement, normality was assessed for all measures by examining the skewness and kurtosis statistic (Field, 2018; Tabachnick & Fidell, 2013). Each skewness and kurtosis statistic was converted to standardized z-scores by dividing each value by its own standard error. Values greater or less than $\pm$ 3.29 were considered significantly skewed or kurtotic at $p < 0.001$ (Field, 2018; Tabachnick & Fidell, 2013). A transformation (e.g., logarithmic, square root) was performed on any significantly skewed or kurtotic values (Tabachnick & Fidell, 2013). The transformation was used to attempt to make the distribution more normal. The skewness and kurtosis statistic for the transformed data were examined using the same procedure described above. If the distribution of the transformed data was still significantly skewed, the original data were used.

Second, bivariate correlations were conducted to explore relationships among all dependent measures. Multicollinearity between variables was examined with an $r > .80$ reflective of variables that were highly related. To address the first purpose of the study, relationships between movement reinvestment and balance outcomes were highlighted.

Third, four separate hierarchical linear regressions were conducted to predict SLS duration, TUG duration, FR distance, and OC score (duration + errors). For all four regressions, age, sex (0 = male; 1 = female), fall status (0 = non-faller; 1 = faller), health status (0 = no chronic conditions reported; 1 = chronic conditions reported) and balance confidence were the predictor variables entered simultaneously on the first step (Model 1), followed by CMP and MSC entered together as predictor variables on the second step (Model 2). SLS duration, TUG duration, FR distance and OC score were the dependent variables. To address the second purpose of the study, this approach was used to determine the unique variance in balance performance explained by CMP and MSC over and above that of balance confidence and more commonly used predictors such as age, sex, fall status, and health status. For all analyses, alpha was set at 0.05 to indicate statistical significance.

Chapter 4: Results

4.1. Data Screening and Normality

Age, ABC, CMP, MSC, SLS duration, TUG duration, FR distance, and OC score measures were screened for univariate outliers. First, data were converted to standardized z-scores with a z-score greater than 3.29 or less than 3.29 considered as an outlier. Second, the potential outlying value was visually inspected to determine if it should be replaced with the next closest value in the dataset not identified as an outlier. For any replacements made, data were screened again, and any new cases identified as outliers were replaced using the same method. This procedure was repeated until no new outliers emerged. The following is the summary of the number of outliers replaced: ABC (6), TUG duration (3) and OC score (7). Outlying values that were replaced are shown in Table 2.

After outlier removal, skewness and kurtosis statistics were calculated for each measure; these statistics are displayed in Table 2. ABC and FR distance distributions were considered left-skewed, while TUG duration and OC score distributions were considered right-skewed. Logarithmic transformations applied to TUG durations produced a distribution identified as normal (skewness statistic =.360; kurtosis statistic = .283). This type of transformation was also applied to OC scores and had the same effect on correcting the distribution (skewness statistic =.235; kurtosis statistic = .325). The transformed data for TUG durations and OC scores were used in the statistical analyses. Transformations (square root) applied to ABC scores and FR distances did not correct the distribution and the original data were used in the statistical analyses. An examination of the kurtosis statistics showed that ABC, TUG duration, and OC score had sharper peaks and heavier tails compared to a normal distribution while MSC and SLS duration had flatter peaks and thinner tails.

Table 2: Data screening and normality results for all measures.

·	Skewness Statistic	Kurtosis Statistic	Outlying Values Replaced
Age (years)	0.301	-0.577	-
Height (m)	0.501	0.288	-
Weight (kg)	0.408	-0.384	-
ABC (0-100)	**-1.513**	**1.764**	41.2, 42.5, 43.8, 45.0, 48.1, 54.4
CMP (5-30)	-0.363	-0.746	-
MSC (5-30)	0.273	**-1.056**	-
SLS (s)	-0.004	**-1.606**	-
TUG (s)	**0.985**	**1.321**	13.0, 13.6, 14.2
FR (cm)	**-0.630**	0.898	-
OC (duration + errors)	**0.957**	**1.110**	51.0, 56.2, 56.7, 56.7, 57.0, 68.9

Note: ABC = Activities-specific Balance Confidence (range: 0-100); CMP = conscious motor processing (range: 5-30); MSC = movement self-consciousness (range: 5-30); SLS = Single Leg Stance; TUG = Timed-Up-and-Go; FR = Functional Reach; OC = Obstacle Course. Outlying values were replaced by next closest value in the direction the value was outlying until no further outliers were identified. Standard error values for skewness and kurtosis statistics were .156 and .311, respectively. Bold font represents measures with significant skewness or kurtosis.

4.2. Descriptive Statistics

Descriptive statistics for all measures are presented in Table 3. There were 243 participants included in this thesis. The mean age (SD) of the participants was 66.79 (7.31) years. Age ranged from 55 to 86 years. The mean height (SD) and weight (SD) of the participants was 1.67 (0.09) metres and 81.00 (17.20) kg, respectively. There were 173 females and 70 males. There were 171 non-fallers and 72 fallers. There were 180 participants who self-reported no chronic conditions and 63 participants who self-reported a chronic condition of diabetes, osteoporosis, or knee/hip replacement surgery (2 years prior to testing).

Table 3: Descriptive statistics for all measures.

	Mean	SD	Min	Max
Age (years)	66.79	7.31	55.00	86.00
Height (m)	1.67	0.09	1.46	1.91
Weight (kg)	81.00	17.20	50.00	135.40
ABC (0-100)	91.68	9.09	63.13	100.00
CMP (5-30)	17.62	6.26	5.00	30.00
MSC (5-30)	14.08	6.52	5.00	29.00
SLS (s; max. 30s)	17.60	10.40	1.53	30.00
TUG (s)	7.63	1.54	4.46	12.56
FR (cm)	36.19	8.45	11.00	62.00
OC (duration + errors)	27.60	6.38	14.19	46.56

Note: SD = standard deviation; Min = minimum; Max = maximum; ABC = Activities-specific Balance Confidence (range: 0-100); CMP = conscious motor processing (range: 5-30); MSC = movement self-consciousness (range: 5-30); SLS = Single Leg Stance; TUG = Timed-Up-and-Go; FR = Functional Reach; OC = Obstacle Course.

4.3. Bivariate Correlations

Bivariate correlations were conducted to examine linear relationships between measures. The results of the bivariate correlations between demographic, balance confidence, movement reinvestment, and clinical balance measures are presented in Table 4. Significant correlations are outlined below. No variables were considered highly related ($r > 0.80$).

4.3.1. Relationships between demographics measures and balance confidence and clinical balance measures

Significant correlations were observed between age and health status (r (241) = .178, p = .005), SLS duration (r (241) = -.319, p < .001), TUG duration (r (241) = .369, p < .001), FR distance (r (241) = -.220, p = .001), and OC score (r = .385, p < .001). Advanced age was associated with self-reported chronic conditions, shorter SLS durations, longer TUG durations, shorter FR distances and higher OC scores. Biological sex was significantly correlated with fall status (r (241) = 0.134, p = .037) and ABC (r (241) = -.185, p = .004). Being female was associated with being a faller and lower balance confidence. No significant correlations between biological sex and any clinical balance measure were observed. Fall status was significantly correlated to ABC (r (241) = -.185, p = .004) and OC score (r (241) = 0.162, p = .011). Being a faller was associated with lower balance confidence and higher OC scores. Health status was significantly correlated with age (as mentioned previously) and TUG (r (241) = 0.129, p = .044). duration. A self-reported chronic condition was associated with longer TUG durations.

4.3.2. Relationships between balance confidence and clinical balance measures

Significant correlations were observed between ABC and SLS duration (r (241) = 0.264, p < .001), TUG duration (r (241) = -.362, p < .001), FR distance (r (241) = 0.129, p = .045), and

OC score (*r* (241) = -.388, *p* < .001). Lower balance confidence was associated with shorter SLS durations, longer TUG durations, shorter FR distances, and higher OC scores.

4.3.3. Relationships between movement reinvestment and demographic measures

A significant correlation was observed between CMP and health status (*r* (241) = 0.137, *p* = .033) and between MSC and sex (*r* (241) = .169, *p* = .008) and health status (*r* (241) = 0.156, *p* = .015). Higher MSC was associated with being female and higher CMP and MSC were associated with self-reporting a chronic condition. There were no other significant correlations observed between CMP and MSC and any other demographic variables.

4.3.4. Relationships between movement reinvestment and balance confidence

There was a significant correlation observed between CMP and ABC (*r* (241) = -.224, *p* < .001). Higher CMP scores were associated with lower ABC scores. There was also a significant correlation between MSC and ABC (*r* (241) = -.356, *p* <.001). Higher MSC scores were associated with lower ABC scores.

4.3.5. Relationships between movement reinvestment and clinical balance measures

No significant correlations were observed between CMP and any clinical balance measure. Significant correlations were observed between MSC and SLS duration (*r* (241) = -.199, *p* = .002), TUG duration (*r* (241) = 0.203, *p* = .001), and OC score (*r* (241) = 0.259, *p* < .001). Higher MSC was associated with shorter SLS durations, longer TUG durations and higher OC scores. MSC was not significantly correlated with FR distance.

Table 4. Bivariate correlations for all measures.

	Age	Sex	Falls	Health	ABC	CMP	MSC	SLS	TUG	FR	OC
Age	-	-.093	-.008	**.178****	-.103	-.011	.083	**-.319****	**.369****	**-.220****	**.385****
Sex		-	**.134***	.107	**-.185****	.126	**.169****	-.022	-.042	-.057	.099
Falls			-	.089	**-.185****	.000	.096	-.115	.044	-.097	**.162****
Health				-	-.122	**.137***	**.156***	-.099	**.129***	-.071	.103
ABC					-	**-.224****	**-.356****	**.264****	**-.362****	**.129***	**-.388****
CMP						-	**.688***	-.101	.034	.028	.081
MSC							-	**-.199****	**.203****	-.031	**.259****
SLS								-	**-.460****	**.146***	**-.495****
TUG									-	**-.291****	**.704****
FR										-	**-.287****
OC											-

Note: ABC = Activities-specific Balance Confidence (range: 0-100); CMP = conscious motor processing (range: 5-30); MSC = movement self-consciousness (range: 5-30); SLS = Single Leg Stance; TUG = Timed-Up-and-Go; FR = Functional Reach; OC = Obstacle Course. TUG and OC reflect transformed data. Bold font identifies a significant correlation (** $p < 0.01$, 2-tailed; * $p < 0.05$ level, 2-tailed).

4.4. Hierarchical Linear Regressions

Hierarchical linear regressions were conducted to predict clinical balance performance. There were two blocks of predictor variables. The first model included age, sex, fall status, health status, and ABC as the predictor variables. The second model added CMP and MSC as predictor variables. Four hierarchical linear regressions were conducted with SLS duration, TUG duration, FR distance and OC score as the dependent variables.

4.4.1. Single Leg Stance

The results of the hierarchical linear regression predicting SLS duration are presented in Table 5. The first model was significant [$F(5, 237) = 9.110$, $p < .001$, adjusted $R^2 = .144$] with the combination of predictor variables explaining 14.4% of the variance in SLS duration. Age and ABC were identified as significant predictors. Advanced age was significantly associated with shorter SLS durations ($\beta = -.294$, $t = -4.803$, $p < .001$). Low balance confidence was significantly associated with shorter SLS durations ($\beta = .218$, $t = 3.520$, $p < .001$). Based on the semi-partial correlations, age uniquely accounted for 8.18 % of the variance in SLS duration ($r_{sp} = -.286$) while ABC uniquely explained 4.37 % ($r_{sp} = .209$).

The second model was also significant ($F(7, 235) = 6.895$, $p < .001$, adjusted $R^2 = .146$). Age and ABC remained the only significant predictors associated with SLS duration ($\beta = -.289$, $t = -4.691$, $p < .001$; $\beta = .185$, $t = 2.838$, $p = .005$, respectively). Based on the semi-partial correlations, age accounted for 7.78 % ($r_{sp} = -.279$) of the variance in SLS duration independent of the other predictor variables in the model while ABC accounted for 2.86 % ($r_{sp} = .169$). This second model did not show significant improvement from the first model in explaining variance in SLS scores ($\Delta F(2, 235) = 1.301$, $p = .274$, $\Delta R^2 = .009$). This suggests that CMP and MSC did not assist in providing additional information to explain SLS durations over and above that provided by age, sex, fall status, health status, and balance confidence.

Table 5. Summary of regressions predicting single leg stance (SLS) duration.

Predictors	β	Adjusted R^2	r_{sp}	ΔR^2
Model 1				
Age	**-0.294****		-0.286	
Sex	0.002		0.002	
Falls	-0.076		-0.074	
Health	-0.014		-0.013	
ABC	**0.218****	**0.144****	0.209	
Model 2				
Age	**-0.289****		-0.279	
Sex	0.013		0.012	
Falls	-0.073		-0.071	
Health	-0.004		-0.004	
ABC	**0.185***		0.169	
CMP	0.015		0.01	
MSC	-0.113	**0.146****	-0.078	0.009

Note: β = standardized beta values; r_{sp} = semi-partial correlations; bold font indicates significant beta value, model, or model change; * $p < .05$; ** $p < .001$

4.4.2. Timed-Up-and-Go

The results of the hierarchical linear regression predicting TUG duration are presented in Table 6. The first model was significant [F (5, 237) = 15.751, $p < .001$, adjusted $R^2 = .234$] with the combination of predictor variables explaining 23.4% of the variance in TUG duration. Age and ABC were identified as significant predictors. Advanced age was significantly associated with longer TUG durations ($\beta = .319$, t = 5.516, $p < .001$). Low balance confidence was significantly associated with longer TUG durations ($\beta = -.341$, t = -5.813, $p < .001$). Based on the semi-partial correlations, age uniquely accounted for 9.61 % of the variance in TUG duration ($r_{sp} = .310$) while ABC uniquely explained 10.69 % ($r_{sp} = -.327$).

The second model was also significant (F (7, 235) = 12.177, $p < .001$, adjusted $R^2 = .244$). Age, ABC and MSC were significantly associated with TUG duration ($\beta = .305$, t = 5.266, $p < .001$; $\beta = -.316$, t = -5.142, $p < .001$; $\beta = .181$, t = 2.225, $p = .027$, respectively). Advanced age, lower balance confidence and higher movement self-consciousness were significantly associated with longer TUG durations. Based on the semi-partial correlations, age accounted for 8.64 % ($r_{sp} = .294$) of the variance in TUG duration independent of the other predictor variables in the model while ABC and MSC accounted for 8.24 % ($r_{sp} = -.287$) and 1.54 % ($r_{sp} = 0.124$), respectively. However, the second model did not show significant improvement from the first model in explaining variance in TUG duration (Δ F (2, 235) = 2.685, $p = .070$, $\Delta R^2 = .017$). This suggests that CMP and MSC did not assist in providing additional information to explain TUG duration over and above that provided by demographic variables and balance confidence.

Table 6. Summary of regressions predicting Timed-Up-and-Go (TUG) duration.

Predictors	β	Adjusted R^2	r_{sp}	ΔR^2
Model 1				
Age	**0.319****		0.310	
Sex	-0.078		-0.075	
Falls	-0.010		-0.010	
Health	0.040		0.039	
ABC	**-0.341****	**0.234****	-0.327	
Model 2				
Age	**0.305****		0.294	
Sex	-0.084		-0.081	
Falls	-0.022		-0.021	
Health	0.040		0.039	
ABC	**-0.316****		-0.287	
CMP	-0.153		-0.110	
MSC	**0.181***	**0.244****	0.124	0.017

Note: β = standardized beta values; r_{sp} = semi-partial correlations; bold font indicates significant beta value, model, or model change; * $p < .05$; ** $p < .001$

4.4.3. Functional Reach

The results of the hierarchical linear regression predicting FR distance are presented in Table 7. The results showed that the first model was significant [F (5, 237) = 3.508, p = .004, adjusted R^2 = .049] with the combination of predictor variables explaining 4.9% of the variance in functional reach distance. Age was the only significant predictor. Advanced age was significantly associated with shorter functional reach distances (β = -.215, t = -3.332, p = .001). Based on the semi-partial correlations, age uniquely accounted for 4.37 % of the variance in functional reach distance (r_{sp} = -.209).

The second model was also significant (F (7, 235) = 2.598, p = .013, adjusted R^2 = .044). Age remained the only predictor variable significantly associated with functional reach distance (β = .-.212, t = -3.262, p = .001). Based on the semi-partial correlations, age accounted for 4.20 % (r_{sp} = -0.205) of the variance in functional reach distance independent of the other predictor variables in the model. However, this second model did not show significant improvement from the first model in explaining variance in functional reach distance (Δ F (2, 235) = .371, p = .691, Δ R^2 = .003). This suggests that CMP and MSC did not assist in providing additional information to explain obstacle course performance over and above that provided by age, sex, fall status, health status, and balance confidence.

Table 7. Summary of regressions predicting functional reach (FR) distance.

Predictors	β	Adjusted R^2	r_{sp}	ΔR^2
Model 1				
Age	**-0.215***		-0.209	
Sex	-0.050		-0.049	
Falls	-0.076		-0.074	
Health	-0.011		-0.011	
ABC	0.082	**0.049****	0.079	
Model 2				
Age	**-0.212***		-0.205	
Sex	-0.055		-0.053	
Falls	-0.073		-0.071	
Health	-0.017		-0.017	
ABC	0.094		0.085	
CMP	0.056		0.040	
MSC	0.000	**0.044***	0.000	0.003

Note: β = standardized beta values; r_{sp} = semi-partial correlations; bold font indicates significant beta value, model, or model change; * $p < .05$; ** $p < .001$

4.4.4. Obstacle Course

The results of the hierarchical linear regression predicting OC score are presented in Table 8. The first model was significant [F (5, 237) = 18.893, $p < .001$, adjusted $R^2 = .270$] with the combination of predictor variables explaining 27.0% of the variance in the OC score. Age and ABC emerged as significant predictors. Advanced age was significantly associated with higher obstacle course scores (i.e., worse performance; $\beta = .362$, t = 6.399, $p < .001$). Low balance confidence was significantly associated with higher obstacle course scores ($\beta = -.323$, t = -5.635, $p < .001$). Based on the semi-partial correlations, age uniquely accounted for 12.32 % of the variance in obstacle course performance ($r_{sp} = .351$) while ABC uniquely explained 9.61 % ($r_{sp} = -.310$).

The second model was also significant (F (7, 235) = 14.612, $p < .001$, adjusted $R^2 = .283$). Age, ABC and MSC were significantly associated with obstacle course scores ($\beta = .348$, t = 6.171, $p < .001$; $\beta = -.285$, t = -4.766, $p < .001$; $\beta = .196$, t = 2.478, $p = .014$, respectively). Advanced age, lower balance confidence and higher movement self-consciousness were significantly associated with higher obstacle course scores. Based on the semi-partial correlations, age accounted for 11.29 % ($r_{sp} = .336$) of the variance in obstacle course performance independent of the other predictor variables in the model while ABC and MSC accounted for 6.71 % ($r_{sp} = -0.259$) and 1.82 % ($r_{sp} = 0.135$), respectively. This second model did show significant improvement from the first model in explaining variance in obstacle course scores (Δ F (2, 235) = 3.080, $p = .048$, $\Delta R^2 = .018$). This suggests that CMP and MSC did assist in providing additional information to explain obstacle course performance over and above that provided by demographic variables and balance confidence.

Table 8. Summary of regressions predicting obstacle course (OC) score.

Predictors	β	Adjusted R^2	r_{sp}	ΔR^2
Model 1				
Age	**0.362****		0.351	
Sex	0.062		0.060	
Falls	0.099		0.096	
Health	-0.016		-0.015	
ABC	**-0.323****	**0.270****	-0.310	
Model 2				
Age	**0.348****		0.336	
Sex	0.051		0.049	
Falls	0.089		0.086	
Health	-0.021		-0.020	
ABC	**-0.285****		-0.259	
CMP	-0.118		-0.085	
MSC	**0.196***	**0.283****	0.135	**0.018***

Note: β = standardized beta values; r_{sp} = semi-partial correlations; bold font indicates significant beta value, model, or model change; * $p < .05$; ** $p < .001$

Chapter 5: Discussion

5.1. Overview

This thesis examined trait movement reinvestment, or the tendency to consciously attend to and control one's movements or to be self-conscious about one's movements, and its relationship to falls and perceived and actual clinical balance outcomes in adults aged 55 years and older. The first objective of the thesis was to explore linear relationships between CMP and MSC, the two dimensions of movement reinvestment, and fall status, balance confidence, and clinical balance performance. Based on past research, it was expected that both dimensions but especially CMP would be related to these measures with higher CMP and MSC scores associated with falling, lower balance confidence, and poorer clinical balance outcomes. First, the results of the bivariate correlations showed that CMP and MSC were not significantly associated with fall status. This observation did not support past research that has shown CMP as a predictor of both fall status (Wong et al., 2008) and future fall risk (Musculus et al., 2021). Second, CMP and MSC were significantly related to balance confidence with higher CMP and MSC scores associated with lower ABC scores. Although this finding is in line with a reported relationship between low fall-related efficacy and falls in older adults (Chu & Wong, 2020), it provides novel evidence of a relationship between movement reinvestment and balance confidence as past work did not reveal a relationship between these two measures (Uiga et al., 2020a). Third, MSC but not CMP was significantly related to clinical balance measures with higher MSC scores associated with poorer performance on SLS, TUG and OC tests. Surprisingly, CMP was not related to performance on any of the clinical balance tests. These results extend past research that has shown a relationship between movement reinvestment and gait performance (Uiga et al., 2020a; Young et al., 2016) and self-presentational concerns and clinical balance performance (Lamarche et al., 2014).

The second objective of this thesis was to investigate whether CMP and MSC explained variation in balance performance over and above that of age, sex, fall status, health status, and balance confidence. It was expected that CMP and MSC would assist in providing additional information to predict performance on clinical balance tests. The results of the hierarchical linear regressions partially supported this hypothesis. CMP and MSC did provide unique information in explaining variation over and above that of the other demographic and balance confidence measures for OC performance but not for the other three clinical balance tests examined. MSC but not CMP emerged as a significant predictor with age and ABC for OC performance. This result may be due to the nature of the balance test that required speed and accuracy with individuals with a greater tendency to be self-conscious of their movements influencing their performance in this evaluative setting. This result is in line with research that has shown greater self-presentational concerns explaining worse clinical balance performance over and above that of other predictors including balance confidence (Lamarche et al., 2014). In general, as expected, age and ABC were strong predictors for clinical balance test performance. If feasible, the measurement of trait movement reinvestment may provide additional information to explain variation in balance performance especially for challenging tasks like navigating an obstacle course.

5.1. Relationship between movement reinvestment and falls and health status

The results of this thesis did not support a significant relationship between movement reinvestment and fall status. Follow-up group comparisons between fallers and non-fallers also did not reveal differences in CMP or MSC, confirming the lack of a relationship. A relationship between movement reinvestment and falls has been established in the literature. Research has shown that there is a significant difference in movement reinvestment between older adult fallers compared to non-fallers (Wong et al., 2008; Wong et al., 2009) with fallers having increased CMP and MSC compared to non-fallers. Research has also shown that only CMP was higher in those that had fallen in the past compared to those that had not fallen (Musculus et al., 2021). Based on this research, the lack of a relationship between movement reinvestment and falls was surprising. One explanation for this finding may be the age cut-off of 55 years and above that was set for the current thesis. In the other studies that reported significant differences in movement reinvestment scores between fallers and non-fallers, a cut-off of 65 years of age and above was used and the mean ages in these studies were older (i.e., mean age ranged from 74.6 to 84.4 years; Musculus et al., 2021; Wong et al., 2008, Wong et al., 2009). Another explanation may be how fall status was obtained. In the current thesis, participants were asked to report the number of falls within the past year with any reported falls identifying the participant as a faller. In the other studies, older adults had to identify when, where, and why they had fallen to be classified as fallers with no set time frame applied (Musculus et al., 2021; Wong et al., 2008;) or they had to be considered repeat fallers (i.e., 2 or more falls; Wong et al., 2009). In combination with these factors, it is also possible that sample size contributed to the different results between studies. The current thesis had a larger sample size (N=243) compared to the previous studies (i.e., 35 fallers compared to 19 non-fallers, Wong et al., 2008; 15 fallers compared to 15 non-fallers, Wong et al., 2009; 17 fallers compared to 4 non-fallers, Musculus et al., 2021).

The results of the thesis did show a relationship between movement reinvestment and health status. Individuals who reported higher CMP or MSC scores were more likely to self-report a chronic condition. For the purpose of this thesis, a chronic condition was considered diabetes, osteoporosis, or knee/hip replacement (beyond 2 years prior to testing). This evidence is in line with expectations as it suggests that there may be greater attempts to consciously attend to and control one's movements and to be self-conscious about how one is presenting themselves when moving in those reporting these conditions. This is similar to previous research that showed differences in movement reinvestment (i.e., higher CMP and MSC) between people with Parkinson's Disease and healthy controls (Masters et al., 2007) and people with stroke and healthy controls (Orrell et al., 2009). The results of the current study also support previous research findings that individuals reporting knee pain have higher CMP scores compared to those that do not (Selfe et al., 2015) and that older individuals with total knee replacement have higher CMP and MSC scores compared to healthy controls (Street et al., 2018). The greater tendency to reinvest in movement for those with chronic conditions in this thesis justified the inclusion of health status as a predictor variable in the hierarchical linear regressions.

5.2. Relationship between movement reinvestment and balance confidence

The results of this thesis showed a significant relationship between CMP and balance confidence. Individuals who had a greater tendency to consciously attend to and control their movements were more likely to have lower ABC scores. The results also showed a significant association between MSC and balance confidence. Individuals who were more self-conscious of their movements were more likely to exhibit lower ABC scores. These results partially support work that showed a relationship between movement reinvestment and concerns for falling. Lower fall-related efficacy, as assessed using the Chinese version of the Falls Efficacy Scale-International, was observed in a group of 14 individuals reporting low movement reinvestment compared to group of 14 individuals reporting high movement reinvestment (Chu & Wong, 2019). However, no relationship between movement reinvestment, as assessed with the Chinese version of the MSRS, and balance confidence, as assessed with the Chinese version of the ABC scale, has been reported in 92 older adults (Uiga et al., 2020a). In this work by Uiga and colleagues, the total MSRS score was used, and movement reinvestment was not significantly correlated with balance confidence ($r = -0.12$; $p > .05$). For comparison, the total MSRS score was significantly correlated with ABC ($r = -.318$, $p < .001$) in this thesis. Thus, the results of this thesis provide new evidence of a relationship between both dimensions of movement reinvestment and balance confidence. It also appears that the relationship between MSC and balance confidence is stronger ($r = -.356$) compared to that between CMP and balance confidence ($r = -.224$).

5.3. Relationship between movement reinvestment and clinical balance performance

The results of this thesis showed significant linear relationships between MSC and clinical balance test performance. There were significant correlations observed between MSC and outcome measures on three of the four clinical balance tests examined. Higher self-consciousness about presentation while moving was associated with poorer clinical balance performance including longer SLS durations, longer TUG durations and higher OC (duration + errors) scores. Individuals with a greater tendency to be self-conscious of their movements in this evaluative setting (i.e., balance assessment with the expectation of joining an exercise and balance training program) may have influenced their performance on these clinical balance tests. Supporting this finding, Lamarche and colleagues showed significant relationships between social anxiety and self-presentational concerns and TUG durations in older women, with higher social anxiety and more self-presentational concerns related to longer TUG durations (Lamarche et al., 2014).

No significant relationships were observed between CMP and clinical balance outcomes for any of the four tests. This result was surprising considering past research has identified CMP as a predictor of falls and poor balance outcomes. For example, older adults who were asked questions during an adaptive gait task and stopped walking while talking had higher CMP scores compared to those who did not stop walking while talking (Young et al., 2016). Musculus and colleagues showed that CMP was a predictor of future fall risk suggesting that falls and stumbles may result from consciously attending to and controlling one's movements (Musculus et al., 2021). Studies have also shown a relationship between overall movement reinvestment score and specific measures of gait on a stepping accuracy task in older adults (Uiga et al., 2020a). In addition, other studies have shown that movement reinvestment alters the allocation of attention when walking in older adults with those who report higher levels of trait reinvestment more accurate in answering questions concerning their body awareness and less accurate when answering questions about the external environment (Uiga et al., 2015). However, there are studies that have shown no relationship between movement reinvestment and stance and gait outcome measures in older adults (de Melker Worms et al., 2017; Uiga et al., 2018; Uiga et al., 2020b). Furthermore, a recent meta-analysis reported that trait movement reinvestment measures, including overall MSRS, CMP and MSC scores, were not associated with motor performance including performance on balance and gait tasks (Tang et al., 2023). This result did not support the authors' hypothesis that the direction of the relationship between movement reinvestment and motor performance would be negative (Tang et al., 2023).

Thus, the results of this thesis support a relationship between MSC but not CMP and clinical balance performance in this group of adults 55 years of age and older. By establishing this relationship between movement reinvestment and clinical balance outcomes, insight into how movement reinvestment, specifically being self-conscious about movement, can potentially confound balance assessment was gained.

5.4. Movement reinvestment as a predictor of clinical balance performance

An accurate assessment of balance is critical in older adults as it can detect fall risk, identify mobility issues, and provide direction for balance training programs. As such it was important to explore the unique variance in clinical balance performance explained by CMP and MSC. To accomplish this objective, a hierarchical linear regression approach was used. The first model included age, sex, fall status, health status, and balance confidence as predictor or independent variables. The second model added CMP and MSC to determine the unique variance in clinical balance performance explained by these predictors after controlling for the other demographic variables and balance confidence. Four regressions were conducted with SLS duration, TUG duration, FR distance, and OC (duration + error) score as the dependent variables.

A combination of demographic variables and balance confidence scores significantly explained variation in clinical balance performance for all four tests examined. As expected, the strongest predictors that emerged were age and ABC score. Age was a significant predictor in both the first and second models for all four clinical balance tests. Based on the semi-partial correlations, the unique variation in clinical balance performance explained by age ranged from 4.20 % to 12.32 % across these tests. This result supports previous research showing age-related changes in balance and gait control across a wide variety of postural tasks including clinical balance tests (Maki & McIlroy, 1996; Mancini & Horak, 2010; Osoba et al., 2019; Sturnieks et al., 2008). ABC was a significant predictor in both the first and second models for SLS, TUG, and OC performance. Based on the semi-partial correlations, the unique variation explained by ABC ranged from 2.86 % to 10.69 % across these tests. This result supports previous research that has shown a relationship between concerns related to falling including balance confidence and performance on clinical balance tests (Schepens et al., 2012). For example, older adults with lower ABC scores have longer TUG durations (Cho et al., 2004; Schepens et al., 2010), shorter SLS times (Cho et al., 2004) and shorter FR distances (Schepens et al., 2010). Sex, fall status and health status were not identified as significant predictors in the first or second model for any of the clinical balance tests.

The results of the hierarchical linear regressions also showed that movement reinvestment did not contribute to explaining variation in clinical balance performance for three of the four tests. This included the regressions run with SLS duration, TUG duration, and FR distance as dependent measures. More specifically, CMP and MSC were not identified as significant predictors for SLS duration or FR distance and there was no significant change in R^2 between the first and second model. MSC was identified as a significant predictor for TUG duration but the change in R^2 between the two models was not significant (p = .07). Thus, these results show that MSC and CMP did not contribute to explaining variance in clinical balance performance for the SLS, TUG or FR tests over and above that of age, sex, fall status, health status and balance confidence.

MSC was identified as a significant predictor for OC (duration + error) score and the change in R^2 between the first and second models was significant. Upon examination of the semi-partial correlation, MSC uniquely explained 1.8 % of the variation in OC score with higher MSC scores associated with poorer performance on the obstacle course. The results of this regression showed that movement reinvestment and specifically MSC did contribute to explaining variation in OC performance after controlling for other demographic variables and balance confidence. Poorer performance on the obstacle course in individuals with a tendency to be more self-consciousness about their movements may have resulted from the nature of the balance test as the obstacle course test was a complex adaptive gait task that had both speed and accuracy requirements (Tang et al., 2023). Furthermore, self presentational concerns have been shown to predict poorer performance albeit on a less challenging adaptive gait task (i.e., TUG test) over and above other measures including balance confidence (Lamarche et al., 2014).

Although MSC was associated with changes in SLS and TUG duration (as observed in the correlation analyses), it is possible that it did not provide unique ability to predict clinical balance performance beyond age and balance confidence for these tests. This view may be supported by the observed linear relationship between MSC and ABC. MSC did emerge as a significant predictor of OC performance over and above that of other demographic measures and balance confidence. It is possible that this type of test with duration and errors as outcome measures including a variety of discrete postural tasks may have prompted more opportunities to be self-conscious when moving carried out over a longer period. This type of adaptive gait test might be more sensitive to identify relationships between trait movement reinvestment and balance and gait performance.

Based on the results of this thesis, a recommendation to include a measure evaluating general concerns related to falling like the ABC scale in clinical balance assessment protocols was confirmed (Ellmers et al., 2023). A recommendation for the inclusion of a trait movement reinvestment measure is not as clear. It is possible that trait movement reinvestment levels may confound performance on certain balance tests especially those that are adaptive gait tasks like the obstacle course and possibly the TUG test. It is possible that a state assessment of CMP and MSC taken after the completion of each clinical balance test may provide added insight into whether movement reinvestment can confound clinical balance performance. Recent work has suggested that state measures of movement reinvestment or more movement specific trait measures may be more appropriate than the MSRS in answering this question (Tang et al., 2023; Young et al., 2020). This approach has also been used when assessing state changes in movement reinvestment and balance under threatening and non-threatening conditions (e.g., Huffman et al., 2009). Future work using these measures and experimental manipulations may assist in strengthening the recommendation to consider movement reinvestment measures as part of balance assessment protocols.

5.5. Limitations

There are several limitations to consider when interpreting the results of this thesis. One limitation is that the results are generalizable only to adults 55 years of age or older, high functioning, living in the community, and cleared for and having the expectation of joining an exercise and balance training program. In addition, participants with certain self-reported chronic conditions such as diabetes, osteoporosis, and knee/hip replacements were included in the thesis participant pool to maintain sample size. As the inclusion of these participants had the potential to influence the results, health status was addressed in the statistical analysis. It is possible that the results of this thesis may differ for an older and lower functioning participant group. A second limitation is the use of a trait movement reinvestment tool (i.e., MSRS). Recent work has suggested that trait movement reinvestment does not necessarily alter balance rather it has the potential to make changes depending on the movement situation or state (Tang et al., 2023). For future work, a state version of a CMP and MSC questionnaire may provide better insight into clinical balance performance. A third limitation is the clinical balance tests and the outcome measures examined in this thesis may have limited the results. It is possible that trait movement reinvestment may have been able to explain added variation in performance for other clinical balance tests, especially tests that include more challenging postural tasks (e.g., Dynamic Gait Index), or when using quantitative posturography measures (e.g., centre of pressure from a force plate). A fourth limitation is that causal relationships between variables could not be determined. Future work should examine changes in movement reinvestment under anxiety manipulations (e.g., Geh et al., 2011), which have been shown to better reveal the confounding effects of movement reinvestment on balance and gait control (Tang et al., 2023).

5.6. Conclusion

While CMP, or attempts to consciously attend to and control movements, has been shown to be a predictor of fall status (Wong et al., 2008), future fall risk (Musculus et al., 2021) and negative changes in gait performance (Uiga et al., 2020a; Young et al., 2016), the results of this thesis showed that MSC or greater self consciousness concerning movement style was associated with poorer clinical balance outcomes in healthy, community-living adults over the age of 55 years of age. MSC, as opposed to CMP, may be more of a concern in these individuals due to negative aging stereotypes such as looking unfit or unable to perform balance tasks in the evaluative setting used to collect data for this thesis (Lamarche et al., 2014). The results also showed that movement reinvestment, specifically MSC, provided added insight into performance on a challenging postural task over and above that of other commonly used predictors including age, sex, fall status, health status and balance confidence. The results of this thesis suggest that trait movement reinvestment may be important to consider in clinical balance assessment protocols especially for complex adaptive gait tasks.

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Appendix A: Research Ethics Clearance

Brock University
Office of Research Ethics
Tel: 905-688-5550 ext. 3035
Email: reb@brocku.ca

Health Science Research Ethics Board

Certificate of Ethics Clearance for Human Participant Research

DATE:	4/9/2024		
PRINCIPAL INVESTIGATOR:	ADKIN, Allan - Kinesiology		
FILE:	23-293 - ADKIN		
TYPE:	Masters Thesis/Project	STUDENT: SUPERVISOR:	Kaitlyn McKay

TITLE: The relationship between movement reinvestment, balance confidence, and clinical balance performance in healthy older adults

ETHICS CLEARANCE GRANTED

Type of Clearance: NEW Expiry Date: 4/1/2025

The Brock University Health Science Research Ethics Board has reviewed the above named research proposal and considers the procedures, as described by the applicant, to conform to the University's ethical standards and the Tri-Council Policy Statement. Clearance granted from **4/9/2024** to **4/1/2025**.

The Tri-Council Policy Statement requires that ongoing research be monitored by, at a minimum, an annual report. Should your project extend beyond the expiry date, you are required to submit a Renewal form before 4/1/2025. Continued clearance is contingent on timely submission of reports.

To comply with the Tri-Council Policy Statement, you must also submit a final report upon completion of your project. All report forms can be found on the Office of Research Ethics web page at https://brocku.ca/research-at-brock/office-of-research-services/research-ethics-office/#application-forms

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

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

We wish you success with your research.

Approved:

Stephen Cheung, Chair
Health Science Research Ethics Board

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

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

Appendix B: Demographic and Health Questionnaire

Age: __________

Gender (please circle): **Male** **Female**

Height: __________

Weight: _________

How many times have you fallen in the past year? _______

Please list the approximate date of the fall, the medical treatment required, and the reason you fell in each case (e.g., uneven surface, going down stairs, etc.).

____

____

Have you ever been diagnosed as having any of the following conditions? Please check all that apply.

	Yes	If yes, approximate year of onset?
Heart attack	☐	____________
Angina (chest pain)	☐	____________
Transient ischemic attack	☐	____________
Stroke	☐	____________
Respiratory problems	☐	____________
Diabetes	☐	____________
Cancer	☐	____________
Parkinson's disease	☐	____________
Multiple sclerosis	☐	____________
Other neurological disorders	☐	____________
Rheumatoid Arthritis	☐	____________
Other arthritis	☐	____________
Fracture (< 8 weeks)	☐	____________
Osteoporosis	☐	____________
Joint Replacement	☐	____________
Any other problem (e.g., sensory) that interfere with your balance, walking, or ability to do PA?	☐	____________

Do you wear corrective lenses? **Yes** **No**

Do you use an assistive device for walking? **Yes** **No**

Do you currently smoke? **Yes** **No**

Please list the medications you are currently taking and why.

____

Appendix C: Activities-specific Balance Confidence (ABC) Scale

0____10____20____30____40____50____60____70____80____90____100

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

Please use the above scale to rate the <u>amount of confidence</u> you have in <u>avoiding a fall</u> when you have to:

Walk around house	___________
Walk up/down stairs	___________
Pick up object from floor	___________
Reach forward	___________
Reach forward on tiptoes	___________
Stand on chair to reach object	___________
Sweep the floor	___________
Walk outside to nearby car	___________
Get in/out of car	___________
Walk across parking lot	___________
Walk up/down ramp	___________
Walk in crowded mall	___________
Walk in crowd and bumped in to	___________
Ride escalator holding rail	___________
Ride escalator not holding rail	___________
Walk on icy sidewalk	___________

Appendix D: Movement-Specific Reinestment Scale

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

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

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

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

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

3. I reflect about my movement a lot.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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