EVALUATION OF THE COMMUNITY BALANCE AND MOBILITY SCALE IN A CARDIAC REHABILITATION POPULATION

by

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In dedication to:

My family, without whom none of this would have been possible

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ABSTRACT

Recent research indicates the need for a functional balance assessment in cardiac rehabilitation (CR) programs. One assessment technique that may be appropriate is the Community Balance and Mobility Scale (CBMS). The purpose of this study was to investigate psychometric properties of the CBMS when testing patients with cardiovascular disease (CVD). Thirty-one participants from community CR programs were recruited to perform the CBMS and measures of computerized dynamic posturography. Convergent validities between the measures were investigated using correlation coefficients, and floor and ceiling effects of the CBMS were analysed. The results indicated that the CBMS was moderately correlated with all computerized posturography variables, with no floor or ceiling effects present. Analysis of posturography results indicated that CR patients have decreased movement characteristics in the anterior and posterior directions. These findings indicate that the CBMS is a suitable tool to assess and monitor balance in a CR population.

LIST OF ABBREVIATIONS USED

CVD:	Cardiovascular disease
CR:	Cardiac rehabilitation
CBMS:	Community Balance and Mobility Scale
LOS:	Limits of Stability Test
mSOT:	Modified Sensory Organization Test
BBS:	Berg Balance Scale
TUG:	Time Up & Go Test
CoM:	Centre of mass
CoP:	Centre of pressure
DC:	Directional control
MDC:	Minimum detectable change
ME:	Maximum excursion
EPE:	End point excursion
RT:	Reaction time
MV:	Movement velocity
ANOVA:	Analysis of variance
BMI:	Body mass index

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CHAPTER 1: INTRODUCTION

Balance is a complex skill that underlies the performance of most physical activities. Balance can be defined as the ability to maintain posture and perform smooth coordinated movements in static and dynamic situations. Not surprisingly, balance also can have a significant impact on an individual's ability to perform physical activity and exercise. Research has shown that individuals with decreased balance perform significantly less physical activity and exercise in their daily lives than those with adequate balance (Alzahrani, Dean, Ada, Dorsch, & Canning, 2012). It has been suggested that this is due to a lack of confidence in their physical capabilities, which often leads to exercise avoidance and increased sedentary behaviours (Vellas, Cayla, Bocquet, de Pemille, & Albarede, 1987). Balance impairments also can cause changes to gait and posture that can impact aerobic exercise performance. Individuals with balance impairments have a slower and shorter gait cycle, leading to a significant reduction in the speed of their aerobic activities (Huang et al., 2010). Together, these limitations can significantly impact an individual's ability to perform physical activities (walking, stepping etc.). Thus, balance limitations should be taken into account when prescribing aerobic exercise.

Cardiac rehabilitation (CR) programs prescribe structured physical activity and exercise to patients with cardiovascular disease (CVD). Current CR guidelines recommend mild to moderate intensity aerobic exercise (walking, stepping, stationary cycling) as well as basic resistance training for major muscle groups (Balady et al., 2007). When performed consistently, these types of activities have been shown to lead to improvements in CVD risk factors such as hypertension, body composition, lipid profile and blood glucose levels

(Dalleck et al., 2009). However, these positive changes are dependent on the patient's ability to properly perform the prescribed exercises. Unfortunately, factors such as balance can negatively impact a patient's performance during therapeutic exercise. This may limit improvements in CVD risk factors and thus negatively affect the outcome of the CR program.

Despite their prevalence in many other clinical populations, the occurrence and impact of balance impairments in a cardiac population have gone largely undiscussed in the previous literature. However, recent research conducted by Goel et al., (2010), found that 58% of patients participating in an American CR program had decreased levels of postural balance. Additionally, a preliminary study found that patients participating in a Canadian CR program had significantly lower levels of balance than would be expected for their age (Martelli, Giacomantonio, & Grandy, 2011). Although the underlying mechanism behind this deficit is still unclear, many CVD risk factors such as aging, obesity, physical inactivity, diabetes, and hypertension all have been associated with limitations to postural balance (Balogun, Akindele, Nihinlola, & Marzouk, 1994; Di Iorio et al., 2009; Handrigan, Corbeil, Simoneau, & Teasdale, 2010). This information suggests that CVD patients may be predisposed to balance impairments due to the effect of CVD risk factors on balance control. This may negatively impact their physical activity and exercise performance in CR and compromise optimal management of the disease. It is therefore important to assess balance in CR patients in order to optimally prescribe therapeutic exercise.

To assess balance in a clinical setting health professionals often use a field test; an assessment designed to evaluate an individual's ability to perform different functional tasks without the need for excess laboratory personnel or equipment. There are many field assessments that have been developed for measuring balance in clinical populations, such as the Berg Balance Scale (BBS) (Berg, Wood-Dauphinee, Williams, & Maki, 1995) Timed Up & Go Test (TUG) (Podsiadlo, & Richardson, 1991) and Tinetti Balance Scale (Tinetti, 1986). These, and other field assessments require participants to perform various functional tasks to assess their ability to function outside of a clinical setting. However, these assessments typically are designed for patients with significant balance impairments, such as those recovering from stroke or traumatic brain injury, and may not be suitable for individuals with only mild to moderate balance impairments (Blum & Korner-Bitensky, 2008; Hiengkaew, Jitaree, & Chaiyawat, 2012). Patients participating in CR programs are likely to present a wide variety of balance capabilities due to their wide age range and varying effects and severity of the disease. This suggests that balance impairments in this population could range anywhere from mild to severe. Thus, field assessments used to measure balance in a cardiac population should be appropriate for patients with only mild or moderate balance impairments as well as those that are more severe.

One such field assessment that may be appropriate is the Community Balance and Mobility Scale (CBMS). The CBMS incorporates challenging functional tasks often performed in daily living, to assess individuals with a wide range of balance capabilities. Despite being originally developed for patients recovering from a traumatic brain injury (Howe, Inness, Venturini, Williams, & Verrier, 2006), the CBMS also has been shown to be appropriate for individuals with less severe impairments. Rocque et al., (2006) examined the usefulness of the CBMS for testing higher functioning individuals by assessing 90 healthy middle-aged adults. The results showed that only 3% of participants were able to score the maximum on the test, indicating its suitability for individuals with only mild to moderate balance impairments (Rocque et al., 2006). These results suggest that the CBMS may be an appropriate field assessment for measuring balance in patients with CVD. However, the psychometric properties of the CBMS in a cardiac population have not yet been assessed.

The purpose of the present study was to investigate psychometric properties of the CBMS in a clinical population participating in CR. The specific objectives were (1) to investigate the floor and ceiling effects of the CBMS when administered to CR patients, and (2) to test the convergent validity of the CBMS with the Limits of Stability Test (LOS) and Modified Sensory Organization Test (mSOT). The LOS and mSOT were performed using the Neurocom Pro Balance Master, a computerized posturography device used to measure balance and postural control. It was hypothesized that the CBMS would not exhibit any floor or ceiling effects when being administered to CR patients. Additionally, it was expected that the CBMS would demonstrate strong convergent validity with outcome measures from the LOS and mSOT.

CHAPTER 2: LITERATURE REVIEW

Balance is a complex interaction of the body's sensory systems that is used to maintain and adjust posture as well as regulate movement. The visual, somatosensory and vestibular systems all provide sensory information to the central nervous system (Grace Gaerlan, Alpert, Cross, Louis, & Kowalski, 2012). Once this information has been integrated and interpreted, a response signal is sent from the nervous system to the required musculature to execute a motor command. While this interaction of sensory information is essential for maintaining balance in both static and dynamic situations, the process is more complex during dynamic situations where the body or its segments are in motion (Takeshima et al., 2013). Dynamic aspects of balance require the same sensory and muscular processes with the added difficulty of producing and regulating movement. During dynamic situations, voluntary and involuntary perturbations can occur which need to be compensated for in order maintain balance. In responding to these perturbations, balance can be described as either anticipatory, or reactive. Anticipatory balance requires an individual to make compensatory postural adjustments to maintain balance during a planned dynamic task (Jacobs & Horak, 2007). For example, in order for an individual to reach out and pick up an object, muscular contractions must occur to compensate for the weight shifting and limb movement associated with the activity. In contrast, reactive balance typically occurs in response to an external perturbation such as a slip or trip (Hu & Qu, 2013). These responses typically involve large rapid motor actions at the arms, legs and trunk to regain balance and prevent a fall (Hu & Qu, 2013). Thus, despite being regulated by the same sensory and muscular processes, there are many different aspects of balance that are important for independent function.

For the purposes of this thesis, balance is defined as the ability to maintain upright posture during static and dynamic situations, by producing smooth coordinated movements. However, balance also can be described in relation to an individual's centre of mass (CoM), or centre of pressure (CoP). An individual's CoM can be defined as the point about which all their mass is considered to be concentrated and thus the point at which gravity exerts its force on the body (Gordon & Robertson, 2004). In order to maintain balance, an individual's CoM must remain within their base of support; the area between body segments contacting the support surface (Lugade, Lin, & Chou, 2011). In contrast, the CoP can be defined as the point of action of the sum of all forces exerted by the body and its segments on a support surface (Neurocom International, n.d.). As the CoM shifts during movement, the CoP must be able to quickly adjust to a position beyond the CoM to accelerate it in the opposite direction and keep it within the base of support (Lugade et al., 2011; Ruhe, Fejer, & Walker, 2011). This can be measured in laboratory settings using computerized dynamic posturography assessments. These assessments measure an individual's *postural control* by providing an objective and quantitative analysis of the individuals balance capabilities. By tracking the movement and velocity of the CoP, information can be gained about an individual's ability to control their CoP in various directions around the body. This is referred to as directional control (DC) and is one of the many variables analysed in posturography assessments. Not surprisingly, individuals with better postural control are better able to perform activities of daily living, and report less physical activity restrictions in their daily lives (Hayashi et al., 2012). Therefore by measuring these biomechanical aspects of postural control, researchers can gain information on an individual’s balance and their ability to function independently in daily life.

In comparison, balance can be described according to its relationship with an individual’s physical capabilities and functionality. Many studies examine patients’ functional balance, which describes their ability to perform functional tasks associated with daily living. Functional balance typically is measured using field assessments such as the BBS, TUG and the CBMS (Hasselgren, Olsson, & Nyberg, 2011; Howe et al., 2006; Wall, Bell, Campbell, & Davis, 2000). Field assessments are typically preferred in clinical settings due to potential time restrictions, smaller available space, and minimal equipment or cost required for the measurements. Furthermore, field assessments provide specific information about an individual’s functional limitations that may be more applicable to a rehabilitation setting. By assessing functional balance, health professionals can gain information about an individual’s physical capabilities and what impact this may have on their ability to participate in the therapeutic exercise prescription.

Recent research suggests that a large proportion of CVD patients participating in CR programs have decreased levels of balance (Goel et al., 2010; Martelli, Giacomantonio & Grandy, 2011). This may negatively impact their ability to participate in prescribed therapeutic exercise, thereby decreasing the efficacy of the CR program. Thus, it is important to assess the balance of CVD patients in order to prescribe an optimal physical activity and exercise program for them. However, to the author’s knowledge no balance assessments have been validated for use in a population with CVD. In order to determine an appropriate balance field assessment for these patients, it is first important to investigate the relationship between balance and CVD.

BALANCE AND CARDIOVASCULAR DISEASE

The relationship between balance and CVD is an area that has not been significantly explored in previous research. However, limited research indicates that patients with CVD also may be at risk for balance impairments. Goel et al., (2010) investigated the prevalence of balance impairments in 284 CR patients in the United States. Balance was measured using common field assessments such as the single leg stance and tandem gait tasks. The results showed that 58% of CR patients had impaired balance compared to age matched normative data, and that this impairment was more prominent with patients above the age of 65 (Goel et al., 2010). This decreased level of functional balance in CR patients is not surprising, considering many CVD risk factors are known to have a negative impact on balance.

Several risk factors for CVD have been linked to decreased balance. To further examine this, Di Iorio et al., (2009) investigated the relationship between balance and CVD risk factors such as smoking, obesity, glucose intolerance, hypertension and cholesterol levels. One hundred and seven patients performed postural stability assessments on a force plate, as well as clinical tests to assess the relationship between balance and the aforementioned CVD risk factors. The results indicated that although no individual risk factor alone appeared to contribute to impaired balance, participants with 3 or more CVD risk factors had significantly impaired balance compared to those with less than 3 or no risk factors (Di Iorio et al., 2009). The authors suggest that the cumulative presence of these CVD risk factors may have a negative impact on sensory systems responsible for balance and postural control. In addition to the effect of CVD risk factors, other studies have demonstrated that single risk factors such as aging, obesity and physical inactivity also can have a negative impact on balance.

AGING

As well as being a non-modifiable risk factor for CVD, aging also is associated with a gradual decline in balance (Akram & McIlroy, 2011; Buckley, Pitsikoulis, Barthelemy, & Hass, 2009; Granacher et al., 2011). While research has identified that balance deficits are common for individuals in their sixties and older (Matheson et al., 1999; Pyykko et al., 1990), recent studies have indicated that balance may begin to decline as early as mid-life. Borah et al., (2007) measured balance in 64 participants in different decades of life. The results showed that significant differences in balance were detected from the fourth decade onwards (Borah et al., 2007). This is consistent with other findings which also have identified initial balance decreases beginning in the forties (Balogun et al., 1994; El Haber et al., 2008).

Additionally, research has shown that balance continues to deteriorate with age. El Haber et al., (2008) investigated age related changes in balance in 212 healthy participants between the ages of 21 and 82. In addition to the initial decrease in mid-life, balance was shown to have a non-linear negative relationship with age (El Haber et al., 2008). This suggests that not only does balance decrease with age, but also the rate of decline increases with age. Thus, individuals who are in their seventh decade are likely to have lower balance, as well as experience a faster decline in balance than individuals in their fifth decade. Previous research has highlighted similar non-linear relationships between lower body strength and aging (Low Choy, Brauer, & Nitz, 2007), which may be an important factor in age related declines in balance.

Overall, these findings indicate that there is an initial decrease in balance beginning in mid-life that accelerates with each decade of life. Since the majority of patients with CVD are above the age of 60 (American Heart Association, 2013; Audelin et al., 2006; Bader et al., 2001), they may already be predisposed to balance impairments. In addition, the presence of other CVD risk factors such as physical inactivity and obesity may lead to further decreases in balance and mobility.

OBESITY

Obesity also is known to be a significant contributor to CVD. Specifically, excess fat accumulation on the trunk is associated with a significantly greater risk of CVD and other chronic diseases (Flint et al., 2010). In addition to an increased CVD risk, many studies have highlighted that individuals who are overweight or obese have a marked impairment in balance compared to those who are of a healthy weight (G. Handrigan et al., 2010; G. A. Handrigan, Corbeil, Simoneau, & Teasdale, 2010). Although there is a negative correlation between body mass index and balance (Greve, Alonso, Bordini, & Camanho, 2007), the location of the adipose tissue also plays an important role. Visceral obesity has been shown to significantly contribute to balance impairments in overweight and obese individuals (Ochi et al., 2010). Specifically, visceral obesity leads to excess weight accumulation on the trunk causing an anterior displacement of the individual's CoM (Wearing, Hennig, Byrne, Steele, & Hills, 2006). This displacement increases the demand on supporting musculature to control the CoM during movement, and increases the risk for a sudden loss of balance (Menegoni et al., 2009).

Obesity also is associated with decreased muscle mass (Ochi et al., 2010). This suggests that overweight/obese individuals may not have enough musculature to compensate for the unnatural placement of their centre of mass, predisposing them to balance impairments. Due to the high occurrence of obesity in conjunction with CVD, many patients participating in CR programs may be predisposed to balance impairments. The impact of these impairments may be exacerbated by physical inactivity and sedentary behaviour, common characteristics associated with both obesity and CVD.

PHYSICAL INACTIVITY

There has been an increasing trend of physical inactivity in patients with CVD over the last several years (Audelin et al., 2006). While the effects of physical inactivity on health and cardiac function are well established (Arsenault et al., 2010), physical inactivity also can have a significant impact on an individual's balance. Huang et al., (1998) followed 4670 healthy individuals above the age of 40 for 5.5 years to determine the relationship between physical activity and functional limitations reported with aging. The results showed that adults who performed more physical activity in their daily lives were less likely to report problems with balance 5 years later (Huang et al., 1998). This suggests that physical activity during mid-life can help prevent balance impairments and functional limitations that occur with aging. In addition, physical activity plays an important role in decreasing one's risk for being overweight or obese which also negatively impacts balance.

In summary, research has shown that many patients participating in CR programs have impaired balance. This is likely due, in part, to the effect of CVD risk factors on postural balance. Specifically, aging, obesity and physical inactivity have all been shown to negatively impact an individual's balance. Since the prevalence of these risk factors is increasing in the Canadian population (Audelin et al., 2006; Statistics Canada, 2011a; Statistics Canada, 2011b), it stands to reason that the incidence of balance impairments in Canadian CR patients also will increase. Therefore, it is important to examine the impact that balance impairments may have on an individual's ability to participate in therapeutic exercise programs, such as those prescribed in CR.

BALANCE AND PHYSICAL ACTIVITY PARTICIPATION

Due to the profound positive effects on an individual's health and cardiac function, physical activity and structured exercise often are considered the cornerstone of many CR programs. Therapeutic exercise programs prescribed in CR consist of moderate intensity aerobic activity, basic resistance training exercises and increasing the patient's daily physical activity volume (Balady et al., 2007). However, balance impairments may limit an individual's ability to perform these activities and negatively affect the therapeutic outcome of the program.

Physical activity is defined as any bodily movement produced by musculature resulting in an increase in energy expenditure (Ceria-Ulep, Tse, & Serafica, 2011). In an early study, Vellas et al., (1987) found that individuals with balance impairments were much less likely to leave their homes, and performed significantly less physical activity in their daily lives compared to age matched individuals with adequate balance (Vellas et al., 1987). A more recent study investigated the relationship between balance and free-living physical activity in 42 participants over the age of 50. Free-living physical activity was defined as any physical activity that individuals were able to perform independently at their own leisure. The results showed that 40% of the variation in individuals' free-living physical activity was accounted for by their level of balance (Alzahrani et al., 2012). These findings suggest that balance deficits can limit an individual's physical activity participation by decreasing the amount of physical activity that they perform in their daily lives. Since many CR programs promote these types of activities of daily living, balance impairments could negatively impact the patient's outcome in the CR program.

In addition, balance deficits also may limit an individual's ability to perform aerobic exercise at a moderate intensity. While research in this area is limited, many studies have indicated that balance deficits can lead to changes in gait patterns that can affect aerobic exercise performance. These individuals often have a significantly slower gait speed and shorter stride length (Espy, Yang, Bhatt, & Pai, 2010), which can affect their ability to perform aerobic exercise. In support of this, Combs et al., (2010) found that when walking on a treadmill, individuals with decreased balance walked slower and were less able to support their own body weight during exercise (Combs et al., 2010). These findings suggest that balance deficits can limit the intensity of aerobic exercise by reducing the speed and increasing the need for support during the activity (Berling, Foster, Gibson, Doberstein, & Porcari, 2006; Manfre et al., 1994). This will decrease the caloric expenditure associated with the activity, and limit improvements in health related fitness. Therefore, balance impairments may negatively impact cardiovascular improvements by limiting aerobic intensity and thus, the cardiac benefit associated with the exercise.

Overall, this information suggests that individuals with balance impairments may be less able to perform moderate intensity aerobic activities, such as walking, stepping or marching. In addition, these individuals are less likely to perform leisure time physical activities. Since these types of activities are a primary component of many CR programs, balance deficits in this population could negatively impact patients' outcome of the therapeutic program. However, if health professionals were able to identify these patients prior to beginning their therapeutic exercise, alternative exercises could be prescribed in order to improve balance, and optimize the patient's performance in the exercise component of the CR program.

TOOLS USED TO ASSESS BALANCE AND MOBILITY

Many field assessments have been developed to assess balance in clinical populations. Typically, these assessments evaluate an individual's performance on various functional activities such as standing up, walking or bending down to determine if there is an underlying balance deficiency. The BBS and TUG, are two of the most common and reliable balance assessments in clinical populations (Blum & Korner-Bitensky, 2008; Gine-Garriga, Guerra, Mari-Dell'Olmo, Martin, & Unnithan, 2009). The BBS measures an individual's performance on 14 different functional tasks to assess their functional balance and risk for falls. It has been shown to have extremely high test-retest reliability, intrarater reliability and interrater reliability with intraclass correlation coefficients from 0.95 - 0.98 (Berg, et al., 1995). In comparison, the TUG measures the time it takes an individual to rise from a chair, walk 3 metres, turn around and return to their starting position. Cut-off times of 10s, 20s and 30s are used to characterize an individual's balance capabilities, with faster times representing better balance. Similar to the BBS, the TUG has extremely high intraclass correlation coefficients (0.91-0.97), indicating excellent intrarater, interrater and test-retest reliabilities in clinical testing (Botolfsen, Helbostad, Moe-Nilssen, & Wall, 2008; Nordin, Rosendahl, & Lundin-Olsson, 2006). However, these tests were designed for patients with significant balance impairments (Berg et al., 1995; Podsiadlo, & Richardson, 1991), and may not be suitable for patients with less severe impairments, such as those with CVD.

Many studies have suggested that the BBS and TUG may not be appropriate for individuals with only mild to moderate balance impairments (Bogle Thorbahn & Newton, 1996; Hiengkaew et al., 2012). Ceiling effects occur when individuals are able to score the maximum, or close to the maximum on any given outcome measure. With respect to balance assessments, ceiling effects represent a lack of suitability for individuals without severe impairments. Several authors have reported ceiling effects for the BBS when assessing stroke and geriatric patients (Blum & Korner-Bitensky, 2008; Bogle Thorbahn & Newton, 1996). Mao et al., (2002) found significant ceiling effects for the BBS when evaluating stroke patients who were between 90 and 180 days past their time of stroke. It was found that 20% of 69 year old stroke patients were able to score the maximum on the BBS (Mao, Hsueh, Tang, Sheu, & Hsieh, 2002). In addition, Bogle found that 11% of elderly individuals with a mean age of 79 were able to score the maximum on the BBS, and 73% of participants were able to score 80% or higher (Bogle Thorbahn & Newton, 1996).

These findings indicate that even individuals with significant functional impairments often are able to score the maximum on the BBS, and may require a more challenging balance assessment. Since the effects of CVD are concentrated on the cardiovascular system and do not primarily lead to neurological or muscular impairments, similar ceiling effects would be expected when using the BBS in a cardiac population. This suggests that the BBS may not be well suited for patients with CVD as these patients may require a more challenging assessment.

Similarly, research suggests that the TUG is not challenging enough to assess balance in individuals with minor to moderate impairments. Individuals with increased muscle strength in their lower body consistently perform better on the TUG than those with impaired lower body strength (Hiengkaew et al., 2012). In addition, it has been suggested that the TUG may actually be a more accurate indicator of lower body musculoskeletal fitness than of functional balance. Hernandez et al., (2010) found significant correlations between the TUG and isometric measures of hip, knee and ankle strength (M. E. Hernandez et al., 2010). This is supported by previous literature which also identified strong associations between the TUG and measures of musculoskeletal fitness in the lower body (McMeeken, Stillman, Story, Kent, & Smith, 1999). Thus, there seems to be an underlying relationship between the TUG and lower body muscular fitness. This may limit its applicability as a functional balance assessment, as there are many other components of functional balance that should be considered in these assessments.

Additionally, research indicates that the TUG may not be sensitive enough to monitor changes in balance in patients with CVD. The minimum detectable change (MDC) represents the amount of change needed in an outcome measure to determine that this was a true change in the measurement, and not due to error or variability. The MDC can be calculated at various confidence intervals to determine the amount of confidence that a true change was observed in the outcome measure. For example, an MDC 95% refers to the minimum change in an outcome measure required to be 95% confident that this was a true change in the outcome, and not due to error or variability. Hiengkaew investigated the MDC 95% of the TUG when assessing individuals with chronic stroke. The results showed that a 7.84s change in time on the TUG was required to be 95% confident this change was not due to individual variation or measurement error (Hiengkaew et al., 2012). This time represents a substantial portion of the test's 10-30 second duration, making it difficult to determine when a true change in balance has occurred, particularly for higher functioning patients who have a faster time. Therefore despite strong psychometric properties and frequent use in clinical populations, the TUG may not be challenging or sensitive enough to accurately assess and monitor balance in patients with CVD.

One field assessment that may be appropriate for testing balance in a cardiac population is the CBMS. The CBMS scores an individual's performance on a variety of challenging tasks to determine their functional balance. The content validity of the CBMS has been well established by structured feedback from physiotherapists and patients, who rated the tasks as moderately to extremely important for functional independence in everyday life (Howe et al., 2006). In addition, the convergent validity has been established with other well-known functional balance assessments such as the BBS and TUG (Knorr, Brouwer, & Garland, 2010), further demonstrating its validity as a field assessment for functional balance. Unlike the BBS and TUG however, the CBMS was designed for individuals with less severe balance impairments, although it is still frequently used for patients recovering from stroke and traumatic brain injury (Inness et al., 2011; Knorr et al., 2010). It also has been shown to be more resistant to ceiling effects than the BBS (Inness et al., 2011). Use of the CBMS in healthy middle aged adults showed that only 3% of individuals were able to score the maximum on the test, indicating a sufficient level of difficulty to prevent ceiling effects in higher functioning patients (Rocque et al., 2006). Furthermore the CBMS also was shown to be resistant to ceiling effects when testing high functioning adolescents recovering from traumatic brain injury (F.V. Wright, Ryan, & Brewer, 2010). In this study, the authors also calculated the MDC 95% of the CBMS at 12 points of a possible 96 (approximately 13% of the maximum score), an appropriate level for testing functional balance in clinical populations (F.V. Wright et al., 2010).

Despite these strong psychometric properties however, no research has been conducted investigating the use of the CBMS in patients with CVD. Tools used to assess balance in a cardiac population should be robust enough to accommodate patients with varying degrees of balance impairments, while still sensitive enough to capture discrete improvements in balance. Since the CBMS was designed for a younger ambulatory population, it is more resistant to ceiling effects and still presents challenges for patients with mild to moderate balance impairments. In addition, its sensitivity to change is similar to those of other functional balance assessments (Hiengkaew et al., 2012). Thus, the CBMS may be the best suited field assessment for measuring balance in patients with CVD. However, research is still required to directly investigate its use in this population before it can be recommended for use in CR programs.

NEUROCOM PRO BALANCE MASTER

The Neurocom Pro Balance Masters is a computerized dynamic posturography device that monitors the movement of an individual's CoP during various weight shifting tasks. The device consists of a dual force plate mounted on transducers in the middle of a large safety upright. A visual feedback screen is mounted at eye-level for individuals to monitor the movement of the CoP and make adjustments as needed. This system is connected to a personal computer with proprietary software to analyse the results of the assessments. Various tests can then be performed, such as the LOS and mSOT, to provide information about an individual's balance capabilities.

The LOS as performed on the Neurocom Pro Balance Master has been shown to be more reliable than other computerized dynamic posturography devices (Pickerill & Harter, 2011). In addition, the LOS has been shown to be a useful balance assessment in both clinical and healthy populations (Grace Gaerlan et al., 2012; Liston, & Brower, 1996). Pickerill and Harter (2011), found high test-retest reliability of the LOS when administering the assessment to healthy individuals in their mid-twenties. Similar findings also have been reported when administering the LOS to older adults with a history of falling (Clark & Rose, 2001). In addition, Liston and Brower (1996) compared the LOS to the BBS and gait velocity in patients recovering from stroke. The results showed high test-retest reliability of the LOS as performed on the Neurocom, as well as strong concurrent validity with both the BBS and gait velocity.

In comparison, the mSOT has not been as extensively evaluated. However, limited research also supports its use in clinical and elderly populations. Ford-Smith et al., (1995) found high test-retest reliability of the mSOT when administered to individuals above the age of 65 (Ford-Smith, Wyman, Elswick, Fernandez, & Newton, 1995). In addition, similar results have been reported when administering the mSOT in an elderly population recovering from a lower body amputation (Jayakaran, Johnson & Sullivan, 2011). These authors concluded that the mSOT is an appropriate measure for assessing and monitoring balance impairments in clinical populations.

These findings indicate the strong reliability and validity of computerized dynamic posturorgaphy measures performed on the Neurocom Pro Balance Master. Despite these findings however, the significant cost and space requirement associated with the device limit its use in clinical populations, such as CR. Since field assessments are more appropriate for a rehabilitation setting, it is therefore important to determine the relationship between posturography measures performed on the Neurocom Pro Balance Master and a suitable field assessment such as the CBMS, to further demonstrate its validity in a cardiac population.

CONCLUSION

In summary, balance deficits have been reported in many patients participating in CR programs. This is likely due to the similarities in risk factors between CVD and balance deficits. These deficits can have a negative impact on the CR process by limiting a patient's ability to properly perform the prescribed therapeutic exercise program. Patients with balance impairments may in fact, require an alternative exercise prescription in order to optimize their performance in CR programs. Therefore, it is important to identify CVD patients with decreased balance in order to provide them with optimal therapeutic exercise programs. While several field assessments for balance have been developed for clinical populations, ceiling effects may limit their applicability to individuals with only mild to moderate balance impairments, such as those in CR. The CBMS is a valid and reliable field assessment that is thought to be challenging and sensitive enough to accurately assess and monitor balance in patients with CVD. However, no research has been done examining its use in this population. Therefore this study will investigate the convergent validity between the CBMS and computerized posturography measures performed on the Neurocom Pro Balance Master, in individuals with CVD. The presence of any floor or ceiling effects of the CBMS also will be examined to help determine its applicability to this population. The findings of this study can be used to help identify a tool to assess and monitor the balance of patients participating in CR programs.

CHAPTER 3: METHODS

PARTICIPANTS

Thirty-one participants were recruited from community and clinical CR programs. Inclusion criteria for the study were: a minimum 18 years of age, a diagnosis of CVD or high risk for CVD and current participation in a CR program. Individuals were excluded if they had suffered a stroke within the past 6 months, or had comorbidities known to negatively impact balance (e.g. diabetic neuropathy, Parkinson's disease, multiple sclerosis, Meniere's disease or other limiting neurological or musculoskeletal conditions). Individuals who had suffered any musculoskeletal injury within the past 3 months that could affect their ability to perform physical activity (such as a strain, sprain or fracture) or those who reported or experienced anxiety with the testing procedure due to mood or anxiety disorders also were excluded from the study. This study was approved by the Capital Health Research Ethics Board.

PROCEDURE

Participants were recruited from clinical and community-based CR programs through the use of a verbal presentation, and recruitment flyers displayed at program sites. Potential participants were addressed as a group following a CR session and given consent forms describing the nature of the study, as well as the possible risks and benefits of participating. Interested parties were encouraged to take the consent form home to review. The researcher returned to the following rehabilitation session to follow up and individually review the consent form with those individuals that were interested. Before obtaining informed consent the individual was asked to tell the researcher the purpose, risks, and benefits of participating in the study to ensure all participants understood the informed consent process. Any individual who was unable to answer these questions was deemed ineligible to provide informed consent and was excluded from the study. Once informed consent was obtained, the individual completed a health screening questionnaire to determine if they were eligible to participate in the study. Eligible participants then scheduled an appointment with the researcher to perform three balance assessments at the School of Physiotherapy, Dalhousie University. Participants were instructed to wear flat soled athletic footwear (not boots, high-heels, sandals, etc.), comfortable clothing and refrain from any alcohol consumption 6 hours prior to their testing appointment. All participants were contacted 24 hours prior to their testing session to remind them of their appointment.

The testing session began with the researcher manually measuring the participant's height, weight, heart rate and blood pressure. Participants were then asked to complete the Godin Leisure Time Physical Activity Questionnaire. Next, participants performed the CBMS, the LOS and mSOT in a randomized order according to a web based random number generator. The LOS and mSOT were both performed using the Neurocom Pro Balance Master, a computerized dynamic posturography device. The protocol for each assessment is described in detail in the following section.

BALANCE MEASURES

COMMUNITY BALANCE AND MOBILITY SCALE (CBMS)

The CBMS evaluates functional balance by assessing participants' performance on 13 tasks (6 of which are performed bilaterally) designed to represent community-dwelling independent living. All tasks target dynamic aspects of balance (with the exception of Task 1), and require the participant to make anticipatory postural adjustments as they perform a variety of functional activities. Tasks are scored on a scale of 0-5 (0 being unable to perform, 5 being able to perform in a smooth and coordinated manner). Tasks 1-11 are performed on an 8m track outlined on the floor using coloured tape (Figure 1). The track is used to determine foot placement during certain tasks, and as a reference to indicate whether or not the participant maintains a straight walking course during others. Tasks 12 and 13 are performed on a set of standard rise steps. Scores on all tasks are summed for an overall CBMS score out of 96 (an extra point may be awarded for Task 12). Two spotters were present during all tasks performed, to minimize the chances of a fall during the assessment. An individual description of each task is provided in Table 1. Previous unpublished research (Appendix E) has shown that there is a high level of agreement between expert and novice testers administering the CBMS in a CR population. Thus, the researcher (novice) was able to accurately administer the CBMS.

Table 1: Task description and scoring for the Community Balance and Mobility Scale

CBMS Task	Description	Bi/Unilateral	Scored out of
1. Unilateral Stance	Stand on one leg and look straight ahead for as long as possible (maximum 45 seconds). Completed for both left and right legs.	Bilateral	10
2. Tandem Walking	Walk along the line, front heel touching back toes. Maximum of 7 steps.		5
3. Tandem Pivot	From a tandem walking position, lift heels off the ground and pivot 180° to face the opposite direction.		5
4. Lateral Foot Scooting	Standing on one leg, alternately pivot from heel to toe of that foot while moving laterally for a maximum of 40cm. Performed with both left and right legs.	Bilateral	10
5. Hopping Forward	Standing on one leg, hop twice to cross the 1m mark. Performed with both left and right legs.	Bilateral	10
6. Crouch and Walk	Walk along the line and without stopping crouch to pick up the bean bag at the 2m mark. Performed on the side of the participant's dominant hand.		5
7. Lateral Dodging	Facing the track, move laterally by repeatedly crossing one leg over the other. Switch directions on command. Performed twice in each direction (2 cycles).		5
8. Walking and Looking	Walk along the track and look at the visual target when instructed, without breaking forward momentum. Performed looking in both directions.	Bilateral	10
9. Running with a Controlled Stop	Run as fast as possible to the end of the track and stop with toes touching the end line.		5
10. Forward to Backward Walking	Walk forwards to the halfway mark, turn around and continue to walk backwards to the end of the track.		5
11. Walk, Look and Carry	Walk along the track carrying two 7.5lb grocery bags. Look at the visual target when instructed without breaking forward momentum. Performed once looking in each direction.	Bilateral	10
12. Descending Stairs	Descend a minimum of 8 stairs, without using the handrail if possible. If completed successfully (5/5), descend the stairs carrying a 2lb weighted laundry basket (performed at the instructor's discretion).		6
13. Step-Ups	Step up and down one step as quickly as possible, using a right-left-up-right-left-down pattern. Performed twice, leading once with each leg.	Bilateral	10

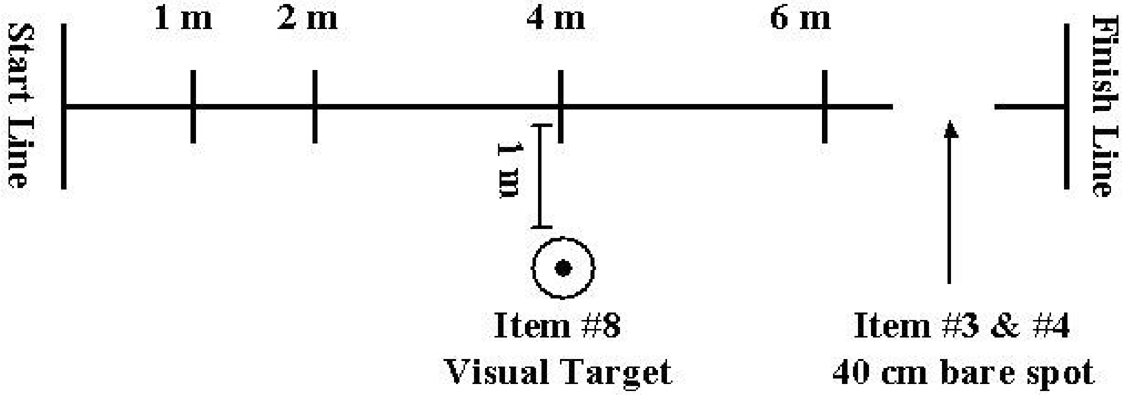

Figure 1: Community Balance and Mobility Scale track (Toronto Rehabilitation, 1998)

NEUROCOM PRO BALANCE MASTER

The Neurocom Pro Balance Master is a computerized dynamic posturography device that measures the forces exerted by the participant's lower body during various weight shifting tasks. Anterior and posterior tilting of the force plate also can be used to simulate balance disruptions in these directions. A visual feedback screen was provided at eye level for the participant to track the movement of their CoP and make postural adjustments as necessary. Before beginning the tests, the participants were asked to remove their shoes and socks. Next, participants were fitted with a safety harness (small, medium or large), which was then secured to an overhead support (Figure 2A). The safety harness eliminated the possibility of falls during Neurocom assessments. The participants were then positioned on the force plate with their feet shoulder width apart, toes pointed forward and their calcanei and medial maleoli lined up with the appropriate markers on the force plate (Figure 2B). This was referred to as the starting position from which both the LOS and mSOT began. After a brief familiarization period with the equipment and testing procedures (2-5 minutes) participants then performed the LOS and mSOT in a randomized order.

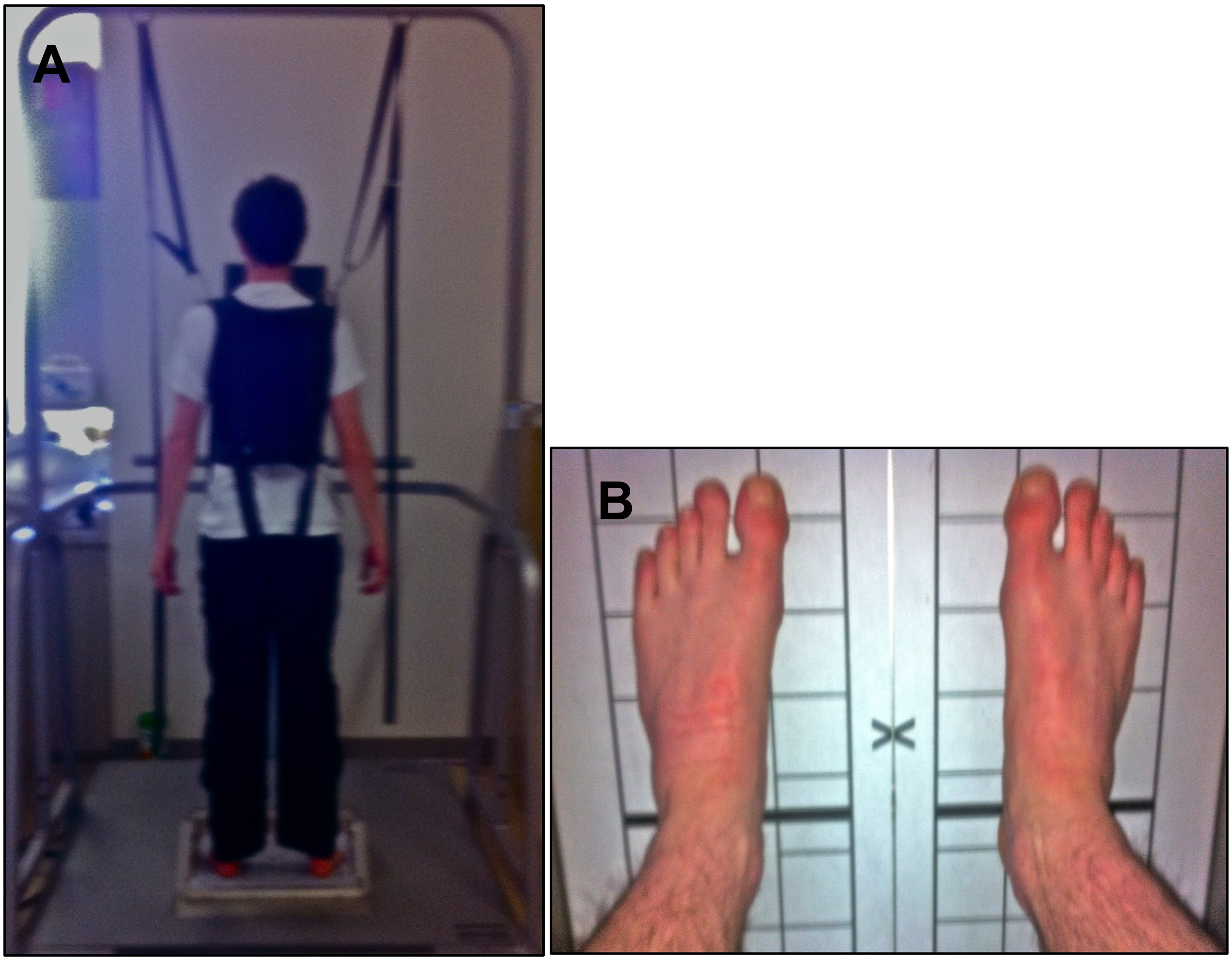

Figure 2: Starting position (A), and foot placement (B) on the Neurocom Pro Balance Master

THE LIMITS OF STABILITY TEST (LOS)

The LOS evaluates balance through dynamic anticipatory means, requiring the participant to shift their CoP without moving their feet towards targets placed at their predicted limits of stability. As the CoP is shifted towards the desired targets, compensatory postural adjustments must occur to maintain an upright posture without moving the feet from the starting position. Eight trials are performed in different directions around the body (anterior/posterior, medial/lateral, and 45 degrees to the front and back diagonals). Participants began in the starting position, with their CoP in the middle of the target provided on the visual feedback screen. On command, participants were instructed to shift their body weight forward (without moving their feet) towards a desired anterior location represented on the visual feedback screen. Constant visual feedback of the position of the CoP was shown on the visual feedback screen so compensatory adjustments could be made as necessary. Participants were allowed 8 seconds to bring their CoP as close to the target location as possible and maintain that position until the trial was completed. One trial was performed in each direction, starting anteriorly and moving clockwise around the body for a total of 8 trials (Figure 3). Any trial in which the participant touched the upright or stepped off the force plate was recorded as a fall. The results of the LOS provide information on movement variables that are important for aspects of dynamic and anticipatory balance. Directional control (DC), represents the degree to which the participant took a direct path towards the desired target. The DC value was derived from the amount of on axis movement of the CoP (movement in line with the target), relative to the amount of off-axis movement (movement not in line with the target), and was expressed as a percentage of the total on-axis movement. Maximum excursion (ME) represents the final position of the CoP at the end of the trial, and was expressed as a percentage of the total on-axis movement. End point excursion (EPE) represents the position of the CoP at the end of the first sustained movement towards the target, and also was expressed as a percentage of the total on-axis movement. Movement velocity (MV), represents the speed at which the participant moved their CoP towards the target, and was expressed in degrees per second. Reaction time (RT), represents the time it took for the participant to initiate movement after the start command was given, and was expressed in seconds. The participant's performance on each trial was used to calculate total scores, as well as directional specific scores (anterior, posterior, left and right) for the aforementioned movement variables. This provided an objective measurement of the participant's postural control when shifting their weight in various directions around the body.

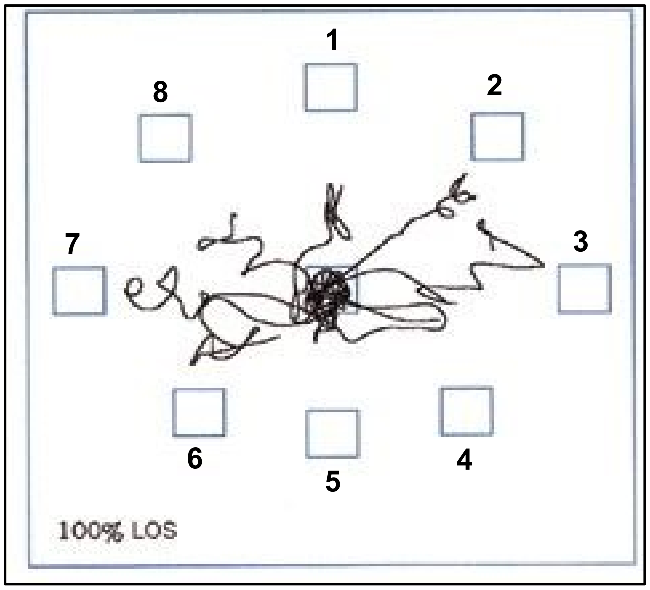

Figure 3: Example of visual output of the Limits of Stability Test (Neurocom International, 2012)

THE MODIFIED SENSORY ORGANIZATION TEST (mSOT)

The mSOT evaluates the contribution of different sensory systems to an individual's balance by removing or delivering incorrect sensory information to the central nervous system. This was done through 4 sets of 3 fifteen-second trials incorporating static, dynamic and reactive components of balance. The mSOT creates conditions in which the participant must react to either their own postural sway (static conditions), or a "controlled sway" induced by anterior/posterior tilting of the force plate (dynamic conditions). The magnitude of the induced sway in dynamic conditions was calculated individually for each participant based on their own amount of postural sway during static tandem stance. The participant’s score on each trial was calculated by comparing their own postural sway to the expected amount of sway for individuals in their age range.

Participants began in the starting position with their CoP in the middle of the target shown on the visual feedback screen. Participants were then instructed to stand as still as possible for 15 seconds, during which movement of the CoP was recorded. This was repeated for a total of 3 trials. The second set of trials followed the same protocol outlined above, but with visual feedback from the screen removed by blindfolding the participant. Participants began in the starting position with a blindfold on, and were instructed to stand as still as possible during which movement of the CoP was recorded. This was repeated twice, for a total of 3 trials.

The third set of trials used anterior/posterior tilting of the force plate to create a controlled sway, for the participant to respond to. Participants’ response to this sway was recorded. Participants began in the starting position, with their CoP in the middle of the target shown on the visual feedback screen. Participants were instructed to stand as still as possible and keep their CoP as close to the centre of the target as possible. During these 15-second trials, the force plate tilted anteriorly and posteriorly (Figure 4A) requiring the participant to adjust their body weight accordingly, without moving their feet. Any trial during which the participant stepped off the force plate or touched the upright was recorded as a fall.

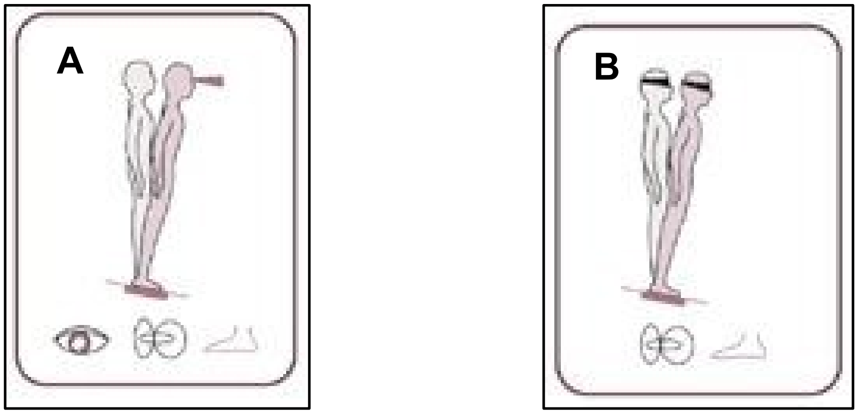

Figure 4: Controlled sway with (A) and without (B) visual feedback during the modified sensory organization test (Neurocom International, 2012)

The final set of trials used the same protocol described above, but with visual feedback removed. Participants began in the starting position and were once again blindfolded. Participants were then instructed to maintain their posture while the force plate once again tilted anterior and posteriorly, requiring them to make compensatory as needed, without visual feedback (Figure 4B). Any trial during which the participant stepped off the force plate or touched the upright was recorded as a fall. The results of the mSOT provide an overall composite score out of 100 that quantified the participants' performance on the test. This score is calculated as a weighted average from the participant's scores on each individual trial.

STATISTICAL ANALYSIS

Data was tested for normality using the Shapiro-Wilk test, as well as visual inspection of the Q-Q plots for each balance measure. Floor and ceiling effects for the CBMS were calculated as the percentage of participants that scored the minimum and maximum scores respectively, with effects of 20% or greater considered significant (Knorr et al., 2010). Parametric and non-parametric correlation coefficients were calculated to investigate the relationship between the CBMS, demographic variables and posturography results. Correlation coefficients between 0 and +/- 0.3 were interpreted as a weak positive or negative relationship. Correlation coefficients between +/- 0.31 and +/- 0.7 were interpreted as a moderate positive or negative relationship, and correlation coefficients between +/- 0.71 and +/- 1 were interpreted as a strong positive or negative relationship. Correlations were deemed significant at a level of 0.05 or less. A one-way repeated measures analysis of variance (ANOVA) was performed on LOS movement variables (DC, ME, EPE, MV, RT) to compare CR patients' results in the anterior, posterior and lateral directions. Multiple comparisons were then performed to identify significant differences between directions. Data analysis was performed using SPSS and Microsoft Excel 2013.

CHAPTER 4: RESULTS

PARTICIPANTS

Table 2 shows the average demographic and clinical characteristics of the participants. Thirty-one individuals (49-88 years of age) who were enrolled in CR programs (17 men, 14 women) volunteered to participate in the study. According to World Health Organization BMI classifications, 29% of participants were normal weight, 29% were overweight and 42% were classified as obese. Of the 31 participants, 18 were recruited from clinical CR programs requiring a doctor's referral after a cardiac event and hospital admission (heart attack, stent insertion etc.), 9 were recruited from community-based programs targeting those with a previous history of heart disease or cardiac event, and 4 were recruited from high functioning preventative programs for younger individuals at risk of developing CVD. Demographic information and CBMS scores between the various CR groups are shown in Table 3. Apparent differences in the between group mean values for self-reported physical activity levels, BMI and CBMS scores did not reach statistical significance. However, this is likely due to the small sample size and large within group variability in these values. Additionally, no sex differences were found for any of the performed balance measures. Since there were no statistically significant differences between groups, all groups were collapsed into a single data set for analysis.

Table 2: Demographic and clinical characteristics of participants (N=31).

Variable	Average ± Standard Deviation (min-max)
Age	65.3 ± 9.0 (49-88)
Height (m)	1.6 ± 0.1 (1.45-1.85)
Weight (kg)	80.7 ± 16.8 (47.0-111.2)
Body Mass Index (kg/m^2)	28.7 ± 5.0 (21.0-40.0)
Resting Heart Rate (bpm)	68 ± 11.1 (48-88)
Systolic Blood Pressure (mm/Hg)	128 ± 12.5 (96-148)
Diastolic Blood Pressure (mm/Hg)	79 ± 8.8 (58-92)

Table 3: Participant demographic information and Community Balance and Mobility Scale (CBMS) score by cardiac rehabilitation program (CR) type. No significant differences were found in self-reported physical activity levels, BMI or CBMS score between the different program types. Participants in the community CR group were significantly older than those in the clinical and preventative groups. *Indicates a significant difference from clinical and preventative groups ($p< 0.05$).

	Age (years)	BMI ($kg/m^{2)}$	Self-reported Physical Activity	CBMS (/ 96)
Clinical (n=18)	62.8 ± 7.3	29.9 ± 5.9	26 ± 21.6	61.7 ± 14.5
Community (n=9)	72.6 ± 9.0*	26.3 ± 3.2	33 ± 11.7	65.4 ± 12.9
Preventative (n=4)	60.5 ± 8.4	28.8 ± 1.5	54 ± 26.0	81.3 ± 7.0

NORMALITY

Table 4 shows the results of the Shapiro-Wilk test of normality for all performed measures of balance. The results indicate that CBMS scores, DC, EPE and MV all were normally distributed. Therefore parametric correlations (Pearson's product) were used to investigate the relationship between these variables. In contrast, mSOT scores, ME and RT were not normally distributed. Thus, non-parametric correlations (Spearman's rank order) were used to investigate relationships involving these variables.

Table 4: Results of normality testing for all balance measures. Community Balance and Mobility Scale (CBMS) score, directional control (DC), end point excursion (EPE) and movement velocity (MV) were normally distributed according to the Shapiro-Wilk test. In contrast Modified Sensory Organization Test (mSOT) score, maximum excursion (ME) and reaction time (RT) were not normally distributed. Therefore relationships that were examined involving these variables were examined using a Spearman's rank order correlation coefficient.*Indicates a non-normal distribution.

Balance Variable	**Shapiro-Wilk (p-value)**
CBMS Score	0.255
mSOT Score	0.002*
Limits of Stability Results	
DC	0.920
ME	0.021*
EPE	0.657
MV	0.053
RT	0.028*

In addition, Q-Q plots of CBMS and mSOT scores are shown in Figures 5 and 6 respectively. These figures allow for a visual inspection of the distribution of the test's scores with respect to normality. Figure 5 indicates that the majority of the CBMS scores followed a similar trend to what would be expected in a normal distribution. In contrast, the mSOT scores have a distinct curvilinear relationship and do not follow the pattern of a normal distribution (Figure 6).

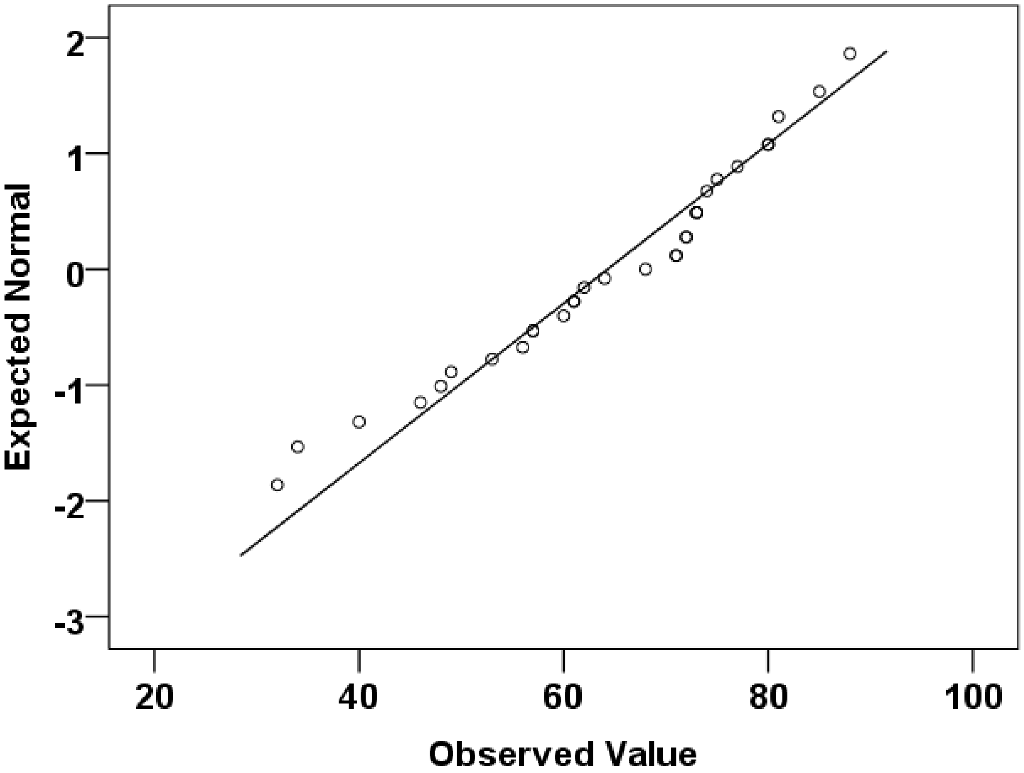

Figure 5: Q-Q plot of Community Balance and Mobility Scale (CBMS) scores. Visual inspection of the Q-Q plot shows that CBMS scores were normally distributed as indicated by the linear relationship between the expected normal values and the observed values.

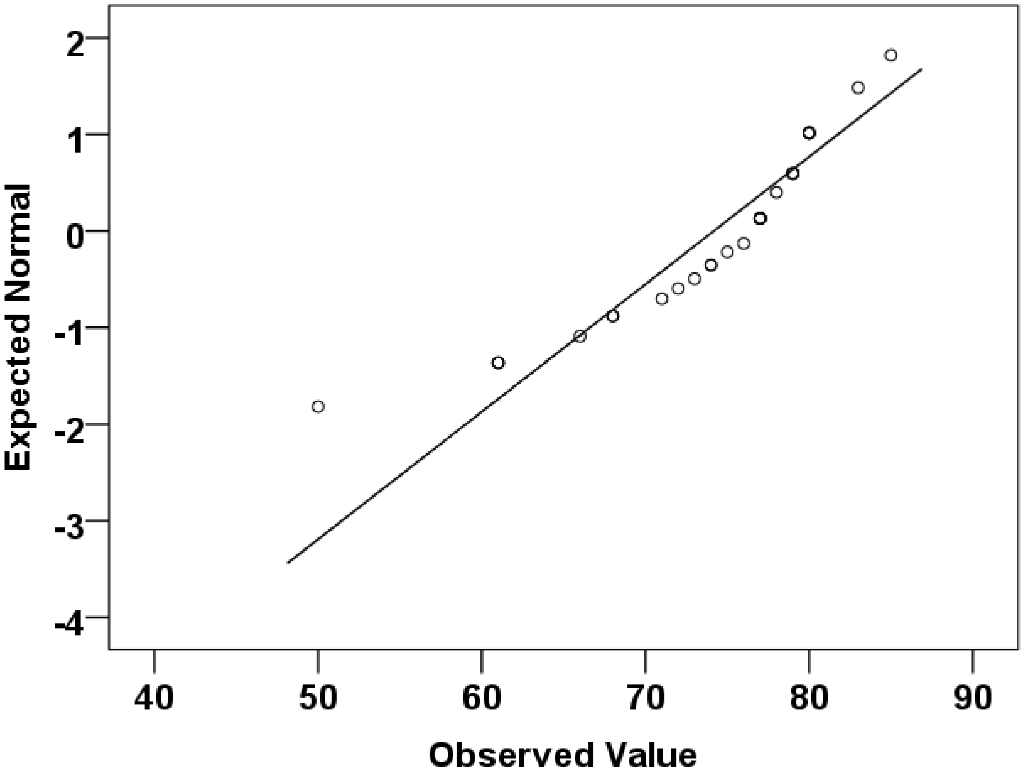

Figure 6: Q-Q plot of Modified Sensory Organization Test (mSOT) scores. Visual inspection shows that mSOT scores were not normally distributed, as indicated by the curvilinear trend in the observed values compared to the expected normal values.

FLOOR AND CEILING EFFECTS

Figure 7 illustrates the distribution of CR patients' CBMS scores. The distribution of CBMS scores covered the upper two-thirds of the scale's range, however no patients scored in the bottom third of the scale. On average CR patients scored 65 ± 14.5 out of a possible 96 points on the CBMS, with minimum and maximum scores of 32 and 88 respectively. The floor and ceiling effects were calculated as the percentage of participants who scored the minimum and maximum possible CBMS scores (0 and 96 respectively). No participants scored the minimum or maximum scores on the CBMS.

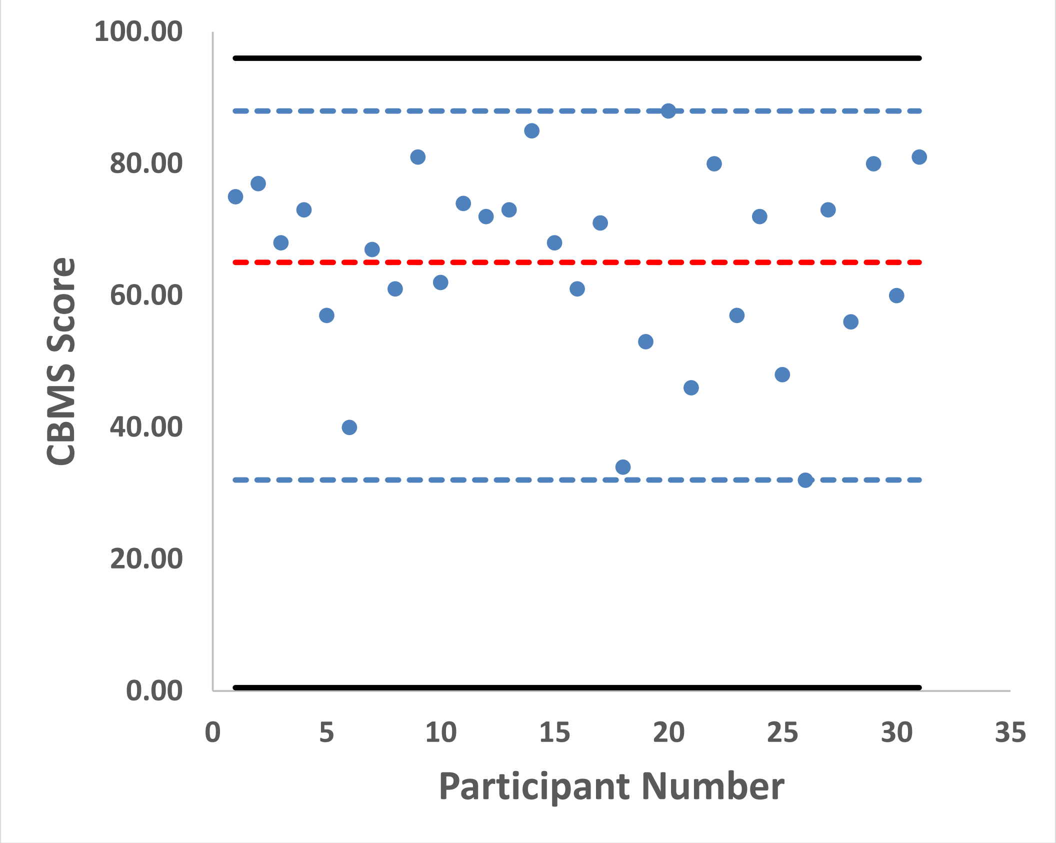

Figure 7: Distribution of Community Balance and Mobility Scale (CBMS) scores. No participants scored the minimum (0) or maximum (96) for the CBMS, as indicated by the solid black lines. The average CBMS score for CR patients was 65 ± 14.5. The minimum and maximum scores were 32 and 88 respectively and are indicated by the dashed lines.

CONVERGENT VALIDITY

The scores of all 31 participants were used to determine the relationship between the CBMS, demographic variables and mSOT results. However, 3 participants were unable to complete the LOS tasks without stepping off the force plate and thus received total scores of 0 for their movement variables. These participants were removed from correlations between the CBMS and LOS movement variables. As a result, all correlations between the CBMS and LOS movement variables were based on data from 28 participants. Table 5 indicates the correlation coefficients between the CBMS and demographic and posturography data. No significant correlations were found between the CBMS and demographic variables (age, BMI), however there was a moderate positive relationship between self-reported physical activity and CBMS score (r=0.365). In addition, the CBMS exhibited significant ($p<0.05$) moderate positive correlations with all dynamic posturography measures, except RT. The strongest correlations were found between the CBMS and ME and DC (r = 0.527, 0.501 respectively).

Table 5: Correlation coefficients between dynamic posturography variables and Community Balance and Mobility Scale (CBMS) score. Correlations were calculated using a Spearman's rank order, or Pearson's product moment correlation where indicated. *Indicates a significant correlation ($p<0.05$). †Calculated using Pearson's product moment correlation. **Calculated from n=28 participants. DC=directional control, ME=maximum excursion, EPE=end point excursion, MV=movement velocity, RT=reaction time, mSOT=Modified Sensory Organization Test

Demographic Variable	**Correlation with CBMS**
Age	-0.54 †
BMI (kg/m^2)	0.157 †
Self-reported Physical Activity	0.365*
Neurocom Variable	
DC Total	0.501*†**
ME Total	0.527* **
EPE Total	0.456*†**
MV Total	0.413*†**
RT Total	0.318**
mSOT Composite Score	0.401*

POSTUROGRAPHY ANALYSIS

A one-way repeated measures ANOVA was performed on each movement variable from the LOS to determine if there were significant differences between the anterior, posterior and lateral directions. The results from the ANOVA indicated that there were significant differences in participants' performances between the four directions for all movement variables. Pair wise comparisons were performed to further explore these differences.

Figures 8 to 12 illustrate the directional differences in CR patients' movement variables while performing the LOS. In general, CR patients had significantly lower values in the anterior and posterior directions than those of the lateral directions. Participants had the lowest DC when moving in the posterior direction, and greatest DC when moving in the anterior direction. Posterior DC was significantly lower than all other directions, and DC in the right was significantly lower than anterior DC. With respect to excursion distances, participants had significantly lower ME and EPE in both the anterior and posterior directions compared to the lateral directions. In addition, EPE to the right also was significantly lower than EPE to the left. There were no significant differences in lateral ME values. Participants also had significantly slower MV in the anterior and posterior directions compared to both lateral directions. Additionally, MV in the right was significantly slower than MV in the left. Participants had the slowest RT in the anterior direction, and the fastest RT in the posterior direction. However, the only significant differences in RT were found between the anterior and posterior directions.

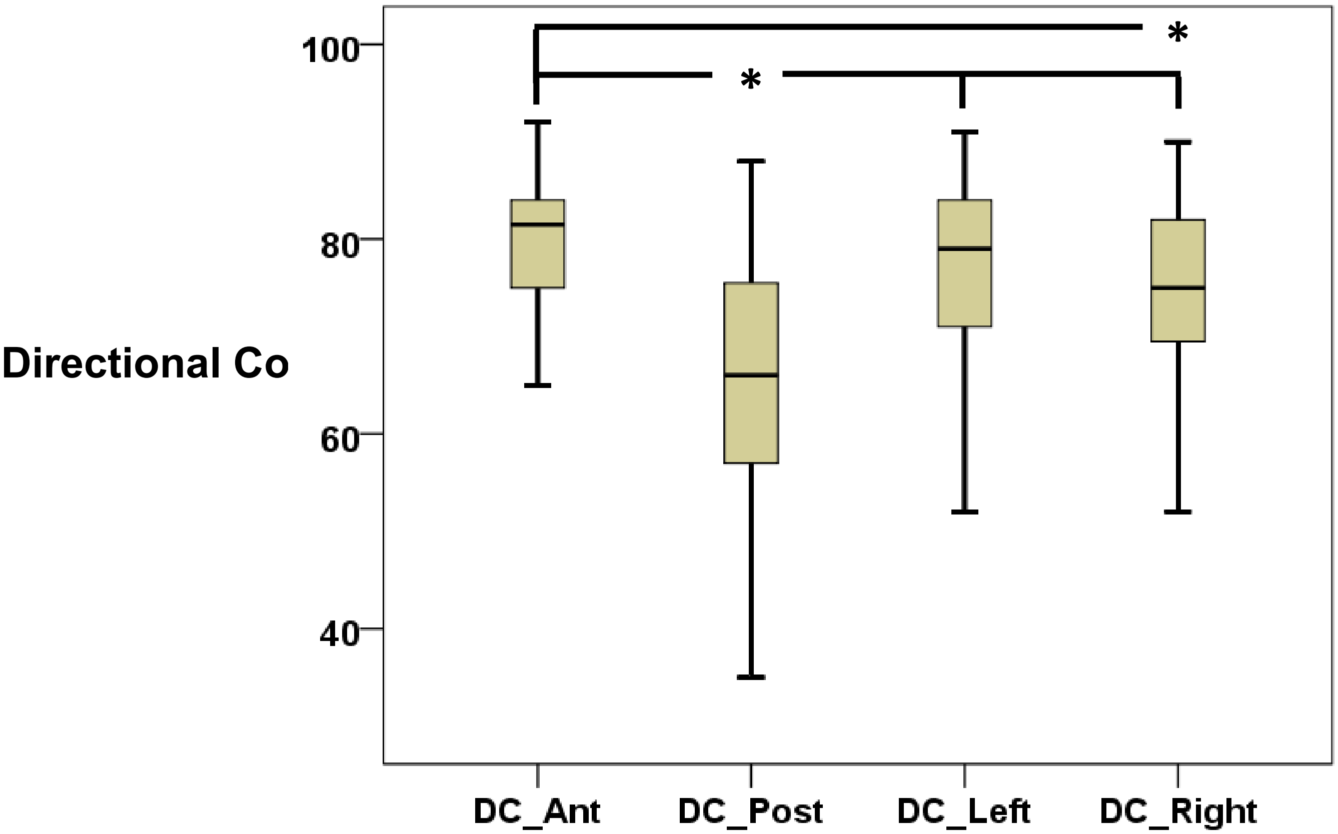

Figure 8: Average directional control (DC) of cardiac rehabilitation patients by direction. Posterior DC (65.2%) was significantly lower than the anterior, left and right directions (79.6%, 76.7% and 75% respectively). Additionally DC was significantly lower in the right compared to the anterior. *Indicates significant difference between directions ($p < 0.05$).

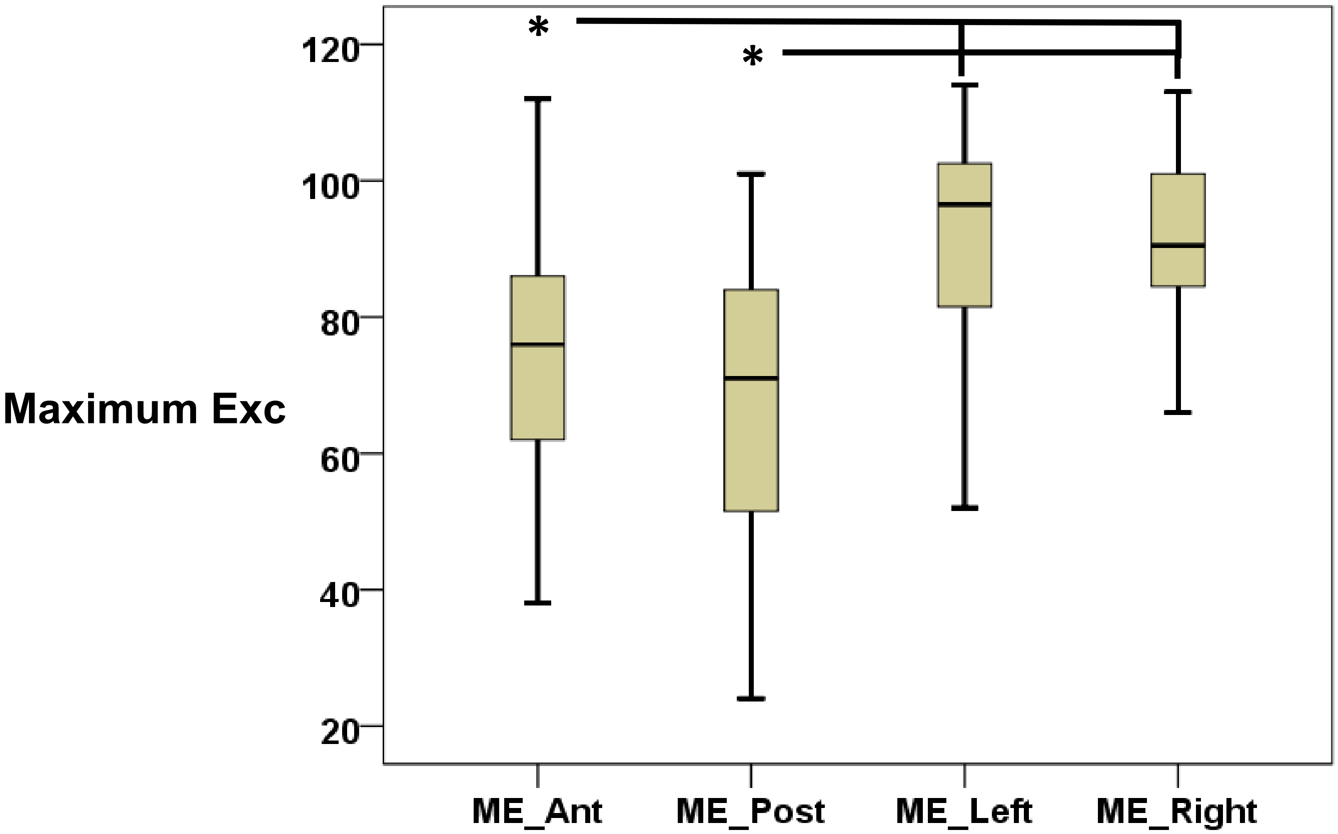

Figure 9: Average maximum excursion (ME) of cardiac rehabilitation patients by direction. The results indicate that the anterior and posterior excursion distances (73.8% and 67% respectively) were significantly lower than those in the left (92.1%) and right (90.4%). *Indicates a significant difference between directions ($p < 0.05$).

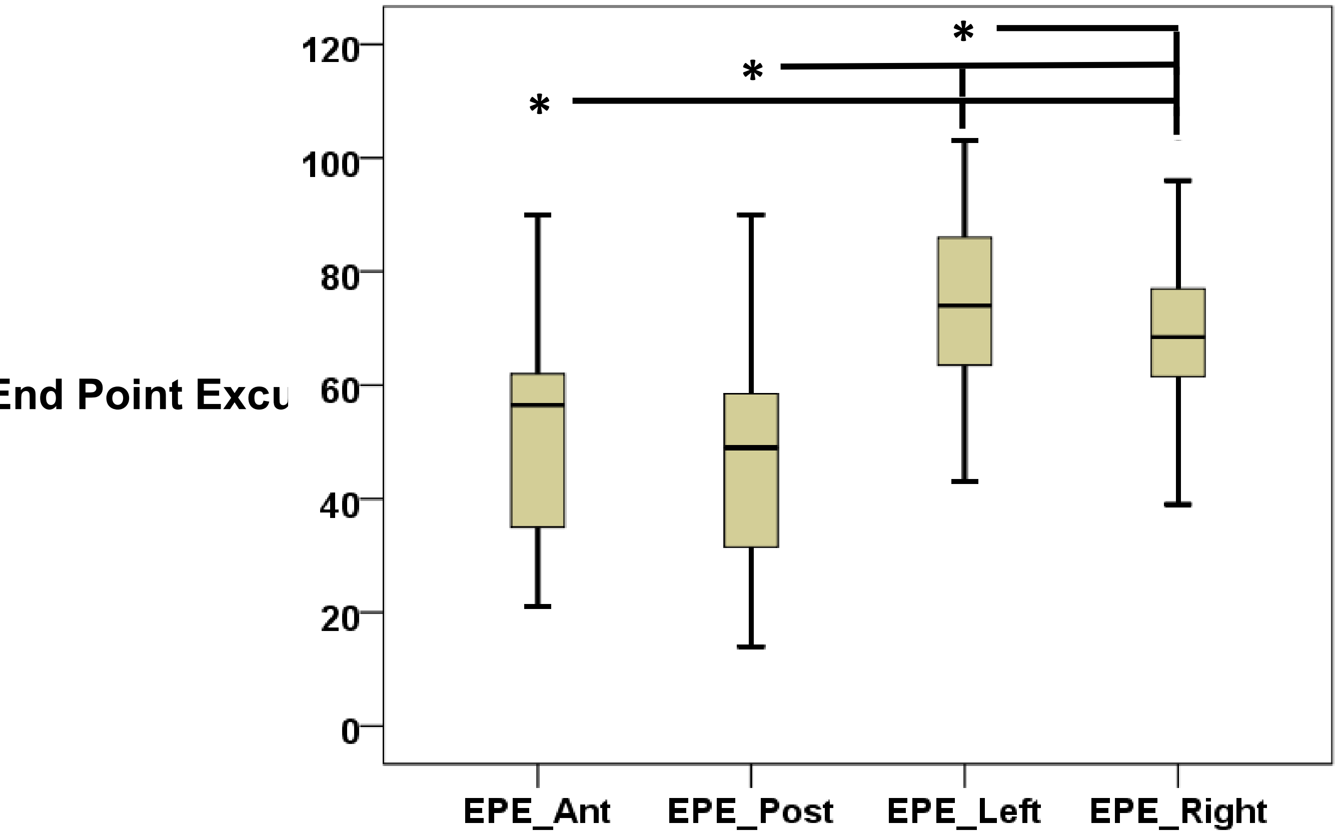

Figure 10: Average end point excursion (EPE) of cardiac rehabilitation patients by direction. The results indicate that final position of the CoP was significantly lower in the anterior and posterior directions (50.9% and 47.9% respectively), compared to the left (74.7%) and right (67.9%). In addition, EPE in the right was significantly lower than in the left. *Indicates a significant difference between directions ($p< 0.05$).

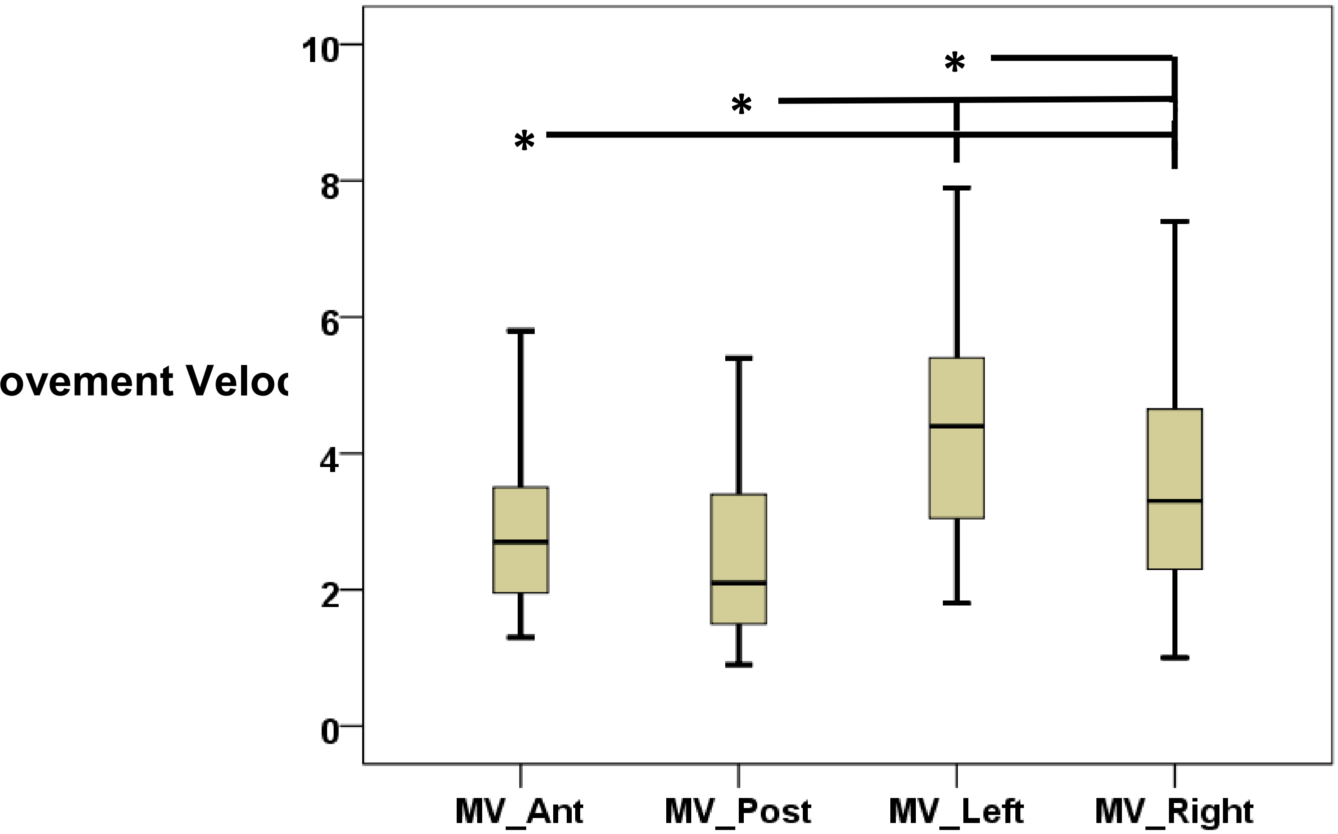

Figure 11: Average movement velocity (MV) of cardiac rehabilitation patients by direction. The results indicate that MV was significantly slower in the anterior and posterior directions (2.9 deg/s and 2.5 deg/s respectively), than the left (4.5 deg/s) and right (3.9 deg/s) directions. Additionally MV in the right was significantly lower than in the left. *Indicates a significant difference between directions ($p< 0.05$).

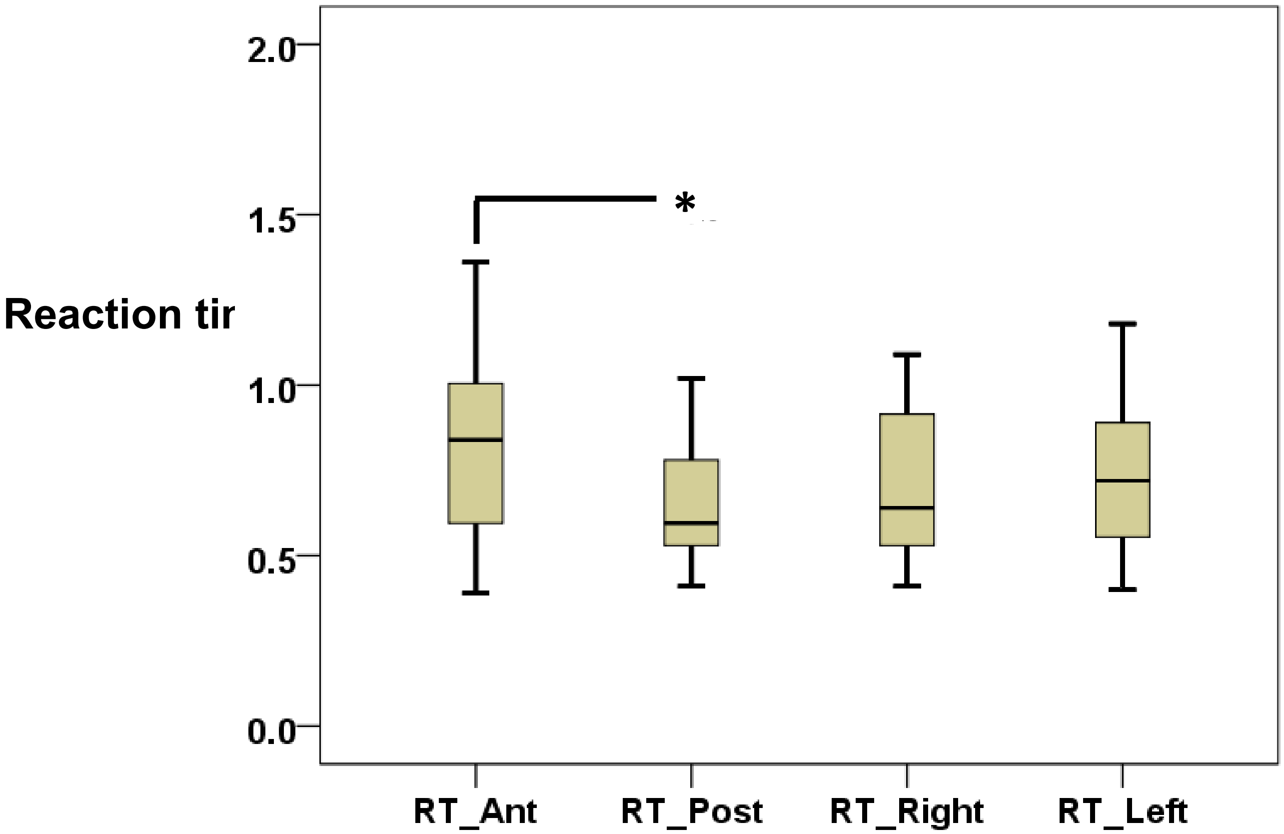

Figure 12: Average reaction time (RT) of cardiac rehabilitation patients by direction. The results indicate that RT in the anterior direction (0.82s) was significantly slower than RT in the posterior direction (0.69s). There were no significant differences involving the left (0.73s) and right (0.74s) directions. *Indicates a significant difference between directions ($p< 0.05$).

CHAPTER 5: DISCUSSION

Previous research indicates that a significant proportion of patients participating in CR programs have decreased levels of postural balance. Balance impairments are known to negatively impact physical activity and exercise capabilities. Since the cornerstone of many CR programs is physical activity and exercise programs, these deficits may negatively impact the CR outcome. It is therefore important to have an appropriate means to measure balance in CR patients in order to prescribe optimal physical activity and exercise. However, no balance assessments have been evaluated for use in CR programs. Therefore, the purpose of this study was to investigate psychometric properties of the CBMS in a clinical population participating in CR programs. The objectives of the study were (1) to investigate the floor and ceiling effects of the CBMS when administered to CR patients, and (2) to test the convergent validity of the CBMS against standardized measures of computerized dynamic posturography. The results showed no floor or ceiling effects when administering the CBMS to CR patients. Additionally, the CBMS demonstrated moderate convergent validity with all measures of dynamic posturography, with the exception of RT. Together, this information suggests that the CBMS is an appropriate measure for assessing balance in patients participating in CR programs. These findings suggest that the CBMS can be applied in a CR setting to identify and monitor patients with balance deficits. This information can then be used to adjust the therapeutic exercise program to better suit the patients' balance capabilities.

FLOOR AND CEILING EFFECTS

Research has shown that many functional balance assessments are limited by ceiling effects when being used in higher functioning populations. This suggests the need for a more challenging functional balance assessment that is appropriate for patients with mild to moderate balance impairments. The present study found that there were no floor or ceiling effects when administering the CBMS to a group of CR patients. Scores were distributed across the mid and upper range of the assessment's continuum, with no participants scoring in the bottom third of the assessment (0-32). These results indicate that the CBMS was an appropriate level of difficulty for CR patients.

Although the floor and ceiling effects of the CBMS have not been previously investigated in a cardiac population, previous research also has shown minimal effects when administering the CBMS in other clinical populations. Similar average CBMS scores have been reported for patients recovering from traumatic brain injuries (Howe et al., 2006; F.V. Wright et al., 2010). The authors also reported no floor or ceiling effects in this population. In addition, Knorr et al., (2010) reported slightly lower average CBMS scores, as well as a 10% floor effect when administering the CBMS to patients recovering from stroke. Furthermore, its appropriateness for higher functioning populations has been shown by a 0% ceiling effect in healthy school aged children (M.J. Wright & Bos, 2012). Thus it was not surprising that no floor or ceiling effects were observed in CR patients as the test has been shown to be appropriate for a wide range of patient capabilities.

The above findings are significant due to the fact that well established balance assessments have shown limited applicability in populations with mild to moderate balance impairments. In a systematic review of the literature, the BBS was identified as the most commonly used balance assessment in clinical populations (Blum & Korner-Bitensky, 2008). However, several authors have reported ceiling effects when administering the BBS to stroke patients (Blum & Korner-Bitensky, 2008; Knorr et al., 2010; Mao et al., 2002). This information suggests that the BBS is not able to accurately measure balance in moderate to higher functioning patients since a maximum score on the assessment may not be a true representation of the patient's balance capabilities. Thus the CBMS may be a more appropriate measure for these individuals as it is better suited for their level of function and balance capabilities.

Overall, the results of this study in conjunction with previously published material demonstrate the applicability of the CBMS in clinical populations with mild to moderate balance impairments, such as CR patients. Lack of floor and ceiling effects in a cardiac population indicates that the CBMS is able to accurately assess and monitor changes in balance in these patients. Therefore in comparison to other common field assessments, the CBMS seems to be the most suitable option for patients participating in CR programs.

CONVERGENT VALIDITY

This study compared the CBMS with computerized dynamic posturography measures to examine the convergent validity between the different types of assessments. This was done to investigate the relationship between the CBMS and objectives measures of postural balance, as well as provide further information on the balance characteristics of CR patients. To this author's knowledge, the present study is the first to examine the relationship between the CBMS and measures of dynamic posturography.

The findings of this study indicate moderate convergent validity of the CBMS relative to measures of dynamic posturography. The CBMS exhibited significant moderate relationships with the mSOT, as well as DC, ME, EPE and MV as measured by the LOS. The strongest relationships were found between the CBMS and the movement variables DC and ME. The only measure of dynamic posturography that did not demonstrate a significant relationship with the CBMS was RT.

It was expected that the CBMS would have a stronger relationship with dynamic posturography measurements. Moderate rather than strong convergent validities are likely due to the different styles of balance assessments, and different aspects of balance that were measured. Functional balance assessments place emphasis on an individual's performance on various tasks representative of independent living. Thus, participants are likely more familiar with these tasks due to their more frequent representation in every-day life. In contrast, dynamic posturography assessments place emphasis on the biomechanical aspects of balance, and require participants to perform stationary weight shifting tasks, which they may not be as familiar with. In addition, computerized posturography measurements are performed from a stationary position and thus likely do not address as many dynamic aspects of balance compared to functional balance assessments, such as the CBMS. Therefore, moderate rather than strong convergent validities are likely the result of the different aspects of balance that are targeted by these assessments, rather than an inadequacy in either of the assessments themselves.

Although the relationship between the CBMS and dynamic posturography has not been previously examined, research indicates similar relationships between the BBS and measures of dynamic posturography. Boulgarides et al., (2003) identified moderate convergent validity between the BBS and movement variables measured by the LOS. Similar to the findings of the present study, the BBS also had the strongest relationship with DC and ME, and there also was no relationship between the BBS and RT (Boulgarides, McGinty, Willett & Barnes, 2003). Given that the convergent validity between the BBS and CBMS has been shown to be excellent (Knorr et al., 2010), it is not surprising that both functional balance assessments exhibited very similar relationships to dynamic posturography measures. This further supports the notion that moderate convergent validity between the assessments are likely due to differences between dynamic posturography and functional balance testing.

The findings of this study indicate that there is a moderate relationship between functional balance assessments and measures of computerized dynamic posturography. Specifically, DC, MV, EPE and ME were all related to CBMS score and thus, may be important contributors to an individual's functional balance. This information suggests that the CBMS is an accurate measure of balance in a cardiac population as it demonstrated moderate convergent validity with posturography results despite the identified differences in assessment variables and techniques.

CHARACTERIZING BALANCE IN CR

The results of the LOS provide information on movement variables that can help to characterize balance in a cardiac population. Movement variables calculated by the LOS were broken down into directional specific components to provide further information on CR patients' balance in the anterior, posterior and lateral directions. Although balance deficits in cardiac patients have been briefly investigated (Di Iorio et al., 2009; Goel et al., 2010), to this author's knowledge this is the first study to further characterize CR patients' balance using directional specific information.

The results of the present study showed that LOS movement variables were significantly lower in the anterior and posterior directions compared to the laterals. Specifically, ME, EPE and MV all were significantly decreased in the anterior and posterior directions. Additionally, posterior DC was significantly lower than DC in any other direction, and anterior RT was the slowest, although only significantly slower than the posterior direction. Thus, when moving in the anterior and posterior directions CR patients on average had slower movement speed and shorter excursion distance compared to movement in the lateral directions. Furthermore, CR patients had the poorest control of their body weight when moving in the posterior direction.

These findings indicate that CR patients have significantly decreased movement capabilities in the sagittal plane (anterior/posterior) compared to the frontal plane (laterals). This may be due in part, to the prevalence of visceral obesity in CR patients. Individuals with visceral obesity have an anterior displacement of their CoM compared to individuals of normal weight (Wearing et al., 2006). Anterior displacement of the CoM increases the distance required for the CoP to travel in order to provide compensatory adjustments to control anterior and posterior movement. This anterior displacement of the CoM in conjunction with shorter CoP excursion distances may lead to significantly reduced movement capabilities in the anterior and posterior directions (Ruhe, Fejer, & Walker, 2011; Wearing et al., 2006). In addition, due to their increased weight obese individuals require greater muscular forces to counteract the ground reaction forces associated with the CoP and maintain the CoM within the base of support (Wearing et al., 2006). This may affect patients' abilities to perform exercises with large movements based in the sagittal plane such as walking, marching or stepping exercises. These activities are common components of many CR aerobic exercise programs. Thus, some CR patients may have difficulty performing these exercises at an optimal intensity, and may require alternative exercises to more effectively target the cardiovascular system.

In addition to alternative aerobic exercises, it may be beneficial to incorporate additional strengthening exercises that target the musculature responsible for anterior and posterior balance control. Movement in the sagittal plane is controlled largely by musculature in the lower leg and ankle, such as the gastrocnemius and tibialis anterior (MacKinnon, & Winter,1993). Therefore, a specific deficit in these directions may be due, in part, to a muscular deficit in the associated musculature. Therapeutic exercise prescriptions in CR may benefit from incorporating specific strengthening exercises for the lower leg and ankle in order to improve patients' balance throughout the CR program. This may also increase their exercise capabilities and allow them to participate in other aspects of the therapeutic exercise prescription at a greater intensity. However, further research is required to investigate this claim.

LIMITATIONS & FUTURE RESEARCH

There is a minor limitation to this study which should be taken into account for future research. The present study did not control for patients' initial physical activity levels, which are an important determinant of their balance capabilities. Participants were recruited from multiple CR programs, at different points during the rehabilitation process. Therefore, some participants had been participating in therapeutic exercise for months or even years (preventative programs), whereas others were recruited prior to beginning any exercise sessions. Although this lends strength to the current study by increasing the heterogeneity of the sample and thus, furthering its applicability to a cardiac population, it does not provide information about patients' level of balance upon entering a CR program.

It is recommended that future studies restrict recruitment to the beginning of a CR program, prior to the participant beginning any therapeutic exercise sessions. The benefit of this is two-fold. Firstly, it allows for a better representation of patients' balance upon entering the program, which may provide further information into their possible physical activity and exercise restrictions. Secondly, it allows for a re-assessment at the end of the CR program to determine what affect, if any, CR exercise prescriptions may have on an individual's balance. In addition, by monitoring variables associated with cardiovascular risk researchers can investigate the relationship between patients' initial level of balance and their improvement in cardiac function and disease risk.

CHAPTER 6: CONCLUSION

The purpose of the present study was to investigate psychometric properties of the CBMS when being administered to a clinical population participating in CR. This was done to determine the suitability of the CBMS for use in CR programs. Floor and ceiling effects were examined to determine if the CBMS represents an appropriate level of difficulty for a cardiac population. Additionally CBMS scores were compared to measures of dynamic posturography to determine the convergent validity between these types of assessments. No floor or ceiling effects were found, indicating that the CBMS represents an appropriate level of difficulty for patients participating in CR programs. In addition the CBMS demonstrated moderate convergent validities with LOS and mSOT results, suggesting that it is an accurate representation of CR patients' balance capabilities. Overall, these findings indicate that the CBMS is an appropriate field assessment for patients participating in CR programs. Therefore, the CBMS may be a useful tool to identify CR patients whose balance is impaired, and monitor improvements when applicable. Additionally, analysis of the posturography data indicates that CR patients have decreased balance and movement capabilities in the anterior and posterior directions. This may impact patients' abilities to perform exercises based in the sagittal plane. Future research is required to determine the impact of CR exercise prescription on patients balance, and the potential relationship this may have with cardiac improvement.

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Appendix A: Recruitment Poster

Capital Health

DALHOUSIE
UNIVERSITY
Inspiring Minds

Do you want to know more about your balance?

If you are over 18 years of age and participating in a cardiac rehabilitation program, you may be eligible to take part in a research study. This study looks at different ways to test balance and mobility for people with heart disease. To take part in this study you will be asked to perform three balance tests at Dalhousie University. Participating in this study will take approximately 1 hour of your time.

Each participant will be required to attend Dalhousie University at a time of your convenience for one session consisting of three different balance tests.

For more information please contact Mr. Luke Martelli using the phone number or e-mail address below.

Luke Martelli, Dalhousie University

Appendix B: Health Screening Questionnaire

Health Screening Questionnaire

Name (Print): ___________________________________.

Phone Number: _____________________ **E-mail:**

Address:_______________________

Gender (Please circle): M F

Date of Birth: _ _ / _ _ / _ _
DD MM Y Y

Please answer the following questions to the best of your ability:

10. Has a doctor ever diagnosed you with cardiovascular disease (heart attack, stroke, arrhythmia, heart failure, atherosclerosis, peripheral artery disease, coronary heart disease, etc) ?

Yes **No**

If so, which condition, and when was it diagnosed?

____

____.

If you have been diagnosed with heart failure, what stage were you classified as?

____.

(2) Have you had any musculoskeletal injuries in the past 2 months that may affect your ability to perform physical activity?

Yes **No**

If so, please specify:

____

____.

(3) Do you have any chronic conditions or diseases that may affect your ability to perform physical activity (e.g. Parkinson's Disease, Rheumatoid Arthritis, Diabetic Neuropathy, Paralysis, etc.) ?

Yes **No**

If so, please specify:

____.

(4) Please list all current health medications you are taking as specifically as possible

____

____

____.

I the undersigned agree that the above information is correct to the best of my knowledge:

Signature:____Date:__________

Appendix C: Godin Leisure Time Physical Activity

Godin Leisure-Time Exercise Questionnaire

INSTRUCTIONS

In this excerpt from the Godin Leisure-Time Exercise Questionnaire, the individual is asked to complete a self-explanatory, brief four-item query of usual leisure-time exercise habits.

CALCULATIONS

For the first question, weekly frequencies of strenuous, moderate, and light activities are multiplied by nine, five, and three, respectively. Total weekly leisure activity is calculated in arbitrary units by summing the products of the separate components, as shown in the following formula:

Weekly leisure activity score = (9 × Strenuous) + (5 × Moderate) + (3 × Light)

The second question is used to calculate the frequency of weekly leisure-time activities pursued “long enough to work up a sweat“ (see questionnaire).

EXAMPLE

Strenuous = 3 times/wk

Moderate = 6 times/wk

Light = 14 times/wk

Total leisure activity score = (9 × 3) + (5 × 6) + (3 × 14) = 27 + 30 + 42 = 99

Godin, G., Shephard, R. J.. (1997) Godin Leisure-Time Exercise Questionnaire. Medicine and Science in Sports and Exercise. 29 June Supplement: S36-S38.

Godin Leisure-Time Exercise Questionnaire

1. During a typical **7-Day period** (a week), how many times on the average do you do the following kinds of exercise for **more than 15 minutes** during your free time (write on each line the appropriate number).

Times Per Week

a) **STRENUOUS EXERCISE**
(HEART BEATS RAPIDLY) __________
(e.g., running, jogging, hockey, football, soccer,
squash, basketball, cross country skiing, judo,
roller skating, vigorous swimming,
vigorous long distance bicycling)

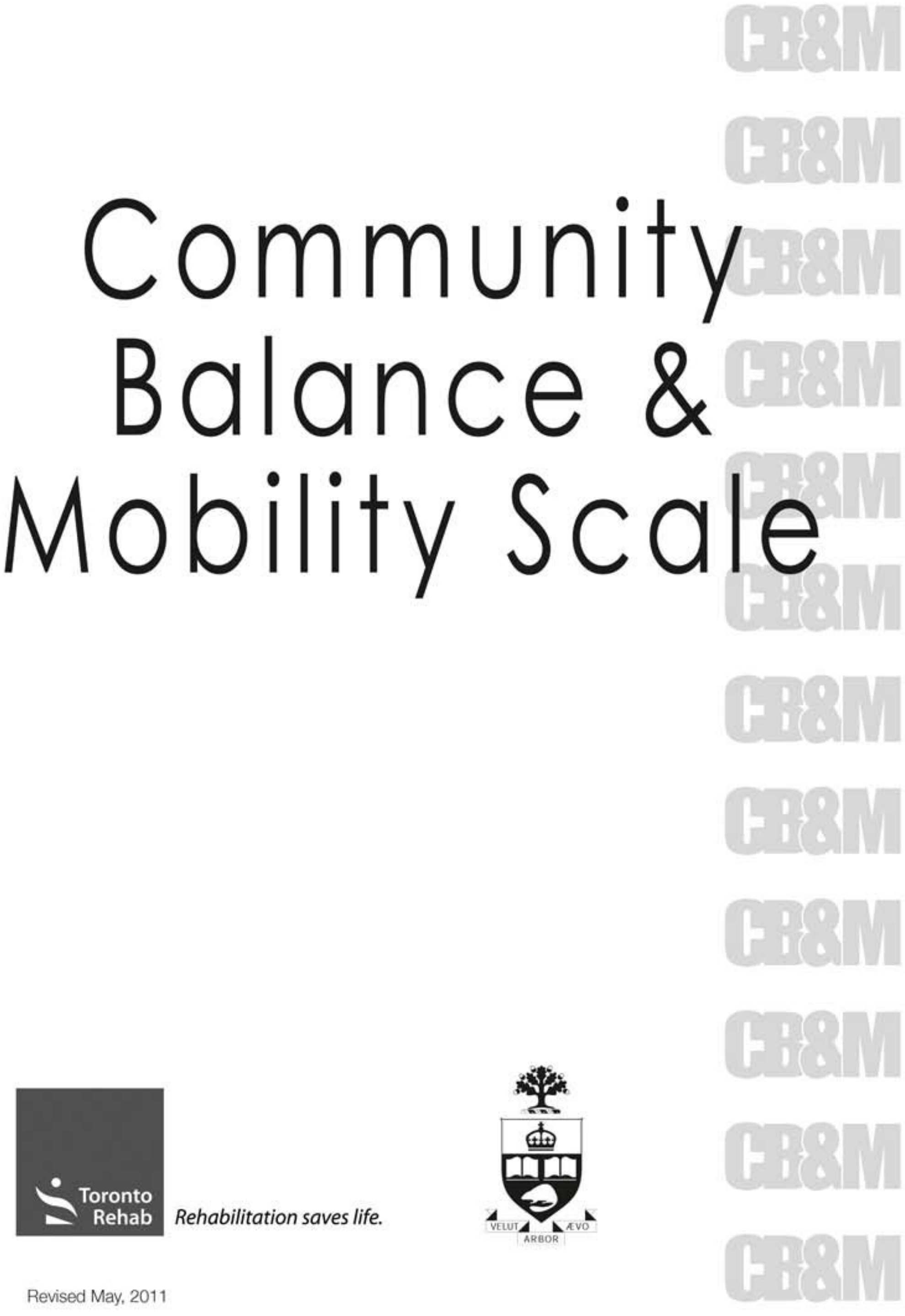
b) **MODERATE EXERCISE**
(NOT EXHAUSTING) __________
(e.g., fast walking, baseball, tennis, easy bicycling,
volleyball, badminton, easy swimming, alpine skiing,
popular and folk dancing)

c) **MILD EXERCISE**
(MINIMAL EFFORT) __________
(e.g., yoga, archery, fishing from river bank, bowling,
horseshoes, golf, snow-mobiling, easy walking)

2. During a typical **7-Day period** (a week), in your leisure time, how often do you engage in any regular activity **long enough to work up a sweat** (heart beats rapidly)?

OFTEN	SOMETIMES	NEVER/RARELY
1. ☐	2. ☐	3. ☐

Appendix D: Community Balance and Mobility Scale



Community Balance & Mobility Scale

Toronto Rehab
Rehabilitation saves life.

VELUT ARBOR ÆVO

Revised May, 2011

INTRODUCTION

The consequences of postural dyscontrol are pervasive and have a significant impact on activities of daily living, community mobility and social, work and leisure pursuits. The Community Balance and Mobility Scale (CB&M) was designed to evaluate balance and mobility in patients who, although ambulatory, have balance impairments which reduce their full engagement in community living.

The following is a brief summary of the key measurement properties of the CB&M established to date with individuals with traumatic brain injury (TBI). Content validity was obtained by the involvement of patients with TBI (n=7) and clinicians (n=17) during the item generation process. The CB&M demonstrates intraclass correlation coefficients (ICC's) of 0.977 for both intra- and inter-rater reliability, 0.898 and 0.975 for test-retest reliability (5-day and immediate, respectively) and Cronbach's alpha of 0.96 for internal consistency.[1]

Additional studies have shown that in ambulatory patients with TBI, the CB&M is less susceptible to a ceiling effect than the commonly used Berg Balance Scale and better able to capture change in this higher functioning group.[2]

The construct validity of the CB&M was supported by associations with laboratory measures of dynamic postural control and measures of community integration and balance confidence.2 Statistically significant correlations were demonstrated between the CB&M and spatiotemporal measures of gait including walking velocity, step length, step width and step time (r values ranging from 0.38 to 0.87). Importantly, variability in step length and step time, used as a marker of dynamic stability, also correlated significantly with CB&M scores (r values ranging from 0.46 to 0.70). Significant associations were also achieved with self-report measures of balance confidence and participation in the community using the Activities-specific Balance Confidence (ABC) scale (r=0.60) and the Community Integration Questionnaire (r=0.54), respectively.

The CB&M has been able to capture the decline in balance that occurs with aging in healthy individuals supporting the validity and sensitivity of the scale.3 Healthy age-referenced data across the decades is available from the authors to assist in interpretation of patient scores. Determining if patients are within the range of healthy values for their age group is helpful in identifying the presence and degree of balance impairment.

Clinical feedback and user reports have indicated that the scale is also appropriate for high-functioning clients with diagnoses other than traumatic brain injury but further studies are warranted.

The positive results support that the CB&M is a reliable and valid clinical outcome measure for detecting dynamic instability and evaluating change in ability in the higher functioning ambulatory patient with TBI.

For further information, please contact:

howe.jo-anne@torontorehab.on.ca or inness.liz@torontorehab.on.ca

1. Howe J, Inness E, Venturini A, Williams JI, Verrier MC. (2006) The Community Balance and Mobility Scale: A balance measure for individuals with traumatic brain injury. *Clinical Rehabilitation*, 20, 885-95.

2. Inness EL, Howe J, Niechwiej-Szwedo E, Jaglal S, McIlroy WE, Verrier MC. (2011) Measuring balance and mobility after traumatic brain injury: Validation of the Community Balance & Mobility Scale (CB&M). *Physiotherapy Canada,*63 (2), 199-208.

3. Zbarsky, K, Parsley D, Clegg H, Welch T, Fernandes C, Jaglal S, Inness E, Williams J, McIlroy WE, Howe J. (2010) [Abstract] Community Balance & Mobility Scale (CB&M): Age-related reference values. *Physiotherapy Canada,* 62 (Suppl), 46.

Community Balance & Mobility Scale (CB&M) Administration And Scoring

PHYSICAL SETTING

Much of the testing of the CB&M is designed to occur within a clinic setting upon a measured track. (The set-up is outlined below.) The therapist must also have access to a full flight of stairs (minimum 8 steps).

The following materials are required for testing:

- stop watch (digital preferred)
- average size laundry basket or large rigid box of same dimension
- 2 lb. & 7 1/2 lb. weights
- visual target used in Item 8
  (a paper circle 20cm in diameter with a 5cm diameter black circle in the middle)
- bean bag

CLOTHING

The patient should wear comfortable clothing and enclosed, flat footwear. Footwear should be consistent on subsequent testing. The patient is allowed to use whatever orthotic is customarily worn at the time of testing.

RATING PROCEDURE

Use of Ambulation Aides: All tasks are to be performed without ambulation aides (with one exception in Item 12 - Descending Stairs).

Timed Tasks: The clock beside the title of an item indicates that the task is timed.

Demonstration of Tasks: To ensure understanding of the task, the therapist should demonstrate all tasks while instructing the patient.

Standardized Starting Position: Unless otherwise indicated, the following starting position should be used: standing feet slightly apart, arms at sides, head in neutral position with eyes forward, toes touching start line.

Scoring Patient Performance: Score on the first trial. In cases where it is clear that the individual did not understand the task, only then is re-instruction and a second trial allowed.

The therapist should judge the patient's performance in comparison to a young adult with a normal neuro-musculoskeletal system.

Scale descriptors are detailed and precise. It is recommended that the grading criteria be reviewed well, including criteria for when the 'test is over' prior to performing the tasks.

Patient Safety: If in the therapist's clinical judgment the patient would be unsafe in performing part or all of a task, the patient should not attempt it. Score according to the guidelines if part of the task is attempted or "0" if it is not attempted.

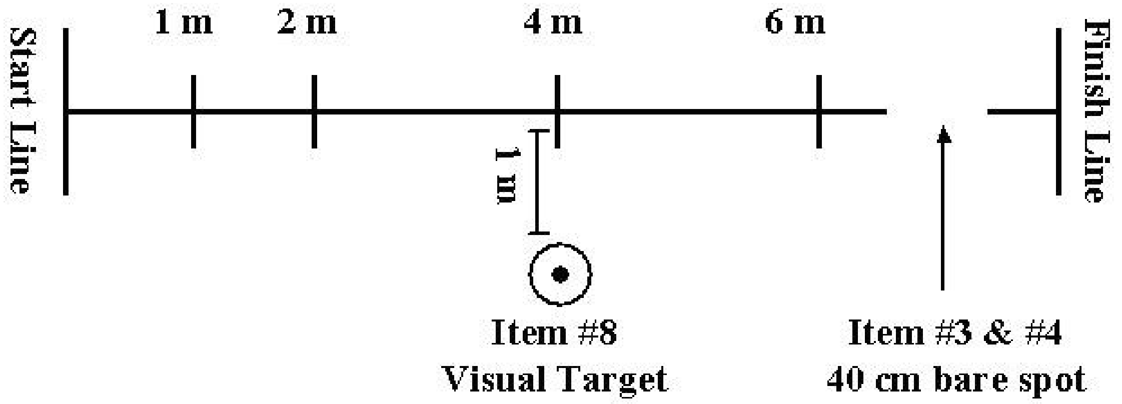
Rest Periods: Rest periods are acceptable between tasks, as required.

DEFINITION OF TERMS

Equilibrium Reactions: For the purpose of this measure, the term equilibrium reactions is defined as the use of movement strategies of the trunk and limbs to maintain centre of mass within the base of support.

THE TRACK

Set-up: The total area recommended for testing is 10 metres by 2 metres. The track is an 8 metre line with a perpendicular start and finish line. It may be applied to the floor with paint or duct tape, 5cm wide. The 1m, 2m, 4m, and 6m points should be indicated. A 40cm bare spot for items #3 and #4 as the diagram shows below is recommended if tape is used. The visual target for Items 8 and 11 is placed at the 4m mark, at patient's eye level and 1m from the outside edge of the track.



Use of the track for measurement:

The track is used in two ways for measurement of the balance items:

i) as a direct measurement, when foot placement on the line is part of the scoring criteria e.g. Tandem Walking,

ii) as a reference to indicate whether the patient maintains a straight course or veers from a straight trajectory during the task e.g. Walking & Looking.

OMMUNITY BALANCE & MOBILITY SCALE (CB&M) SCORE SHEET

Full CB&M guidelines must be reviewed to ensure accurate administration and scoring. To score 5, actions must appear coordinated and controlled without excessive equilibrium reactions.

CB&M Tasks	Notes	Initial	Mid	D/C
1. UNILATERAL STANCE 0 unable to sustain 1 2.00 to 4.49 sec. 2 4.50 to 9.99 sec. 3 10.00 to 19.99 sec. 4 ≥ 20.00 secs. 5 45.00 sec., steady and coordinated	"Look straight ahead" Test is over if stance foot moves from start position or raised foot touches ground.	Left		
		Right		
2. TANDEM WALKING 0 unable 1 1 step 2 2 to 3 consecutive steps 3 > 3 consecutive steps heel-toe distance < 3" *(for levels 2 &3 only)* 4 > 3 consecutive steps 5 7 consecutive steps in good alignment = heel-toe contact and feet straight *(for levels 4 & 5 only)*	"Look ahead down the track, not at your feet."			
3. 180° TANDEM PIVOT 0 unable to sustain tandem stance 1 sustains tandem stance but unable to unweight heels or initiate pivot 2 initiates pivot but unable to complete 180° turn 3 completes 180° turn but discontinuous pivot (e.g. pauses on toes) 4 completes 180° turn in a continuous motion but can't sustain reversed position 5 completes 180° turn in a continuous motion and sustains reversed position	Test is over if touches heels down or steps out of position.			
4. LATERAL FOOT SCOOTING 0 unable 1 1 lateral pivot 2 2 lateral pivots 3 ≥ 3 pivots but < 40 cm 4 40 cm in any fashion and/or unable to control final position 5 40 cm continuous, rhythmical motion with controlled stop.	Test is over if patient hops or opposite foot touches down.	Left		
		Right		
5. HOPPING FORWARD 0 unable 1 1 to 2 hops, uncontrolled 2 2 hops, controlled but unable to complete 1 metre 3 1 metre in 2 hops but unable to sustain landing (touches down) 4 1 metre in 2 hops but difficulty controlling landing (hops or pivots) 5 1 metre in 2 hops, coordinated with stable landing	Test is over if opposite foot touches down.	Left		
		Right		
6. CROUCH AND WALK 0 unable to crouch 1 able to descend only 2 descends and rises but hesitates, unable to maintain forward momentum 3 crouches and walks in continuous motion, time ≤ 8.00 sec. protective step 4 crouches and walks in continuous motion, time ≤ 8.00 sec. excess equilibrium reaction 5 crouches and walks in continuous motion, time ≤ 4.00 sec.				

7. LATERAL DODGING 0 unable to perform 1 cross-over in both directions without support 1 1 cross-over in both directions in any fashion 2 1 or more cycles, but does not contact line every step 3 2 cycles, contacts line every step 4 2 cycles, contacts line every step 12.00 to 15.00 sec. 5 2 cycles, contacts line every step < 12.00 sec. coordinated direction change	"Do this as fast as you can yet at a speed that you feel safe."			
8. WALKING & LOOKING 0 unable to walk and look e.g. stops 1 performs but loses visual fixation at or before 4 metre mark 2 performs but loses visual fixation after 4 metre mark 3 performs and maintains visual fixation between 2-6 metre mark but protective step 4 performs and maintains visual fixation between 2-6 metre mark but veers 5 performs, straight path, steady and coordinated ≤ 7.00 sec.	"Walk at your usual pace."	Left		
		Right		
9. RUNNING WITH CONTROLLED STOP 0 unable to run 1 runs, time > 5.00 sec. 2 runs, time > 3.00 but ≤ 5.00 sec., unable to control stop 3 runs, time > 3.00 but ≤ 5.00 sec., with controlled stop, both feet on line 4 runs, time ≤ 3.00 sec., unable to control stop 5 runs, time ≤ 3.00 sec., with controlled stop, both feet on line, coordinated and rhythmical	"Run as fast as you can." Hold position on finish line.			
10. FORWARD TO BACKWARD WALKING 0 unable 1 performs but must stop to regain balance 2 performs with reduced speed, time > 11.00 sec. or requires 4 or more steps to turn 3 performs in ≤ 11.00 sec. and/or veers during backward walking 4 performs in ≤ 9.00 sec. and/or uses protective step during or just after turn 5 performs in ≤ 7.00 sec., maintains straight path	"Walk as quickly as you can yet at a speed that you feel safe."			
11. WALK, LOOK AND CARRY (Score same as #8 Walking and Looking)	"Walk at your usual pace."	Left		
		Right		
12. DESCENDING STAIRS 0 unable to step down 1 step, or requires railing or assistance 1 able to step down 1 step with/without cane 2 able to step down 3 steps with/without cane, any pattern 3 3 steps reciprocal or full flight in step-to pattern no railing 4 full flight reciprocal, awkward no cane 5 full flight reciprocal, rhythmical and coordinated +1 bonus for carrying basket				
13. STEP-UPS X 1 STEP 0 unable to step up, requires assistance or railing 1 steps up, requires assistance or railing to descend 2 steps up and down (1 cycle) 3 completes 5 cycles 4 completes 5 cycles in > 6.00 but < 10.00 sec. 5 completes 5 cycles in ≤ 6.00 sec., rhythmical	"Do this as quickly as you can. Try not to look at your feet."	Left		
		Right		
TOTAL SCORE		96	96	96

Signature(s)______________________________ Date(s)__________________________________

1. UNILATERAL STANCE

i) Test to be performed on right leg
ii) Test to be performed on left leg

Starting position: Standardized starting position.

Instructions to Patient: *Stand on your right/left leg and hold for as long as you can up to 45 seconds. Look straight ahead.*

Instructions to Therapist: Begin timing as soon as the patient's foot leaves the ground. Do not allow the patient to brace the elevated leg against the supporting leg.

Test is over: Stop timing if stance foot moves from starting position or opposite foot touches ground.

GRADING:

0 unable to sustain unilateral stance independently, i.e. able to unweight leg for brief moments only

1 able to sustain unilateral stance for 2.00 - 4.49 sec.

2 able to sustain unilateral stance for 4.50 - 9.99 sec.

3 able to sustain unilateral stance for 10.00 - 19.99 sec.

4 able to sustain unilateral stance for $\geq$ 20.00 sec.

5 able to sustain unilateral stance for 45.00 sec. in a steady & coordinated manner
NOT Acceptable: excessive use of equilibrium reactions

2. TANDEM WALKING

Starting position: Standardized starting position with one foot positioned on the 8m line.

Instructions to Patient: *Walk forward on the line, heel touching toes. Keep your feet pointing straight ahead. Look ahead down the track, not at your feet. I will tell you when to stop.*

Instructions to Therapist: If able, allow the patient to take a maximum of 7 steps. For your scoring, count only those consecutive steps for which the heel is on the line and the heel-toe distance is ≤ 8cm (3 inches).

GRADING:

0 unable to complete 1 step on the line independently, i.e. requires assistance, upper extremity support, or takes a protective step

1 able to complete 1 step independently, acceptable to toe out

2 able to complete 2 or 3 steps consecutively on the line, acceptable to toe out

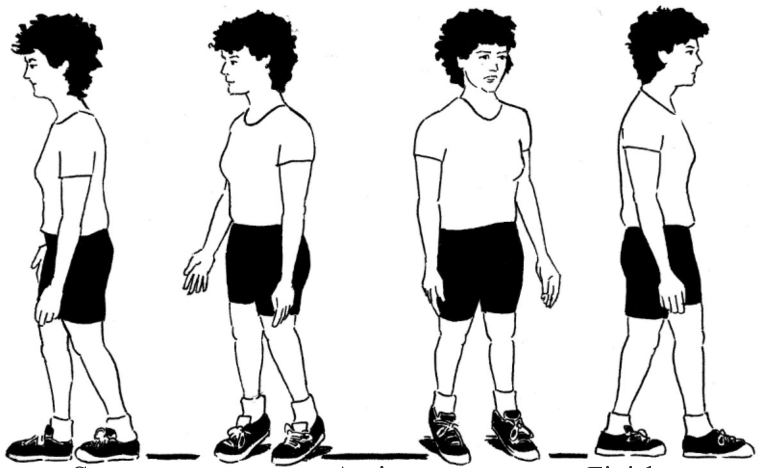
3 able to complete more than 3 steps consecutively, acceptable to toe out

4 able to complete more than 3 steps consecutively, in good alignment (heel-toe contact, feet straight on the line, no toeing out), but demonstrates excessive use of equilibrium reactions

5 able to complete 7 steps consecutively, in good alignment (heel-toe contact, feet straight on the line, no toeing out), and in a steady & coordinated manner.
NOT Acceptable: excessive use of equilibrium reactions
looking at feet

3. 180° TANDEM PIVOT

Starting position: Tandem Stance on bare spot in track (see set-up diagram) – aligned heel to toe, no toeing out, arms at sides, head in neutral position and eyes forward. Patient allowed to choose either foot in front and may use assistance or upper extremity support to achieve, but not sustain, tandem stance.



Instructions to Patient: *Lifting your heels just a little, pivot all the way around to face the opposite direction without stopping. Put your heels down and maintain your balance in this position.*

Instructions to Therapist: When right foot is in front in tandem position, patient to turn towards left. When left foot is in front in tandem position, patient to turn towards right. Therapist may assist patient to assume starting position.

Test is over: When patient puts heels down or steps out of position.

GRADING:

0 unable to sustain tandem stance independently, i.e. requires assistance or upper extremity support

1 able to sustain tandem stance independently, but unable to unweight heels and/or initiate pivot

2 able to initiate pivot, but unable to complete 180° turn

3 able to complete 180° turn but discontinuous, i.e. pauses on toes during pivot

4 able to complete 180° turn in a continuous motion, but unable to sustain reversed position
NOT Acceptable: heel-toe distance > 8cm (3 inches)

5 able to turn 180° in a continuous and coordinated motion and sustain reversed position (Acceptable to have feet slightly angled out in reversed position)
NOT Acceptable: heel-toe distance > 8cm (3 inches); excessive use of equilibrium reactions

4. LATERAL FOOT SCOOTING

Lateral foot scooting is defined as alternately pivoting on the heel and toe of one foot while moving sideways.
i) move to the right when performing on right leg
ii) move to the left when performing on left leg

Starting position: Standing on the line beside the bare spot in unilateral stance on right/left foot, arms at sides. Foot is perpendicular to the track.

Instructions to Patient: *Stand on your right/left leg and move sideways by alternately pivoting on your heel and toe. Keep pivoting straight across until you touch the line and maintain your balance in this position.*

Instructions to Therapist: The patient moves laterally along the length of the bare spot (40cm). For the grading, one lateral pivot is defined as either pivoting on heel, moving toes laterally OR pivoting on toes, moving heel laterally.

Test is over: When patient steps, hops, or touches opposite foot to floor.

GRADING

0 unable to sustain unilateral stance independently, i.e. requires assistance or upper extremity support

1 able to perform 1 lateral pivot in any fashion

2 able to perform 2 lateral pivots in any fashion

3 able to perform $\geq$ 3 lateral foot pivots, but unable to complete 40cm

4 able to complete 40cm in any fashion, acceptable to be unable to control final position

5 able to complete 40cm in a continuous and rhythmical motion, demonstrating a controlled stop briefly maintaining unilateral stance
NOT Acceptable: pausing while pivoting to regain balance
veering from a straight line course
excessive use of equilibrium reactions
excessive trunk rotation while pivoting

5. HOPPING FORWARD

i) to be performed on right leg
ii) to be performed on left leg

Starting position: Unilateral stance on right/left with entire foot on the track. Heel placed on inside edge of starting line.

Instructions to Patient: *Stand on your right/left foot. Hop twice straight along this line to pass the 1m mark with your heel. Maintain your balance on your right/left leg at the finish.*

Instructions to Therapist: It is recommended that the therapist assess safety prior to commencing task by having the patient hop in one spot. Patient is successful in completing 1m when the heel of the foot is touching or beyond the 1m line.

Test is over: If patient touches down with suspended foot between hops.

GRADING

0 unable to sustain unilateral stance independently or hop, i.e. requires assistance or upper extremity support

1 able to perform 1 or 2 hops with poor control, i.e. unable to sustain 1 foot landing for even brief moments, unable to complete 1m

2 able to perform 2 hops sequentially in a controlled manner, unable to complete 1m

3 able to complete 1m in 2 hops, but unable to sustain 1 foot landing, i.e. touches down or steps with opposite limb upon landing. Acceptable to deviate from the line

4 able to complete 1m in 2 hops, but difficulty controlling landing, i.e. hops or pivots on stance foot to maintain landing. Acceptable to deviate from the line
NOT Acceptable: touching down or stepping with opposite limb to achieve stability on landing

5 able to complete 1m in 2 hops in a coordinated manner and sustain a stable landing
NOT Acceptable: deviate from line
excessive use of equilibrium reactions

6. CROUCH AND WALK

Starting Position: Standardized starting position. Bean bag is placed to right or left side of the 2m mark considering which hand the patient will use to pick it up.

Instructions to Patient: *Walk forward and, without stopping, bend to pick up the bean bag and then continue walking down the line.*

Instructions to Therapist: This task is performed using only half of the track. Start timing when the patient's foot leaves the ground. Stop timing when both feet cross the 4m line.

Patient should use the less affected upper extremity for the task. This will avoid downgrading the score due to limitations of upper extremity function as opposed to balance function.

GRADING

0 unable to crouch (descend) to pick up bean bag independently, i.e. requires assistance or upper extremity support

1 able to crouch (descend), but unable to maintain crouch to pick up bean bag or rise to stand independently, i.e. requires assistance or touches hands down to floor

2 able to crouch to pick up bean bag and rise to stand independently but must hesitate at any time during activity, i.e. unable to maintain forward momentum

3 able to crouch and walk in a continuous motion (i.e. maintaining forward momentum) with time ≤ 8.00 seconds and demonstrates protective step at any time during the task

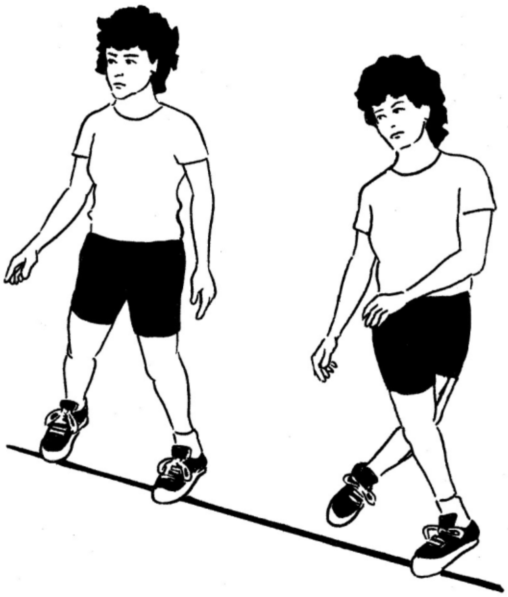
4 able to crouch and walk in a continuous motion with time ≤ 8.00 seconds and/or uses excessive equilibrium reactions to maintain balance at any time during the task
NOT Acceptable: veering off course

5 able to crouch and walk in a continuous and rhythmical motion with time ≤ 4.00 seconds
NOT Acceptable: veering off course
excessive use of equilibrium reactions

7. LATERAL DODGING

Starting Position: Standing at the 2m mark with feet perpendicular to the track. The toes of both feet should cover the track

Instructions to Patient: *Move sideways along the line by repeatedly crossing one foot in front of and over the other. Place part of your foot on the line with every step. Reverse direction whenever I call "Change!" Do this as fast as you can, yet at a speed that you feel safe.*



Instructions to Therapist: Patient moves laterally back and forth along the line, between the 2m and 4m marks by repetitively crossing one foot over and in front of the other.

It is acceptable for the patient to look at the line to monitor foot placement.

One cross-over includes crossing one leg over to land beside the other and returning the back leg to an uncrossed position.

One cycle requires the patient to cross-over for a 2m distance and return. The test requires that the patient perform two of these cycles (a total of 8m). Begin timing as soon as the patient's foot leaves the ground. Stop timing when both feet cross over the final mark. To cue the patient to change direction, call out "Change!" when one foot passes the 2 and 4m marks. The patient should believe direction changes are random.

GRADING

0 unable to perform one cross-over in both directions without loss of balance or use of support.

1 able to perform one cross-over in both directions without use of support, but unable to contact the line with part of the foot.

2 able to cross-over for 1 or more cycles to and from the 2m mark, but unable to contact the line with every step.

3 able to perform 2 cycles in any fashion (to the 2m line and back twice) and one part of each foot must contact the line during each step.

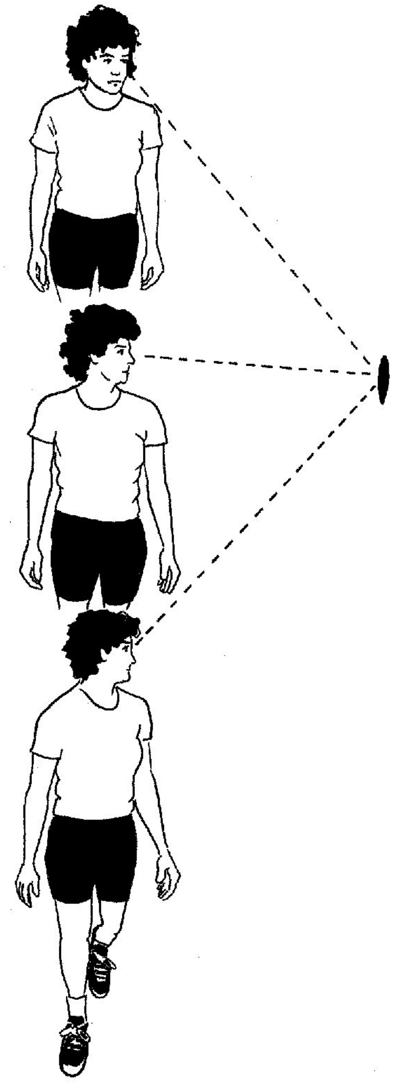
4 performs 2 cycles as described in level 3 in 12.00 to 15.00 sec.

5 performs 2 cycles in less than 12.00 sec. in a continuous, rhythmical fashion with coordinated direction changes immediately after verbal cue.

8. WALKING & LOOKING

i) to be performed looking right
ii) to be performed looking left

Starting position: Standardized starting position. (See set-up diagram for placement of visual target.)



Instructions to Patient: *Walk at your usual pace to the end of the line. I will tell you when to look at the circle. Keep looking at it while you walk past it. I will then tell you when to look straight ahead again. Try not to veer off course while you walk.*

Instructions to Therapist: Score client as defined in the guidelines, irrespective of the underlying limiting impairments, e.g. decreased neck or trunk rotation. Start timing when the patient's foot leaves the ground. Stop timing when both feet cross the 8m finish line.

1. At the 2m mark, ask the patient to "Look at the circle."

2. Cue the patient to "Keep looking at the circle" as they look back over their shoulder until they reach the 6m mark.

3. At the 6m mark, ask the patient to "Look straight ahead and continue walking until the end of the line."

Stand in a location where the patient's ability to maintain fixation can be assessed, that is, beside the target. Thus, a second person may be needed to walk with the patient to ensure safety. It is acceptable to continue to remind the patient of where they should be looking at each segment.

To score in the opposite direction, repeat task starting from opposite end of the line.

8. WALKING & LOOKING (CONTINUED)

GRADING

0 unable to walk and look, i.e. has to stop to look, or requires assistance or upper extremity support at any point during the test

1 able to continuously walk and initiate looking, but loses visual fixation on circle at or before 4m mark

2 able to continuously walk and look, but loses visual fixation on circle after 4m mark, i.e. while looking back over the shoulder

3 able to continuously walk and fixate upon the circle between the 2m and 6m mark, but demonstrates a protective step.

4 able to continuously walk and fixate upon the circle between the 2m and 6m mark, but veers off course at any time during task.

5 able to continuously walk and fixate upon circle between the 2m and 6m mark, maintains a straight path, in a steady and coordinated manner, time $\leq$ 7.00 sec.
NOT Acceptable: inconsistent or reduced speed
looking down at feet

9. RUNNING WITH CONTROLLED STOP

Starting position: Standardized starting position.

Instructions to Patient: *Run as fast as you can to the end of the track. Stop abruptly with both feet on the finish line and hold this position.*

Instructions to Therapist: Begin timing when initial foot leaves ground. Stop timing when both feet reach the finish line. It does not matter whether the feet land consecutively or simultaneously on the finish line.

GRADING

0 unable to run (with both feet off ground for brief instant), rather demonstrates fast walking or leaping from foot to foot

1 able to run in any fashion, time > 5.00 sec.

2 able to run in any fashion, time > 3.00 sec. but ≤ 5.00 sec., but is unable to perform a controlled stop with both feet on the line, i.e. uses protective step or excessive equilibrium reactions

3 able to run in any fashion, time > 3.00 sec. but ≤ 5.00 sec., and perform a controlled stop with both feet on the line
NOT Acceptable: excessive use of equilibrium reactions

4 able to run in any fashion, time ≤ 3.00 sec., but is unable to perform a controlled stop with both feet on the line, i.e. uses protective step(s) or excessive equilibrium reactions

5 able to run in a coordinated and rhythmical manner and perform a controlled stop with both feet on the line, time ≤ 3.00 sec.
NOT Acceptable: excessive use of equilibrium reactions

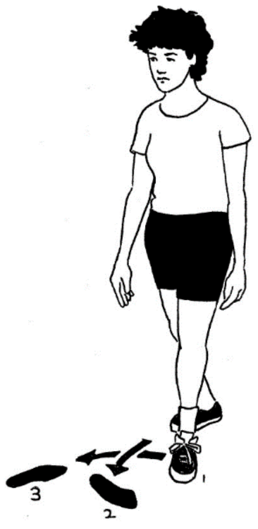
10. FORWARD TO BACKWARD WALKING

Starting position: Standardized starting position.

Instructions to Patient: *Walk forwards to the halfway mark, turn around and continue to walk backwards until I say "Stop." Try not to veer off course. Walk as quickly as you can, yet at a speed that you feel safe.*

Instructions to Therapist: Start timing when the patient's foot leaves the ground. Stop timing when both feet cross the 8m finish line. The patient is to turn at the 4m mark. It is acceptable for the subject to turn in any direction s/he chooses.

- When counting the steps required to turn 180°:
  i) the first step in the turn is angled away from the forward trajectory, ii)
  the last step in the turn completes the 180° turn and is oriented
  towards the starting line, initiating backwards walking.
- It is also acceptable to pivot on one foot rather than stepping around.



GRADING

0	unable to complete task, i.e. requires assistance or upper extremity support
1	able to complete task independently, but must stop to maintain/regain balance at any time during this task
2	able to complete the task without stopping but must significantly reduce speed, i.e. total time is > 11.00 sec., AND/ OR requires 4 or more steps to complete the turn
3	able to complete task with time ≤ 11.00 sec. and/or veers from straight path during backwards walking
4	able to complete task in a continuous motion, time ≤ 9.00 sec., and/or uses protective step(s) during or just after turn
5	able to complete the task in a continuous motion with brisk speed, time ≤ 7.00 sec. and maintaining a straight path throughout

11. WALK, LOOK & CARRY

i) to be performed looking right ii)
to be performed looking left

Starting position: Standardized starting position, but carrying a plastic grocery bag in each hand by the handle, with a 7 1/2 lb. = 3.4 kg weight inside each bag. (See set-up diagram for placement of visual target.)

Instructions to Patient: *Walk at your usual pace to the end of the line carrying the grocery bags. I will tell you when to look at the circle. Keep looking at it while you walk past it. I will then tell you when to look straight ahead again. Try not to veer off course while you walk.*

Instructions to Therapist: Same instructions as in Item 8 Walking & Looking. Patient to carry only one grocery bag if unable to perform bilaterally due to motor control problems of the upper extremity. Indicate on the score sheet if patient carried only one bag.

GRADING

0 unable to walk and look, i.e. has to stop to look, or requires assistance or upper extremity support at any point during the test

1 able to continuously walk and initiate looking, but loses visual fixation on circle at or before 4m mark

2 able to continuously walk and look, but loses visual fixation on circle after 4m mark, i.e. while looking back over the shoulder

3 able to continuously walk and fixate upon the circle between the 2m and 6m mark, but demonstrates a protective step. Acceptable for patient to demonstrate inconsistent or reduced speed

4 able to continuously walk and fixate upon the circle between the 2m and 6m mark but veers off course. Acceptable for patient to demonstrate inconsistent or reduced speed

5 able to continuously walk and fixate upon circle between the 2m and 6m mark, maintains a straight path, in a steady & coordinated manner, time $\leq$ 7.00 sec.
NOT Acceptable: inconsistent or reduced speed
looking down at feet

12. DESCENDING STAIRS

Starting position: Quiet standing at top of staircase (minimum 8 steps). Depending on patient's skill on the stairs, may begin by descending from the first or third step at the bottom of the flight.

Instructions to Patient: *Walk down the stairs. Try not to use the railing.*

Instructions to Therapist: Depending on patient's skill on stairs, may use a cane as in level 1 and 2.

GRADING

0 unable to step down 1 step OR requires the railing or assistance

1 able to step down 1 step with/without use of cane
NOT Acceptable: use of railing (from this level onwards)

2 able to step down 3 steps in any pattern with/without the use of cane, i.e. step-to pattern with/without cane or reciprocal pattern with cane

3 able to step down 3 steps in a reciprocal pattern, without cane OR able to step down a full flight in a step-to pattern, without cane
NOT Acceptable: use of cane (from this level onwards)

4 able to step down a flight in a reciprocal pattern but awkward, uncoordinated*

5 able to step down a flight in a reciprocal pattern in a rhythmical and coordinated manner*

***BONUS**

If the patient achieves a score of 4 or 5, and if deemed safe by the rating therapist, the patient is asked to repeat the task and descend stairs while carrying a weighted basket (laundry basket with 2 lb. weight in it). It is acceptable for the patient to intermittently look at the steps.

Add one bonus point to the score of 4 or 5 if the patient can descend the stairs safely while carrying the basket without the need for continuous monitoring of their foot placement. If the patient is unable to hold the basket with one or both arms, they are not eligible for the bonus point.

Instructions to Patient: Hold this basket, keeping it in front of you at waist level. Walk down the stairs and try not to look at your feet. You may look at the steps once in a while for safety.

13. STEP UPS x 1 STEP

i) to be performed leading with right leg ii)
to be performed leading with left leg

Starting position: Standardized starting position in front of step at bottom of stairs.

Instructions to Patient:
i) Step up and down on this step as quickly as you can until I say "Stop." The pattern is Right-Left Up and Right-Left Down. Try not to look at your feet.
ii) Step up and down on this step as quickly as you can until I say "Stop." The pattern is Left-Right Up and Left-Right Down. Try not to look at your feet.

Instructions of Therapist: Start timing when the patient's foot leaves the ground. Stop timing after the completion of 5 cycles. A cycle is one complete step up and down.

GRADING

0	unable to step up independently, requires assistance and/or railing to ascend
1	able to step up independently, but unable to step down independently, i.e. requires railing and/or assistance to descend
2	able to step up and down (1 cycle) independently without railing or assistance. Acceptable to look at feet
3	able to complete 5 cycles. Acceptable to demonstrate incoordination or inconsistent speed/rhythm **NOT Acceptable:** to look at feet
4	able to complete 5 cycles in > 6.00 but < 10.00 sec. Acceptable as in Level 3 **NOT Acceptable:** as in level 3
5	able to complete 5 cycles in ≤ 6.00 sec. in a rhythmical and coordinated manner **NOT Acceptable:** to look at feet

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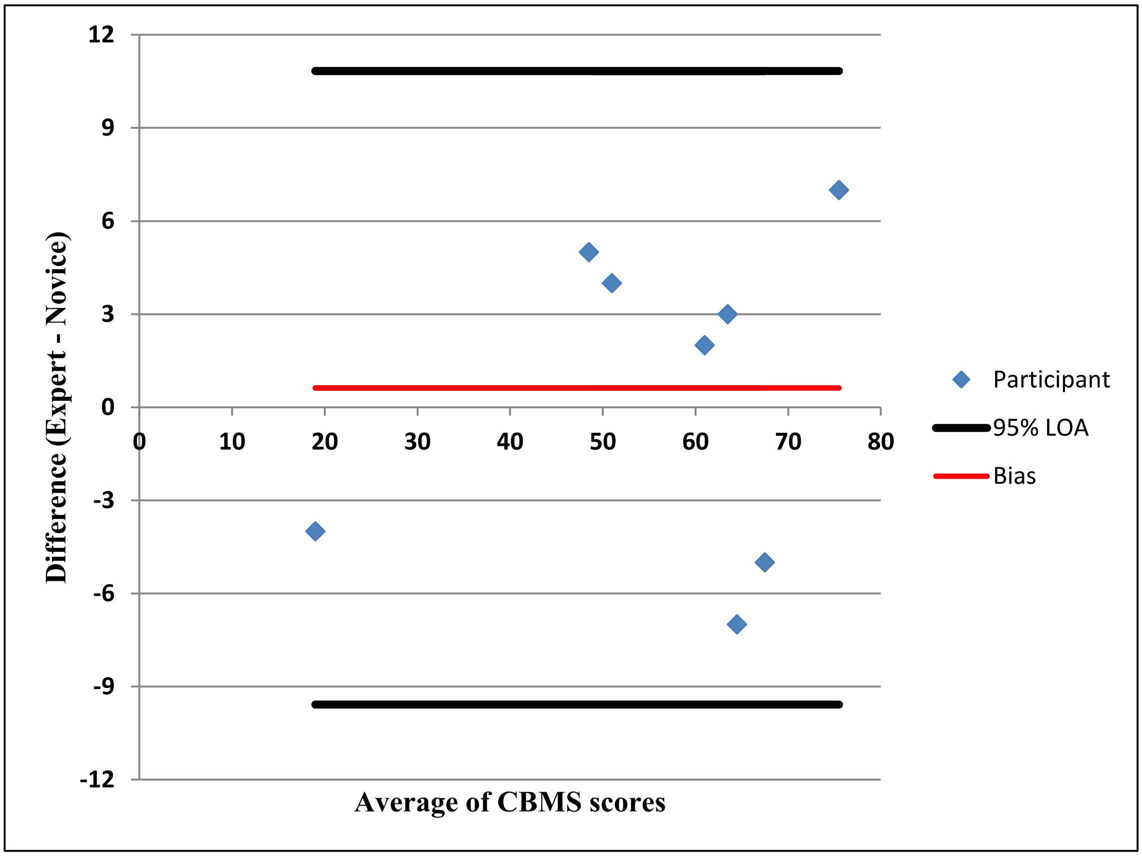
Appendix E: Agreement between expert and novice testers administering the CBMS

Balance deficits limit an individual's ability to participate in physical activity and exercise. This can have a negative effect on therapeutic exercise programs commonly prescribed to individuals with chronic disease. Therefore it is important to assess the balance of individuals participating in these programs in order to optimally prescribe therapeutic exercise. Many balance assessments have been developed for use in clinical populations. One such tool is the Community Balance and Mobility Scale (CBMS). The CBMS is commonly used by expert health professionals with years of testing experience for individuals recovering from stroke or traumatic brain injury. However, the amount of testing experience that is required to perform a reliable assessment on the CBMS is still unclear. Therefore, the purpose of this study is to test the interrater reliability between novice and expert testers administering the CBMS. Eight participants were recruited from the Heart for Life Cardiac Fitness Program to perform the CBMS while being assessed by a novice and expert tester simultaneously. The agreement between the testers was investigated using a correlation coefficient and Bland-Altman plot. Novice and expert CBMS scores were strongly correlated ($r=0.95$) and demonstrated little bias (mean difference 0.625 points). As well, all differences in scores fell well within the 95% limits of agreement (LOA) for the CBMS assessments. These findings suggest that health professionals with limited balance testing experience provide similar results to those of an expert tester and can be used interchangeably to monitor patients in therapeutic exercise programs.



Bland-Altman plot of the difference in CBMS scores vs. the average of the CBMS scores. Differences in CBMS scores were calculated by subtracting the novice from the expert testers' scores.