Rehabilitation Boot Camp: an Innovative, Four-Week Program to Deliver Intensive Balance and Mobility Therapy to People with Acquired Brain Injury (ABI)

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Abstract:

People with Acquired Brain Injury (ABI) often suffer from residual balance and mobility problems, which prevent activity and participation in their homes and communities. Cognitive problems can further impair balance and functional mobility, since cognitive and balance tasks can compete for limited attention. Intensity of the Repetitive Functional Task Practice (RFTP), the treatment best supported by evidence to promote neuro adaptation, has been shown to often be inadequate even in in-patient rehabilitation facilities.

This case series looked at the feasibility of treating community-dwelling people with ABI, in a group format, thus allowing economical, intense rehabilitation. Four participants attended a "Boot Camp" aimed at improving balance and mobility for four weeks, three days/week, 4.25 hours/day and run by one licenced Physical Therapist and one Rehabilitation Aide. One-to-one and semi-supervised, challenging, goal-directed activities, with and without use of computer gaming to drive cognitive-visual function was delivered with one therapist and one assistant. The mean amount of time engaged in RFTP related to balance/mobility was 89.51 minutes per treatment day. The total amount of time spent in other physical rehabilitation activities including strength, endurance and stretching was 134.82 minutes. On 5 of 12 boot camp days, extra assistance was required (mean 0.56 hours of extra assistance/day).

A focus group was held to explore the participants' experience of this type of rehabilitation. Positive perceptions included enjoyment of the social aspect of the group, variety of therapy activities, feeling of physical and self-confidence improvements, and a consensus that although the program was challenging, it was "do-able". Challenges included transportation issues and

participant desire to have more supervision in order to feel safe while practicing balance hands-free.

Pre and post-intervention measures were compared to determine if any there were any positive changes in balance, mobility or participation measures for the individual clients. Three of 4 participants demonstrated positive change on the PART-O 17. All participants had improvement on at least one of a battery of clinical performance measure. The Sway Path Length (SPL) of the centre of foot pressure (COP) ML and/or AP reduced, indicating balance performance improvements for all participants during clinical measures and/or Single and Dual Task balance performance. The secondary visual tracking and cognitive tasks showed inconsistent improvements. The participant, who could perform dual task walking, demonstrated improvements in the walking performance measure COV SW, but not on Paretic/Non-Paretic Single Leg Stance time.

Another goal of this project was to determine if daily, electronic monitoring may be beneficial in determining a) if balance ability is changing and b) if the rehabilitation exercises are of an appropriate level of difficulty for individuals. Features of the Centre of Foot Pressure (COP) signal from the FSA pressure sensor were analysed to determine this. Total load from each foot for hemi-paretic participants and COP-ML excursion during preparation for single leg stance phase may be useful to automate for future clinical use.

This project allowed the formation of guiding principles for future research and development of this ABI Boot Camp model.

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Above all, thank you to my participants whose perseverance and courage is an inspiration.

Dedication

I dedicate this to my mother, Emily Margaret Nett, whose life-time of exemplary scholarship has inspired me to look at apparent truths with a critical eye.

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I. INTRODUCTION

An exploratory, case series was performed to test the feasibility of providing rehabilitation for people with chronic ABI with balance/mobility impairments using the following essential treatment components:

- a group setting
- task-specific training
- interactive computer-based exercise
- daily objective monitoring
- collaborative activities and social support
- a four-week block of high intensity intervention with cognitive enrichment

Rationale for study of this area:

There is a significant number of people surviving ABI and returning to the community. Of an estimated 1.7 million people who sustain an ABI due to trauma in the United States, 223,000 (13 %) require hospitalization and survive (Faul, Xu, Wald, & Coronado, 2010). Forty percent of these are left with residual deficits (Corrigan, Selassie, & Orman, 2010). One study estimates that 2% of the US population lives with disability associated with trauma-related ABI (Kraus, Chu, Silver, McAllister, & Yudofsky, 2005)

People with moderate to severe ABI are discharged from in-patient rehabilitation before they attain their full recovery potential. The rationale is sound. Participation in home and community life is part of the rehabilitation process; it is desirable and is less costly than institutionalization. Patients and families want to return to non-institutionalized life as soon as possible for social reasons. However, once they are no longer receiving in-patient rehabilitation, many do not have adequate opportunity to practice new functional tasks, due to little time in out-patient therapies.

Cognitive and motivational deficits inherent to the injury, as well as care-giver burden can prevent functional mobility practice in an unsupervised setting. The literature supports supervised activity to enhance client participation (Hassett et al., 2009; Lynch, Harling, English, & Stiller, 2008; Wise, Hoffman, Powell, Bombardier, & Bell, 2012).

For this reason, an intensive “boot camp” model of therapy provided in a group was proposed. It was postulated that this model would provide greater supervised practice time, including motivational interactive gaming, at the cost of one hour of individual physical therapy daily. Although an intensive “boot camp” model could not be sustained throughout the entire rehabilitation process, it was hoped that it would improve functional level to the point that the client could participate more consistently and effectively in functional activity afterwards, thereby reinforcing and progressing gains.

There is a deficit of research into the logistics and benefits of group physical rehabilitation for ABI’s apart from Cerebral Vascular Accident (CVA). Although some things can be extrapolated from the CVA literature, more global brain damage (traumatic or anoxic brain damage, etc.) differs in that these patients tend to be younger and there are more behavioural/cognitive deficits to impede treatment than the average community-dwelling person with CVA. Therefore although support for certain aspects of therapy can be derived from the CVA literature, it is not as clear whether group therapy is well-supported.

Finally, current clinical outcome measures do not provide sufficient information about quality of movement and are not change-sensitive enough to help therapists determine a) if treatment is appropriately challenging or b) if the small gradations of improvement are present on a day-to-day basis. More objective and sensitive measures that are easily obtained in the course of treatment would be valuable. Part of the focus of this study will be to utilize on-going recording of centre of foot pressure (COP) and motion monitor signals as part of the boot camp to determine if more objective, sensitive and frequent evaluation of progress concurrent with treatment can be derived seamlessly from this type of outcome measure.

II. RESEARCH OBJECTIVES:

- To observe and describe the workings of the proposed principles for running an intensive, group-treatment model for treating balance/mobility deficits in chronic, community-dwelling, brain-injured adults, especially with regards to practicality, safety and user appeal.
- To record the volume of balance and mobility practice, as well as other therapeutic exercise, delivered with this treatment model.
- To note if a trend towards positive change in balance, and mobility impairment, disability and participation occurred after the intervention.
- To determine if daily monitoring of the amplitude of COP-ML during and ability to perform balance tasks hands-free could provide useful information re: trajectory of improvement and difficulty of tasks for therapists providing balance and mobility interventions.

III. HYPOTHESES

Hypothesis # 1:
Group therapy for people with moderate to severe ABI can effectively deliver a large volume of challenging, evidence-based therapy, which ensures safety, is appealing to participants and cost-effective.

Outcome Measures:

- Average amount of RFTP/therapy day (minutes)
- Extra staffing required/therapy day (minutes)
- Adverse Events (number)
- Participant satisfaction (description of Participant semi-structured interviews)

Hypothesis # 2:
Participants in the program will demonstrate improvements in an individualized battery of outcome measures of Impairment, Activity and Participation, as defined by the World Health Organization's International Classification of Functioning (ICF) (WHO, 2001) after 4 weeks in the Rehabilitation "Boot Camp" Program.

Primary Outcome Measures:

- **Related to Participation:** Participation Assessment Recombined Tools – Objective 17 (PART-0 17)
- **Related to Balance Impairment:** Sway Path Length of the Centre of Foot Pressure (SPL-COP ML-AP) during a Single Balance Task versus Dual Balance Task

Secondary Outcome Measures:

- **Related to Balance Impairment:**
  - Percentage of Time Performing Task without Hand Support during an individualized daily balance task (% time/assessment performing task without hand support)
  - Multi-directional Reach Test (MDRT) (distance in cm)

- Balance Performance during Multi-directional Reach Test determined by the Sway Path Length (SPL) Centre of Foot Pressure Medial-lateral and Antero-posterior during (mean sample velocity COP-ML and COP-AP (cm/s)).
- Balance Performance during Sponge Conditions of the Modified Clinical Test of Sensory Integration in Balance (mCTSIB) as determined by Sway Path Length (SPL) Centre of Foot Pressure Medial-lateral and Antero-posterior during (mean sample velocity COP-ML-AP (cm/s)).
- Effect of a Concurrent Task on Walking Performance while walking on a treadmill.

- **Related to Walking Balance Impairment:**
  - Coefficient of Variance Gait Step Width (COV-SW)
  - Ratio of Paretic/Non-paretic Single Leg Stance (SLS) time

- **Related to Concurrent Visual Cognitive Task Performance:**
  - **Horizontal and Vertical Visual Head Tracking Performance:** as measured with the co-efficient of determination compared to a perfect sinusoid **(COD horizontal and COD Vertical)**
  - **Visual-Cognitive Performance**: as measured with a) target success (%) b) reaction time (ms) and c) path length (cm)

- **Related to Balance and Mobility Activity Measure**:
  - Chedoke McMaster Stroke Assessment (CMSA) Activity Inventory: Gross Motor Function Sub-scale (out of possible 70 points)
  - Five Times Sit to Stand (5XSTS) measured by time to complete (s)
  - Balance Performance during Five Times Sit to Stand Test measured by the mean velocity of the COP-ML (cm/s)

- Two-Minute Walk Test (2MWT) (m)
- Unsupported Treadmill Walking Ability at 1 km/hour (yes/no)

Hypothesis #3:
Features of electronic pressure mat monitoring obtained concurrently with treatment will demonstrate within subject trends indicative of improvement.

Outcome measures:

- Percent Time Performing Individualized Balance Task Hands-free.
- Mean Trajectory of Centre of Foot Pressure-Medial Lateral (COP-ML) during transition to Single Leg Stance during Individualized Balance Task

IV. LITERATURE REVIEW

Support for the Proposed Treatment Model

Based on concepts of neural plasticity and adaptation, current best practices in rehabilitation after brain injury support repetitive functional task practice (RFTP) (Daly & Ruff, 2007; Marshall, Aubut, Willems, Teasell, & Lippert, 2013). The underlying theoretical basis for this practice is that the residual central nervous system has the ability to adapt and that specific, experience-based therapies will help to drive this in a positive way.

Plasticity of the adult central nervous system (CNS) in response to repetitive practice has been established in many realms of learning in normal mammals including human beings (Buonomano & Merzenich, 1998; Jones & Jefferson, 2011). Studies of new skills practice demonstrate the following neuro-adaptive mechanisms: enhanced synaptic responses leading to synaptogenesis, dendritic growth and change in morphology, axonal sprouting and expansion of the cortical map of the trained areas (Kleim, 2011). Similar processes are seen after insult to the brain and in fact, a cascade of physiological conditions occur post-injury to enhance this (Cramer et al., 2011; Dancause & Nudo, 2011; Dimyan & Cohen, 2011; Jones & Jefferson, 2011; Kleim, 2011; Winship & Murphy, 2009; Wittenberg, 2010). Animal (rodent and primate) models (Castro-Alamancos & Borrel, 1995; Dimyan & Cohen, 2011; Friel, Heddings, & Nudo, 2000; Nudo & Milliken, 1996) and neuro imaging studies of humans after CVA support the occurrence of neurological remodelling in response to task practice. (Forrester, Wheaton, & Luft, 2008a; Hodics, Cohen, & Cramer, 2006; Luft et al., 2008; Nelles, Jentzen, Jueptner, Muller, & Diener, 2001).

Although the CNS is primed to "rewire" after injury, connections will not necessarily be adaptive. Animal models have shown that a lack of use has a negative effect. This is illustrated by Taub's seminal work on learned disuse in de-afferented monkeys who not only avoided using their affected upper limb, but actually lost ability to use it (Taub, 1976). Kleim & Jones (2008) summarize the large body of research on central nervous system reorganization in response to varied sensory and motor deprivation, noting consistent loss or reallocation of the related cortical representation. A number of studies have been done comparing recovery of cortically lesioned rodents in "enriched" (EE) versus "impoverished" (IE) environments; the actual difference being that the EE's provide opportunity for the animals to engage in socialization and task practice, whereas the IE's do not. Functional improvements and physiological measures are better with the EE, indicating that without functional task practice, meaningful new neuronal connections will not occur (Hamm, Temple, O'Dell, Pike, & Lyeth, 1996; Will, Galani, Kelche, & Rosenzweig, 2004; Xerri & Zennou-Azogui, 2003). It has also been demonstrated that inappropriate task practice will not facilitate neuro-adaptation. Unilateral training of the non-paretic side in rats with motor cortex lesion of the dominant forepaw showed decreased paretic side function compared to those who trained the affected limb or did bilateral training. Training the intact forelimb also decreased FosB/ΔFosB, a transcription factor used as a measure of neuronal activation, in the lesioned supplementary motor area of the cortex compared with the animals that did not selectively train the non-affected limb (Allred & Jones, 2008).Therefore, practice must be related to the desired outcome (i.e. be functionally related to the task requiring improvement).

It could be argued that many people recovering from a moderate to severe brain injury experience an impoverished environment and/or not enough appropriate task practice upon discharge from in-patient rehabilitation. Often out-patient therapy time is limited due to fiscal constraints, and many prior, meaningful activities can no longer be performed or require significant support. Previous social contacts are often lost, due to the radical change in the person's cognition and behaviour, thus the bulk of input falls to immediate family members or home service workers (Lippert et al., 2013). Time and energy pressures, as well as lack of education in principles of rehabilitation can cause care-givers to encourage compensatory strategies rather than those which will ultimately lead to improved quality and independence of mobility. It is for this reason that a more cost-effective, intensive out-patient treatment model is proposed.

Repetitive Functional Task Practice

In human research, RFTP is defined as actively engaging people on a regular and frequent basis in meaningful tasks that are specific to the desired outcome. A review of repetitive functional task practice in stroke survivors (French et al., 2008) supports efficacy of this type of therapy with strongest evidence for lower limb task specific practice. The stroke rehabilitation literature has since produced two large multi-centre trials that support RFTP.

The Extremity Constraint Induced Therapy Evaluation (EXCITE) trial (S. L. L. Wolf, 2006; S. L. Wolf et al., 2008) studied Constraint Induced Movement Therapy (CIMT), an intensive upper limb re-education program. It randomized 222 participants who were 3-9 months post-stroke into two groups based on upper limb functional ability. 106 subjects received immediate CIMT and the others received “usual and customary care” which ranged from no care, splinting, to therapy either in the home or out-patient setting, in the same time frame. The control subjects were also offered CIMT 12 months later. The intervention was provided 5 days a week, 6 hours per day for 2 weeks.

Primary outcome measures were the Wolf Motor Function Test (WMFT), including Performance Time, and Functional Ability Scale (which was videotaped to allow rating of movement quality) and the Motor Activity Log (MAL), including patient and care-giver rating of amount of use and how well the affected limb was used on a battery of 30 functional upper limb tasks. Secondary outcomes were the Stroke Impact Scale (SIS) hand function and physical function subsets and the WMFT Weight to Box Test and Grip Strength. Measures were performed on groups, at baseline, post-treatment, and 4, 8, and 12-months follow-up. Significant improvements were noted in both groups at all of these points, but the CIMT group had significantly greater gains in all outcome measures. This group also achieved a score of ≥ 3 on significantly more tasks of the Quality of Movement subset of the MAL, which is clinically relevant as it indicates at least a 50% increase in arm and hand use and without assistance of the unimpaired arm (S. L. L. Wolf, 2006). A second study followed the initial treatment group 24 months later and found that gains were either maintained or, in some cases, continued in the second year. (S. L. Wolf et al., 2008)

The Loco-motor Experience Applied Post-Stroke (LEAPS) trial (Duncan et al., 2011) a large multi-centre, single-blind randomized controlled trial studying the effects of Bodyweight-supported treadmill training (BWSTT) was also published after the French et al review. Four-hundred and eight participants who had had a stroke within 2 months were included. They were stratified to moderately or severely impaired walking groups and randomized to three groups; those who received loco-motor training (LT) via body-weight supported treadmill training immediately, those who received an intensive home therapy program aimed at gait and mobility, and those who received "regular care" and were offered LT 6 months later. Both of the immediate treatment groups were treated by a physiotherapist for thirty-six 90 minute sessions over the course of 12 to 16 weeks.

At 6 months, both the RFTP groups (either LT or Home therapy) had significantly more improvement than the Late LT group in the following measures: Walking speed, Six Minute Walk Test (6 MWT) distance, Short Form 36 (SF-36) mobility subscale, Berg Balance Scale (BBS) and (Activities-specific Balance Confidence) ABC Scale. This indicates that the groups who had received systematic, experiential training at that point made more gains than those who did not regardless of whether it was via treadmill training or other appropriate exercise. At the 12 month point, there was no change in the groups as the Late LT group, after having received intensive training, caught up. The result indicates that this type of treatment can be effective even slightly later in the recovery phase.

Ways to Increase Volume of Practice

One of the fundamental ingredients of RFTP is the high level of practice intensity (Forrester, Wheaton, & Luft, 2008b). In the case of RFTP, intensity is not defined by the biomechanical concept of work or power (which would be appropriate in such things as bicycle ergometry) but rather as either duration of or number of repetitions of practice (Kwakkel, 2006). It has been noted that animal studies have required in the order of 1000-2000 step iterations per day to improve walking ability (Hornby et al., 2011).

There is evidence that intensity of practice can make an impact on functional outcomes in humans. The classic model of CIMT used to treat upper limb dysfunction in CVA provides structured practice for 6 hours a day for 10 consecutive working days, with multiple repetitions of a variety of functional tasks (for a total of in the order of 100's of activity repetitions). Further practice is encouraged by constraint of the less affected UL during non-therapy hours (S. L. Wolf et al., 2008).

Similar benefits have been found in a study of a much smaller scale of CIMT for ABI subjects (Shaw et al., 2005). Twenty-two people with chronic trauma-related ABI were provided with CIMT (2 weeks, 6 hours/day with expectation to use constraint mitt during non-therapy hours) and regardless of initial levels of impairment (divided into 3 categories) made gains in WMFT, Fugl-Myer Motor Abilities Scale Upper Limb (FM MAS UL) and MAL, including the Quality of Movement and Caregiver subscales as well as participant scoring. The amount of improvement was greater in the subjects who complied more consistently with the less affected limb constraint in the off hours, further supporting the benefits of more repetitions of practice.

Further to upper limb therapy, (Byl, Pitsch, & Abrams, 2008) looked specifically at dose of RFTP in chronic stroke survivors. Fifty-two subjects were randomized into 3 treatment groups. Actual therapy activities were the same for all groups but the groups received the following therapy intensities: 1x/week for 1.5 hours/visit, 3 times per week for 0.75 hours/visit, 4x/ week for 3 hours/visit. The third group demonstrated significant improvements compared to the other groups in the following measures: Functional Independence (tested with the California Functional Evaluation (questionnaire) and the WMFT), Sensory Discrimination (tested with the Byl, Cherney, Boczai Test, graphaesthesia testing) and Fine Motor Skills (stopwatch on/off, finger tapping speed). There were no changes in grip strength improvements.

Ability to generate volume of practice is one of the driving forces behind BWSTT (Hornby et al., 2011). Moore, Roth, Killian, & Hornby (2010) found that chronic stroke patients, who had been considered to have plateaued in conventional physical therapy, during which they received an average of 1000 steps per treatment session, improved their 6MWT distance and oxygen consumption with BWSTT in which they received an average of 4000 steps. They were also noted to perform more steps in non-therapy hours, as measured with a pedometer. The LEAPS trial (Duncan et al., 2011) demonstrated that it was not specifically the BWSTT, but rather the intense volume of practice of walking-related activities that improved walking function. A review article of a variety of CVA programs designed specifically to increase the dose of gait-related practice showed moderately significant summary effects of these interventions to improve walking ability, speed and instrumental activities of daily living (ADL's) (Veerbeek, Koolstra, Ket, van Wegen, & Kwakkel, 2011). Canning et al. (2003) studied a program to provide increased practice of sit-to-stand for sub-acute severely brain injured individuals. Of twenty-four subjects, 13 were randomized to the augmented practice group and received additional daily practice of 100 repetitions of sit-to-stand (STS) and 60 repetitions of step ups, 5 days a week for 4 weeks, while participating in customary physical therapy. The additional practice group improved the number of STS repetitions that could be performed in 3 minutes by 18% (significant), but did not change VO_2 outcomes. As a result, increased speed was seen as an indication of improved efficiency of movement rather than improved aerobic capacity.

Cifu, Kreutzer, Kolakowsky-Hayner, Marwitz, & Englander (2003) used contact time, as indicated by billing records, to determine intensity of various therapies for 491 brain injured patients in an in-patient rehabilitation facility. They noted great variation between patients but that higher contact time with Physical Therapy correlated with higher motor Functional Independence Measure (FIM) scores, thus supporting the value of more practice related to the desired outcome. Higher intensity of Occupational Therapy and psychology services did not correlate with increased the motor subset of the FIM which would also support this.

In practice, large volume of FRTP is not always successfully delivered even in rehabilitation settings (Bernhardt, Dewey, Thrift, & Donnan, 2004; Kimberley, Samargia, Moore, Shakya, & Lang, 2010; Lang, Elson, English, & Hillier, 2009). Lang et al (2009) studied the amount of time and the number of repetitions per therapy session focussing on a given activity during in-patient Stroke Rehabilitation. Upper limb practice occurred during 51% of the treatment session time and provided an average of 32 repetitions of the functional activity. Therapy sessions focussed on gait practice provided actual practice 84% of the time providing an average of 357 steps.

An audit of a 69-bed New Zealand Rehabilitation Unit on two occasions showed that only approximately 11% of patients' waking time was spent in therapy activities while close to 45% of the same time was spent alone in their rooms (Thompson & McKinstry, 2009). Another audit of 58 patients on acute, specialized stroke units showed that only 14% of work-hour time was spent doing any sort of therapeutic activity that would improve physical mobility (Bernhardt et al., 2004). These patients were monitored every 10 minutes from 8 am to 5 pm on 2 consecutive days and activities were categorized. Fifty percent of this time was spent in bed.

There is some evidence that ABI patients may fare better than CVA patients in rehabilitation in terms of receiving more active practice but even as in-patients the ideal intensity is not being provided. A descriptive study was done comparing the amount of repetitions of functional practice provided to CVA versus traumatic ABI clients (total n=48) in therapy sessions in both in and out-patient rehabilitation (Kimberley et al., 2010). Although there were differences in the amount provided by individual therapists, overall ABI clients received more practice than CVA clients, possibly due to being younger and having more stamina. However, neither received the order of 400-600 daily repetitions required to effect structural brain changes in animal models. Step practice repetitions were closer to that ideal at one to two-hundred than were upper limb activities, which were in the tens.

As a result there has been study into ways to get patients and family members to facilitate practice outside of the therapy session. The Family-Mediated Exercise (FAME) and Graded Repetitive Arm Supplementary Program (GRASP) trials are examples of effective, structured "homework" during non-therapy time to provide additional RFTP in the stroke population

(Galvin, Cusack, O'Grady, Murphy, & Stokes, 2011; (Harris, Eng, Miller, & Dawson, 2009). While this can be effective, not all clients have family members to assist with this strategy and, as a result of their injury, many people with ABI are lacking the internal drive and memory needed to follow through with independent exercise.

For this reason our model is proposed to fill in some of these gaps. Use of group treatment to improve mobility, balance and fitness has been documented to have multiple benefits. Group treatment allows for increased time spent in therapeutic activity without increasing the cost of service delivery. When an inpatient physiotherapy department implemented circuit training classes in an effort to improve stroke therapy delivery without changing therapy resources, percentage of time spent in therapeutic activity versus non-therapeutic activity increased significantly (De Weerdt et al., 2001).

In the stroke literature, group treatment has been shown to provide treatment which is effective in treating balance and mobility problems. A meta-analysis of six studies by Wevers et al (2009) demonstrated significant improvements for 6MWT scores after group therapy for sub-acute and chronic stroke subjects. The (Fitness Intervention Trial) FIT trial, a multi-centre study, looked at CVA out-patients immediately after discharge from in-patient rehabilitation (van de Port, Wevers, Lindeman, & Kwakkel, 2012). One-hundred, twenty-six subjects received circuit training physiotherapy consisting of 8 stations designed to improve walking performance and 124 received usual physiotherapy care. Treatment occurred for ninety-minute sessions twice weekly for 12 weeks. Improvements in objective walking variables as well as all domains of the Stroke Impact Scale except the fatigue severity subscale were seen in both groups at 24 weeks from intervention start. The circuit group performed significantly better in the 6MWT, 5 metre comfortable walk speed and modified stairs test. No adverse events were noted in either group.

A smaller sample of older adults with stroke (n=10) provided clients with a group treatment that had levels of progression built into each station to allow for individuality and challenge as the subjects improved (Michael et al., 2009). One-hour sessions were provided 3 days/week for 6 months with improvements noted from baseline to 6 months in the BBS, Dynamic Gait Index, 6MWT and the VO2 Peak. In another study, twenty chronic stroke survivors participating in a community exercise group of one hour, two times a week demonstrated significant improvements in the Stroke Impairment Assessment Set (SIAS), BBS, step test, Timed Up and Go Test (TUG) and 6 MWT after 8 weeks (Leroux, 2005). There was no difference in the improvements based on chronicity or age. English, et al (2007) demonstrated that group treatment can be as efficacious as individual treatment. They studied 68 sub-acute inpatients receiving stroke rehabilitation, randomized into circuit-class versus individual physical therapy. At 6 months post stroke, there was no statistical difference in performance of gait speed (5 meter walk test), 2 MWT, BBS, the Upper Limb subscale of the MAS, the Iowa Level of Assist to Walk nor hospital length of stay.

Most importantly, the group format for balance and mobility training does not appear to have a negative impact on safety (Stuart et al., 2009; I. van de Port et al., 2012). A trial of a similar program for older adults with balance and mobility impairment (not limited to but including people with neurological impairment) was also noted to have no adverse events despite the group format (Sherrington et al., 2008). Likewise, patient satisfaction is not altered and may be enhanced (Lynch et al., 2008; Richard, Jakobov, Sosowsky, & Leiser, 2008).

As previously mentioned, there is limited research on the efficacy of RFTP groups for other ABI apart from CVA. However, there is some evidence that this format does improve participation in fitness activities in this population. Mild to moderately brain injured clients provided with a supervised versus unsupervised gym exercise program attended significantly more exercise sessions (Hassett et al., 2009). Even with limited supervised group time, participation in fitness activities outside of the group setting was improved in an out-patient ABI study (Wise et al., 2012).

Other benefits include a positive impact on subjects' psychosocial functioning. Mild head injured people (n=40) participating in an aerobic exercise group 1 time/week for 10 weeks with instruction to exercise 4 additional times per week had significantly improved indicators of mental health and Quality of Life (QOL). (Beck Depression Inventory, Short Form 12-Perceived QOL Scale) and were more likely to increase and sustain increased aerobic exercise for at least 6 months (Wise et al., 2012). Stroke in-patients participating in a circuit physiotherapy program demonstrated a decrease in solitary time (De Weerdt et al., 2001). As well, self-efficacy, as seen in significant changes in the ABC Scale for stroke survivors participating in group walking programs, (Park, Oh, Kim, & Choi, 2011; Salbach et al., 2004) improves.

Another dimension of brain injury that should be addressed in physical rehabilitation is the need to integrate visual spatial processing and multi-task challenge into balance and mobility practice

(Hayes, Donnellan, & Stokes, 2011; K. McCulloch, 2007; McFayden et al., 2009). Because of the global brain damage associated with ABI's, multiple cognitive and perceptual functions can be affected. These can make an impact on recovery of physical mobility in a number of ways. Mobility demands cognitive skills, especially aspects of attention, working memory and processing of sensory information, to navigate effectively through complex environments. In a naturalistic setting where there are distractions and unexpected balance and mobility challenges, cognitive impairment may reduce the person's participation in functional mobility or render them at risk of falls and subsequent injury.

In a review looking at the impact of executive cognitive function impairment on physical therapy in CVA subjects, a correlation was found between lower performance on the Stroop test (a cognitive measure of attention) and lower scores on the BBS, TUG, 6 MWT and stair climbing test (Hayes et al., 2011). Likewise, the reviewers cite two studies that support the effect of reduced cognition on ADL functioning. This becomes a vicious cycle, because the very activities that the brain-injured person should be practicing may not be safe to perform without supervision and guidance.

Real life demands the ability to multi-task mobility and cognitive activities. Multi-tasking is the ability to perform two or more discreet tasks at the same time. For example, a person may be moving around the kitchen while mentally planning and physically performing meal preparation. Attention is normally allocated in alternating periods of time to each task as required, based on novelty, difficulty and urgency of respective tasks (Cernich, Kurtz, Mordecai, & Ryan, 2010; K. McCulloch, 2007). A healthy person can flexibly allocate their attention depending on changing circumstances. McCulloch's (2007) comprehensive review article of the impact of cognition on mobility in ABI describes the following mechanisms proposed in the literature to explain multi-tasking difficulties: deficits in previously automatic cognitive and/or physical functions can cause more attentional resources to be required for one or both of the tasks, thus reducing the surplus attention available for the second task. As well, compromised processing speed of either task can cause the person to not be able to switch back and forth between tasks in a timely fashion. If two tasks require similar, limited modality resources there will be interference. An example would be standing on a moving bus while texting. In this case, visual cognitive cortical space is required for both the processing of visual cues used to maintain balance and for the texting. Additionally, some people may have limited ability to recruit, divide or prioritize the attention required to perform either or both tasks due to executive deficits. This review cites multiple studies demonstrating decline in balance and walking performance upon the addition of a secondary task, in the elderly and neurologically impaired populations.

The dual task paradigm is used to assess the ability to perform more than one task successfully. Performance on both tasks is evaluated individually and then compared to performance when done simultaneously (Abernathy, 1988).This can then generate a dual task cost expressed as a percentage. It is proposed that this model should be used during treatment, with progressive increments in difficulty of one or both tasks to meet desired functional rehabilitation goals (K. McCulloch, 2007). Practically this would mean engaging the client in a program that periodically targets physical and visuo-spatial cognitive retraining simultaneously.

One method of providing this would be through monitored, interactive, computer gaming which has been shown to be effective at providing aspects of cognitive challenge (Cernich et al., 2010). Because interactive gaming necessitates screen interaction, it challenges gaze control, visual spatial perception and attention, all functionally related to balance and mobility. It can easily be combined with physical balance demands to function as an effective dual task treatment paradigm. Gaming is also an easily monitored secondary task, thus providing objective performance measures to assist with grading and progressing activities. Multi-task training would also be an efficient use of the client's time and energy, since cognitive and physical retraining are both important aspects of rehabilitation. Cognitive tasks could also be potentially more effective if delivered in a goal oriented context (Cernich et al., 2010; Ponsford, Sloan, & Snow, 2012).

Integrating computer games into rehabilitation provides other benefits. They are intrinsically fun and motivating which can combat the tedium of RFTP. If games are appropriately selected and graded, they can enhance client attention and energy levels. For example, more physically or cognitively demanding tasks can be combined or alternated to allow for periods of intense challenge and then those of relative rest without activity cessation.

Limitations in Balance and Mobility Measurement during Therapy

Research discussed above has used volume of practice as a measure of intensity. The other dimension of intensity of practice, that is not as well measured, is the level of difficulty/challenge. Skilled clinicians may sense intuitively when their clients are working at an optimal level of difficulty and when small increments in ability indicate that progress, but the ability to monitor this objectively is limited with commonly-used clinical outcome measures.

There are numerous assessment tools that measure aspects of balance (Pollock, Eng, & Garland, 2011; Tyson & Connell, 2009). They are limited in the scope of balance ability that they measure, and many therapists cobble together a number of these tests to get a well-rounded picture of a person's progress. (Horak, Wrisley, & Frank, 2009) proposed the Balance Evaluation Systems Test (BESTest) which consists of six components of evaluation for thoroughness in this area. As a result, formal clinical balance evaluation is time consuming with current clinical balance measures, and in practice, only done every few weeks to few months.

Even with a multi-dimensional approach there are some aspects of balance for which clinical tools are lacking. Measures that aim to look at the effect of multitasking on balance/mobility have inadequacies. For example, the Walking and Remembering Test (K. L. McCulloch, Mercer, Giuliani, & Marshall, 2009), does not truly pose the subject with a concurrent task. Some fail to measure performance on both the motor and secondary cognitive task (TUG-cognitive (Shumway-Cook, Brauer, & Woollacott, 2000) and Walking While Talking Test (de Hoon et al., 2003)) and some do not provide a secondary task that requires significant attention. For example turning the head towards a target in the Community Balance and Mobility Test (Howe, Inness, Venturini, Williams, & Verrier, 2006) limits the visual flow available to walk and balance, but does not actually demand much cognition or gaze control.

Although a comprehensive battery of clinical tests can give a useful snapshot about the client's balance and mobility, it captures little about *how* the balance activity was performed, and if it is closer to being successful than it was the day before. The ability to keep a bi-pedal body upright is tremendously complex and an almost infinite variety of strategies may be used to do this due to the multiple degrees of freedom of body segments and systems of neurological control. Balance re-education for brain injured people is a series of trial and error learning (Harbourne & Stergiou, 2009). The person has altered abilities and needs to attempt different ways of dealing with gravity and other forces in an efficient, effective way. There is not one correct way, so there will be many unsuccessful attempts. Occasionally that person will execute balance activities in a way that works and then with the next trial the same strategy may not be effective due to different circumstances. Although this type of learning is characterized by inconsistency of performance, the therapist would like to know if the attempts are getting closer to being successful either with repetition or through modifications aimed at better grading the activity. If they are not, a different activity must be devised. If they are, eventually the activity must be progressed. Currently therapists must adopt a "wait and see" approach, because there is not this sort of concurrent monitoring of trends in therapeutic activity performance. This may either cause delay in changing therapeutic activities or premature or delayed discontinuation of an activity because it does not appear that the client is progressing. For this reason, part of the focus of this study looked at electronic monitoring during balance task practice to see if features of the centre of foot pressure (COP) could be used to provide ongoing objective information to guide treatment.

Laboratory Outcome Measures

Laboratory technologies used to measure balance ability, including kinematic data derived from multiple cameras (McGinley, Baker, Wolfe, & Morris, 2009), ground reaction forces from force plates and force sensor mats as well as acceleration and/or velocity signals from motion monitors (Allum & Carpenter, 2005; Kavanagh & Menz, 2008; Tong & Granat, 1999) can provide more objective and quantifiable information. However, in the past they have been prohibitive to use clinically due to cost and time-consuming set up and/or data analysis. Technologies are becoming progressively less expensive and less intrusive to use (Bonato, 2005). However, although the technology is fairly accessible, there is difficulty determining which variables of collected data may be the most useful as markers of good functional balance. Research has mainly looked at data during either still standing or walking and has not explored other standing tasks with a dynamic base of support (BOS) that would be commonly performed in daily life.

Findings from Standing Balance Studies:

A review and meta-analysis of force plate findings and fall correlation by (Piirtola & Era, 2006) found that the COP-ML velocity and root mean square (RMS) were indicative of fall risk. The increased amplitude of COP-AP and ML has been correlated with poorer performance on the BBS in CVA patients (Corriveau, Hébert, Raîche, & Prince, 2004; Yu et al., 2008). Desai, Goodman, Kapadia, Shay, & Szturm (2010) found higher values of COP (SPL and peak to peak (PTP) ML) while performing rhythmic oscillatory movements on an unstable surface were seen to differentiate older fallers from non-fallers. It is important to recognize that still standing balance ability cannot shed light on walking balance (Dingwell & Cusumano, 2000). Kang & Dingwell (2006) compared a non-linear measure of local dynamic stability of linear and angular velocity of the trunk during still standing and treadmill walking in normal subjects and determined that there was no correlation between these. They also determined that it takes longer to recover from perturbations while walking than during still standing.

Findings from Walking Balance Studies

Walking balance studies are numerous; however consensus is poor as to which aspects of the data are relevant for quantification of balance ability or falls prediction. Two methodological difficulties contribute to this: the lack of control for walking speed and studies of short steps series. Walking speed affects gait dynamics, (Jordan, Challis, & Newell, 2007; Stoquart, Detrembleur, & Lejeune, 2008) and people typically slow down when they feel off balance (Menz 2003). Therefore, not controlling speed may confound measures such as trunk accelerations (Kavanagh & Menz, 2008). There is a U-shaped correlation between speed and stability; i.e. at both very slow and very high speeds, stability declines. This is especially true where outcome measures are linear such as spatial temporal parameters or average trunk acceleration (Jordan et al., 2007; Stoquart et al., 2008) but is also seen with non-linear analysis of local stability (Dingwell 2006), (England & Granata, 2007). Treadmill studies inherently control for walking speed.

Many walking balance studies are done on overland walking over short courses (4 -10 m). Bruijn, van Dieen, Meijer, & Beek (2009) used a bootstrapping procedure to determine the length of data series needed to render a theoretical mathematics stability analysis indicator of local instability (Lyapanov exponents) of trunk accelerations, valid as a measure of walking balance. They felt that at least 150 consecutive steps were required, which would make testing on a short walking course, such as the GaitRite carpet, questionable.

Because of these concerns, the evidence guiding selection of this study's outcome measures of walking balance is based solely on studies that looked at longer series of data gathered during treadmill walking.

Temporal Spatial Gait Parameters have been used as walking performance measures. Step width variability appears to be an important variable. In a study measuring COP on a treadmill, (Owings & Grabiner, 2004) demonstrated that step width variability was the only spatial temporal parameter that differentiated younger from older healthy walkers. Distorting visual flow input while treadmill walking in normal subjects created significant variability in the COP-ML (reflective of step width) but not in CO-AP (O'Connor & Kuo, 2009). Dingwell, Robb, Troy, & Grabiner (2008) looked at normal subjects walking on a treadmill with and without a visual Stroop test, and noted that variability, as indicated by standard deviation of step width as well as trunk velocity in all directions actually decreased with the Stroop test (i.e. the subjects reduced variability, possibly in an effort to stabilize the head and gaze). Pelvis constraint during treadmill walking, with an elasticized belt tethered to a stationery support, reduced step width variability but made no impact on step length in healthy subjects (Donelan, Shipman, Kram, & Kuo, 2004). This suggests that reducing balance demands during treadmill walking is more likely to make an impact on gait variability in the ML direction, and therefore possibly the corollary, that reduced ability to balance will be reflected in increase ML variability.

Szturm et al. (2013) studied young normal subjects walking on a treadmill while performing head movements that were either simply sinusoidal or requiring foveation and/or visual-cognitive dual tasking. In this study, addition of tasks did not increase the COV of step width, but increased the COV of Stance Time, Swing Time and Double–support Time. Interestingly the COV of measures of ML trunk angular velocity amplitude decreased, suggesting that that this would be a normal strategy to promote gaze control.

VI. METHODS:

Recruitment

Health care practitioners who work with people with ABI in the City of Winnipeg and the surrounding areas were asked to assist with recruitment. This included Dr. Lena Galimova, the physiatrist for the Acquired Brain Injury Rehabilitation Unit at Riverview Health Centre, as well as out-patient Occupational, Physical Therapists and Speech Language Pathologists in the public and private sector, and private Rehabilitation Consultants, including those at the Transitional Living Centre and the Neuro Recovery Services at the Occupational Rehabilitation Group of Canada. These health care workers were asked to either provide potential participants with the primary investigator's contact information or provide her with the contact information of amenable, potential participants. An advertisement poster aimed at the general population was provided to the Manitoba Brain Injury Association for distribution and posting.

Inclusion:

- **Age:** 18 – 55 years old
- **Diagnosis:** Moderate to Severe Acquired Brain Injury due to trauma, anoxia or infection, one to five years since onset. The following definitions apply:
    - **Moderate**=Loss of Consciousness (LOC) 15 minutes to six hours, Post Traumatic Amnesia (PTA) up to 24 hours **OR** Glasgow Coma Scale (GCS) of 9-12 points
    - **Severe**=LOC greater than six hours, PTA greater than 24 hours **OR** GCS 3-8 points
- **Physical Function:**
    - Able to sit independently unsupported at the edge of the bed
    - Able to provide assistance when rising from sit to stand

- Able to stand unsupported (with or without supervision) for at least thirty seconds.
- Standing tolerance of at least three minutes (may use upper limb support to stabilize).
- Able to voluntarily move at least one leg (with or without synergic movements).
- Functional use of at least one arm and able to actively lift to 90˚ shoulder elevation.
- If the person is able to walk independently, he or she requires a walking aide, has difficulty walking outdoors or on uneven terrain, and/or demonstrates an abnormal gait pattern.
- Medically stable and with the tolerance to be physically and mentally active over the treatment day with appropriate rests.
- Can safely and independently eat, drink and use a toilet or availability of an assistant to help with these functions.

- **Cognition:** sufficient for the subject to understand the purpose and demands of the study protocol to an extent that he or she can provide informed consent.

- **Language Ability:**
  - The subject required sufficient ability to communicate with English language users to follow motor instructions consistently and to express needs and/or difficulties that may be experienced over the course of the treatment day.
  - The subject must have sufficient language ability to understand the consent form either in a written or spoken presentation to an extent that he or she can provide informed consent.

- **Behaviour:** Impulse control and social skills are adequate such that ,with only minimal, occasional redirection from therapy staff, the subject can participate in a group setting without disturbing the therapeutic environment.

Exclusion:

- **Diagnosis:**
    - ABI due to primary thrombotic CVA.
    - Mild ABI/concussion.

- **Physical:**
    - People who do not meet the above minimal sitting and standing criteria or are regularly walking in all conditions, outdoors without a walking aide and without any apparent gait deficit will not be eligible.
    - Subject has poor tolerance, and/or is unable to meet biological needs (as above) during treatment times.
    - Unwilling to provide permission for researchers to obtain medical approval to participate in program.

Of twenty-two potential participants, 13 people expressed interest in the program once it was fully explained by the researcher (See Appendix A). Nine of these were deemed inappropriate for the study after the telephone interview. The most common reason that possible participants were considered inappropriate was fully recovered physical function with only cognitive deficits remaining (six people, self-reported). The other reason was that cognitive impairment was such that they could not provide informed consent (three people, as reported by caregivers).

Because there were so few people who both met the criteria and wanted to commit to the demands of the study, the investigators relaxed some criteria to allow more people to participate in the boot camp. One person's primary brain injury was due to an aneurysm, however she had sustained a secondary TBI because she fell at the time of her aneurysm rupture. She was also deemed appropriate, because she did not have any of the co-morbidities associated with embolic CVA. Therefore, it was felt that she could participate in the rigorous activity program and had the global deficits associated with ABI. One participant was 10 months and one was 7 years post-injury.

A total of four eligible people met these relaxed criteria and were interested in participating. They were scheduled for an initial research site visit described below:

Screening Evaluation (approximate time 1 hour)

The potential participants received a tour of the treatment area and demonstration of the types of activities done for assessment and treatment. The Montreal Cognitive Assessment (MoCA) (Nasreddine et al., 2005) was administered to clients who had not had extensive neuropsychological evaluation indicative of cognition adequate to make medical decisions. Participants needed to score 26/30 to participate. As all candidates met this criterion and continued to express interest in participation, the primary investigator then reviewed the consent form with those who were still interested in the program. Once the participants read and signed the consent (See Appendix B) a screen to determine that participants met the physical criteria was performed (See Appendix C). All met these criteria, so a basic evaluation of physical impairments, standard to an initial Physiotherapy Assessment, was performed. This included assessment of Active and Passive Range of Motion, Sensation, Reflexes, Muscle Tone and

Muscle Strength and Coordination (See Appendix D). This was done to determine limb function abilities, provide the therapist with information about tolerance, ability to follow direction, to maintain attention and behave appropriately.

Pre-intervention Assessment (Baseline) (approximate time 1.5 hours)

This was performed 1week prior to the intervention. All clinical tests and the PART-O questionnaire were administered during all assessments by the primary researcher, according to published guidelines (Katz-Leurer, Fisher, Neeb, Schwartz, & Carmeli, 2009a; Miller et al., 2008; Rossier & Wade, 2001a; Shumway-Cook et al., 2000; Whiteneck et al., 2011b; Whitney et al., 2005a). The primary researcher was an experienced Physical Therapist with 27 years of practice, much of it with neurologically impaired people. In this way, although bias may have come into play, inter-rater reliability was not an issue, so only test-retest reliability will be discussed. Table 1 indicates the current evidence on test-retest reliability in populations most similar to this study

For all physical assessment activities there was close supervision of the subject by the assessing therapist, so that physical assistance could be provided should the person be unable to perform a task or lose balance. Safety equipment, including hand rails, and in the case of the treadmill, a safety harness was in place. The following data were recorded:

1) Measure of Participation:

The **Participation Assessment with Recombined Tools-Objective-17** questionnaire was administered by interview. The Part O-17 (Whiteneck et al., 2011a) has 17 questions in 3 domains; productivity, which includes work, school and homemaking (3 questions), social relations (7 questions) and "out and about" (7 questions). For each question, the lowest possible score is 0, the highest 5. An average score is generated for each domain by adding the scores and dividing by the number of domain items. A Balanced Score is then generated to give each domain equal weight. If the subject cannot or will not answer an item, it can be indicated as such and deleted from the average domain score.

It was developed by the Traumatic Brain Injury Model System (TBIMS) which sustains a data base of outcomes of people with complex brain injury requiring in-patient rehabilitation from 16 cites in the United States. This measure combines a number of items from previously developed assessment tools in this area in an attempt to provide a more stream-lined and easy to use questionnaire. These tools include the Craig Hospital Assessment and Reporting Technique (CHART), Community Integration Questionnaire (CIQ) (Corrigan, Deming 1995), Participation Objective, Participation Subjective (POPS) (Brown, Dijkers et al. 2004) and a subset of the Mayo-Portland Adaptability Inventory (M2P2) (Malec 2004). Of note, the above derivative tools ask the responder to estimate time spent in various activities but do not give categories from which to choose which was seen as a detriment to accurate self-report. All 69 items from the above tests were initially included and, using Rasch Analysis these were combined and reduced to create 24 items (Whiteneck et al., 2011b). A subsequent validation study further reduced the scale to 17 items (Bogner, 2013).

Although the Part-O 17 has not yet had reliability testing (Bogner, 2013), the tests upon which it is based have. The CIQ (most closely resembling the Part-O 17) and the CHART both have test-retest reliability determined as excellent for TBI and CVA populations (Cusick, Gerhart, & Mellick, 2000; Dalemans, de Witte, Beurskens, van den Heuvel, & Wade, 2010; Seale et al., 2002; Walker, Mellick, Brooks, & Whiteneck, 2003; Willer, Ottenbacher, & Coad, 1994).
The POPS test-retest reliability is considered adequate to excellent (Brown et al., 2004; Oddson, Rumney, Johnson, & Thomas-Stonell, 2006) and the Mayo-Portland participation inventory adequate to excellent (Oddson et al., 2006).

Impairment and Activity Measures:

The following clinical assessments were selected as a comprehensive battery designed to capture documentation of a) a spectrum of balance/mobility functions and b) a range of functional ability. Given the inherent heterogeneity of any sample of people with ABI, it was assumed that not all of these tests would be appropriate for all individuals. The following describes the battery.

2) Measures of Functional Mobility (Activity):

- **Chedoke McMaster Stroke Assessment (CMSA) Activity Inventory:** Gross Motor Function Subset (Items 1-10) (secondary outcome measure) (Miller et al., 2008).

This consists of 10 bed mobility and transfer items that are rated on a 7 point scale for level of independence (see appendix E). Test-retest reliability has been tested as excellent (Gowland 1993) and a change of 7 points (10%) is the minimal clinically important change (Huijbregts & Gowland, 2000).

- **Five Times Sit to Stand Test** (Whitney et al., 2005b)

The participant was asked to stand up and sit down 5 times as quickly as possible from a standard-height seat surface with his or her arms crossed over the chest. The time to perform this was recorded. If the person could not do this, this test was eliminated. This test reflects not only leg strength but also balance, coordination and speed (Lord, Murray, Chapman, Munro, & Tiedemann, 2002). A minimal detectable change of 3.6 seconds has been established in the CVA population and a cutoff score of 12 seconds has been determined to differentiate between the healthy elderly and those with chronic CVA (Mong, Teo, & Ng, 2010).

3) Measures of Balance (Impairment):

- **Multi-directional Reach Test** (Newton, 2001)

The subject was asked to sit or stand (depending on ability) near a wall with a measuring tape mounted to it, parallel to the floor at the level of the subject’s acromion. With arm elevated to horizontal, he or she was asked to reach as far forward, to the right, to the left and backwards as possible. Measures of fingertip excursion were taken for each reach. COP was measured simultaneously. Three trials were recorded for each direction and an average was calculated.

This test has been validated for sitting (Katz-Leurer, 2009) and standing balance. (Newton, 2001) Age-appropriate, normative data have been recently established with a healthy population (n=180) for the test in standing (Tantisuwat 2014), but a minimal detectable or clinically significant change have not been established. Test-retest reliability is high for both the standing and seated versions (Holbein-Jenny, Billek-Sawhney, Beckman, & Smith, 2005; Katz-Leurer et al., 2009a).

- **Modified Clinical Test of Sensory Integration and Balance (mCTSIB)** (Shumway-Cook et al., 2000).

This was performed with subjects who could maintain unsupported standing for at least 30 seconds. They were asked to stand still with arms crossed and feet together for 30 seconds in each of the following conditions.

- Eyes open standing on solid ground
- Eyes closed standing on solid ground
- Eyes open standing on a 4-inch thick foam sponge
- Eyes closed standing on a 4-inch thick foam sponge

The ability to sustain the posture for the duration of the test time was recorded.

Minimal clinical differences have not been established. Test-retest reliability is high in studies where the Balance Master was not used (Anacker & Di Fabio, 1992; Di Fabio, Badke, McEvoy, & Ogden, 1990). Results of studies using the balance master were not used as, unlike the flexible FSA mat, the Balance Master distorts signals collected while on the foam.

4) Measures of Walking Ability (Activity)

- **Two Minute Walk Test (2 MWT)** (Rossier & Wade, 2001b).

This was performed with participants who could walk with or without aides, but without physical assistance. They were asked to cover as much distance as possible in 2 minutes while walking on an indoor course, using their customary walking aide and/or braces. The distance was recorded.

Test-retest reliability on both the Two and the Six Minute Walk Test, from which the 2MWT is derived, has been established as “excellent” in stroke populations (Eng, Dawson, & Chu, 2004; Fulk, Echternach, Nof, & O'Sullivan, 2008; Gijbels et al., 2010; Hiengkaew, Jitaree, &

Chaiyawat, 2012; Kosak & Smith, 2005; Liu et al., 2008). The minimal detectable change for the 2 MWT has been established as 19.21 m in an MS population (Gijbels et al., 2010), 16.40 m in a varied neurologically impaired population and 21.04 and 13.40 in two separate CVA populations (Hiengkaew et al., 2012; Rossier & Wade, 2001a).

- Ability to walk hands-free on a treadmill at 0.3 m/s (1 km per hour) (yes/no).

Table 1: Summary of Evidence Related to Test-retest Reliability for Clinical Tests

Study	Population	N	Rating of reliability
Five Time Sit to Stand Test			
(Wang, Liao, & Peng, 2012)	Cerebral Palsy (Children)	22; mean age 8.1 (1.8) years	Excellent test-retest reliability (ICC = 0.99) using the average of 3 trials
(Tiedemann, Shimada, Sherrington, Murray, & Lord, 2008)	Community-dwelling elderly:	10; mean age 75.5 (5.8) years	Adequate test-retest reliability (ICC = 0.82)
(Schaubert & Bohannon, 2005)	Community-dwelling elderly:	362; aged 74-98 years	Adequate test-retest reliability (ICC = 0.890)
(Bohannon, 2006)	Community-dwelling elderly:	33,595: 60 – 99 years	Excellent test-retest reliability (ICC = 0.957)
Chedoke-McMaster Disability Inventory			
(Gowland et al., 1993)	CVA	32; mean age 64 years	Excellent test-retest reliability (ICC = 0.98)
Modified Clinical Test of Sensory Integration in Balance			
(Anacker & Di Fabio, 1992)	Community Dwelling Elderly	47; mean age 80.5 (9.0) years	Excellent test-retest reliability (r = 0.75)
(Di Fabio et al., 1990)	Chronic CVA	5; mean age = 58 years	Excellent inter rater reliability: kappa = 0.77
Multi-directional Reach Test			
(Holbein-Jenny et al., 2005)	Personal Care Home Residents	26; mean age 85.3(4.9) years	Excellent test-retest reliability: Forward : ICC = 0.75 Adequate test-retest reliability: Back : ICC = 0.71 Adequate test-retest reliability: Right: ICC = 0.66 Excellent test-retest reliability: Left: ICC = 0.83
(Katz-Leurer, Fisher, Neeb, Schwartz, & Carmeli, 2009b)	Acute CVA inpatients	10; mean age 63 (6)	The test-retest reliability was high forward and sideways (ICC range 0. 90 – 0.95)
PART-O-19			Not tested
Two Minute Walk Test			
(Rossier & Wade, 2001b)	Neurologic Impairment	46; mean age not reported	Excellent test-retest (ICC = 0.97)
(Connelly, Thomas, Cliffe, Perry, & Smith, 2009)	Older Adults	16; mean age 87 (6.0)	Excellent test-retest (ICC = 0.95)
(Hiengkaew et al., 2012)	Chronic CVA	61;mean age 63.5(10)	Excellent test-retest (ICC = 0.98)

Electronic (Physiologic) Measures:

1) During Clinical Measures:

Centre of foot pressure (COP) was collected during the above clinical measures, except for the CMSA Activity Inventory, and during the following described tests. COP was collected while the participant was on a flexible Force Sensor Array (FSA) Mat (Vista Medical, Sampling frequency 30 Hz) for standing or sitting tasks and on a treadmill which has been instrumented with the FSA (sampling frequency 20 HZ) for walking tasks.

2) Single versus Dual Task Performance Measures: Core Balance, Tracking and Cognition:

A motion computer mouse was mounted on the subject's head with Velcro attachment to a cap to allow hands-free computer input through head movements. Using a computer program, which has been developed (Lockery, Peters, Ramanna, Shay, & Szturm, 2011), based on the Useful Field of View Test (Ball, 1988) to record response speed and task accuracy of movements in response to specific targets. Performance without balance demands was first measured on the following tasks while the participant was seated in a chair with a supportive back:

- a visual tracking task requiring rhythmic head movements in the horizontal plane (30 seconds)
- a visual tracking task requiring rhythmic head movements in the vertical plane (30 seconds)
- a visual-cognitive task (60 seconds)

Measures were taken with the participant in the highest posture that he or she could maintain without hand support while remaining still. Thus, participants were either sitting or standing unsupported on an unstable surface (4-inch thick foam sponge with 35 cm X 45.5 cm X 1.8 cm board). Measures were then repeated balancing in the same condition while the subjects performed the above tasks.

3) Single versus Dual Task: Walking Performance Measures:

The participants were asked to walk on a treadmill at 0.3 m/sec (1.0 km/h) without hand support. If they were unable to do this, this was recorded. If they were they were given a one minute acclimatization period. Then the COP data were recorded for one minute in each of the following conditions to obtain the Coefficient of Variation of Step Width (COV SW) and Paretic: Non-Paretic Single Leg Stance Time (P:NP SLS).

- Single Task walking on a treadmill without hand support
- Dual Task walking on a treadmill without hand support with the above head tracking and cognitive tasks

4) Individualized, Standardized Balance Task: Time Performed without Hand Support (%):

This involved a one minute interval of a repetitive rhythmical movement established after the screening assessment. It was performed at the highest postural level possible and was related to aspects of standing and/or walking ability that the subject lacked. Participants were asked to use as little hand support as possible throughout the task.

For the three participants who were able to walk functionally, the recorded individual task consisted of standing on a wooden board (25 cm x 61 cm x 1.8 cm) placed on a piece of dense, closed-cell foam (10 cm x 61 x 122 cm) performing a task designed to improve the weight shift onto and balance during single leg stance phase. Instruction to the participants was to start standing with their the lateral border of their feet 26 cm apart and to step forward and then back to the starting position slowly, using the least amount of hand support necessary to maintain balance. If participants had a hemi-paresis, the stepping foot was the less affected foot, forcing unilateral weight bearing on the paretic side. The supportive surface was positioned so the non-paretic hand could be used as needed. If a participant, who had bilateral problems, this task was performed on both sides with the opposite hand to the single support side available for stabilization.

For the participant who was unable to stand unsupported, the task was to stand on normal ground facing a supportive surface and to alternately “bow” or flex the torso approximately 40 degrees on the femurs and then to return to upright standing in a rhythmical fashion with the minimum of hand support required. This task was designed to train hip strategy to counter the tendency to retro-pulse when standing and stepping

Figure 1: **Set up of Individualized, Standardized Balance Task**

a) Individualized Task Subject 01

b) Individualized Task Subjects 02, 03, 04

Rehabilitation Boot Camp:

This occurred 3 days a week for 4 weeks on Mondays, Wednesdays, and Fridays. This was run concurrently with the University of Manitoba, School of Medical Rehabilitation Physical Therapy Neuro Rehabilitation Clinic which is run as a clinical placement for Physical Therapy

Students in their final year of studies. In this way students acted as research and therapy assistants as well as extra therapy personnel which could be called upon, on an ad hoc basis, if required. For each participant, the individual exercise from the initial and second assessment was performed every intervention day with FSA recording under the feet and supporting hand. Set up and instruction were identical to that during the two assessments.

Therapy Day Activities:

10:00: Welcome/Warm up activity (Active range of motion, low level aerobics and active stretching exercises done in a group to music) for 15 - 20 minutes

10:15-11:05: Circuit training: Participants cycle through 2 of the following stations:

- **Gaze control** with computerized games (sitting or standing as possible without assist)
- **Standing balance weight shifting** activities on unstable surfaces
- **Walking-related** activities
- **Cognitive game** (sitting or standing as possible without assist)
- **Stretching/strengthening** focal muscles
- **Functional** (transfers, step ups, reaching for items)
- **Assessment** station (Multiple repetition of the individualized, standardized balance/walking activity from the Baseline Assessment will be recorded daily.)
- **Aerobics**

11:05 – 11:20: Socialization/bathroom break

11:20-12:15: Participants cycle through 2 of the above stations

12:15- 1:00: Lunch break

1:00-1:25: Participants cycle through 1 of the above stations

1:25-1:45: Group Activity (physical games of some kind, clients could be in two groups if ability levels and interests are very different)

1:45- 2:00: Socialization/bathroom break

2:00 -3:00: Participants cycle through 2 of the above stations (If any repeat, choose different activities)

Specific activities for each station were determined as detailed in Appendix F.

The Physical Therapist and Therapy Assistant recorded the amount and type of activity during the treatment day. Activities that were designed to improve balance/mobility and the cognitive aspects of these functions and which require active participation of the subject (not including isolated muscle strengthening or passive stretching exercises) were counted as RFTP. They also recorded any time that additional staffing was called upon to a) ensure safety b) to complete planned activities or c) to record the daily monitoring data.

Any adverse incidents during the pre-intervention or intervention periods were recorded and categorized as follows:

- **Anticipated**: This includes some muscle soreness or fatigue, mental or general fatigue and, in the case of clients with balance or gaze control issues, some increase in dizziness. The level that were considered to be "anticipated" will be that which some rest during the evening of the treatment day allows the subject to resume his/her normal activity level by the next day.
- **Minor**: These include incidents as above that do not resolve by the next day or other incidents that do not require medical attention.

- **Major**: These include incidents that require medical attention.

Post-intervention Assessment (1.5 hours)

The week after the boot camp, patients were scheduled for the post-intervention assessment. It consisted of the same measures as the Baseline Assessment (above).

Semi-structured Interviews

Semi-structured interviews were organized to obtain participants' impression of the boot camp experience two weeks post-intervention. A graduate student, who was not involved in the study, led the discussion while the primary investigator paraphrased all comments in writing including labelling them by participant number. It was hoped to do the interviewing as a group, but on the day the group interview was scheduled, two participants were unable to attend, so two out of four participants were interviewed individually at a later date.

For the interviews, a set agenda was pre-determined (see Appendix G). Ground rules were established and the researcher ensured confidentiality of comments. Participants were encouraged to speak in an orderly and respectful fashion, but to freely provide negative as well as positive feedback, interact with each other and to make spontaneous comments about their experience even if not directly questioned.

VII. DATA ANALYSIS

Population-based statistics were not appropriate for this case series. Therefore, descriptive methods were used to present the data related to feasibility of the boot camp model of treatment delivery. Comments recorded during the post-intervention semi-structured interviews were categorized under the following headings: a) perceived benefits, b) enjoyable or positive aspects c) difficult or negative aspects c) practicalities of meeting the demands d) feelings of safety and e) feelings of being challenged. These headings were generated by the Primary Investigator, as the answers to them were the intention of the interviews. Because comments were coded by participant, it allowed the investigator to describe on how widely held an opinion was. Related concepts generated by the discussion have been combined in the results text, as described by Galetta (2012).

In the analysis of variables that might indicate positive performance change, either a previously established minimal detectable change (MDC), minimal clinically-important difference (MCID) or a 20% improvement in performance was used to determine positive change. Regarding the benefit of the variables derived from the COP data, a variety of data analyses were utilized. The following describes details of how each measure was examined:

Subjective (Participation) Measures:

The PART-O 17 does not have an established minimal clinical or detectable change so the percent change was determined from the pre- to post-intervention assessment for the 3 domains and the recommended “balanced score”. This was calculated as per test instructions (Whiteneck, Bogner, & Heinemann, 2011) to provide equal weight to all domains despite the fact that there are different numbers of questions in each.

Clinical Measures:

Different clinical measures were selected from a battery of tests for each individual participant based on clinical presentation. The whole battery was selected to reflect a scope of abilities related to balance and mobility. For each subject, all relevant tests were deemed as "positive change" versus "no change" between the pre and post-intervention assessments for each individual participant. If a participant was unable to perform a clinical test on one occasion and was able to on another, this would automatically be considered an improvement. The total number of scores that demonstrated positive changed was tallied to provide a clinical picture of any change between assessment times.

Magnitude and Velocity of Centre of Foot Pressure Trajectory during Clinical Measures:

The COP trajectory in the ML and AP directions was further examined to determine if these had potential to show more sensitivity to performance changes than the MCID's. They were processed with a custom MatLab Program to render mean sample velocity (cm/s), as a time-normalized value for Sway Path Length (SPL), and Total Load data.

SPL was considered in the medial-lateral, the anterio-posterior or both directions (generated by calculating the hypotenuse of the ML and AP values) depending on the demands of the clinical assessment task in question. Specifically, SPL COP ML-AP was examined during the two conditions of the mCTSIB performed on the unstable surface. For the Multi-directional Reach and Five Times Sit to Stand tests it was felt that a reduction in the SPL of the COP in the direction perpendicular to the desired task would reflect an improvement in balance control during that task.

Total Load of Centre of Foot Pressure was also analyzed during the Five Times Sit to Stand in the following way: The load data was cut for each sit to stand event by observing the FSA file recording and noting the samples in which significant weight bearing occurred on the paretic foot. The cells that were activated by the affected foot were then manually noted and the values during the sit-to-stand events were totalled. This allowed a profile of load through the affected foot over time to be created for each sit-to-stand event. The five sit-to-stand events for each assessment were normalized for time by starting at the point when a sharp increase in load occurred for the cells that were activated by the paretic foot, and then cut to the maximal uniform length. The average and standard deviation of each load was calculated and graphed to allow the ability to load the more affected foot to be observed.

Balance, Visual Tracking and Visual-Cognitive Performance during Single versus Dual Task Conditions:

The data collected from the FSA mats and the visual-cognitive computerized assessment module were processed with customized MatLab programs to extract relevant variables, below. These were examined when performed alone and when combined with the second task:

- **Core balance performance**: Sway Path Length (SPL) was generated using the mean sample velocity of COP ML-AP as described above.
- **Walking performance**: (examined for the one participant who could perform this test during two consecutive assessments). The spatial-temporal gait parameters were used to calculate:

a) Coefficient of Variability of Step Width (COV-SW). A decrease in value indicates performance improvement

b) Paretic/Non-Paretic SLS time. An increased value up to 1.0 indicates performance improvement

- **Visual head tracking performance**: Coefficient of Determination (COD) was used to capture how closely the subject's performance matched the perfect sinusoid of the computer during horizontal and vertical sinusoidal tracking. A smaller absolute value of one minus the COD indicates better performance.
- **Cognitive performance**: percent success (%), response time (s) and path length (cm) of game play events. An increased success rate, but reduced response time and path length are indicative of better performance.

Daily Recorded Task COP Data:

The pre-determined performance variable was the amount of hand support required. It was felt that a trend towards less hand support would indicate an improvement in balance ability. In order to analyze these data, the FSA data were put through a custom MatLab Program which totalled the load on the mat for each sample. The samples were cut to exactly one minute, with the beginning point being determined by observing the FSA display to ensure movement was occurring. Because the total load not only responds to the amount of mass going through the mat, but also the vertical acceleration created by the movement, it could not be used simply to indicate the amount of hand support relative to the participant's body weight. Instead, the percent time spent without hand support was calculated. Any sample with a total load of < 10 mm Hg was considered to be "hands-free", based on test run of the FSA mat without hand support.

As well as the change in upper limb support requirements, it was felt that other features of the daily task might be useful for future indicators of improvement, so this was explored in one of the participants. The FSA COP-ML data was cut to include only the preparation of going from double stance time to single support on the paretic side. This was done by looking at the original FSA file to see when the non-paretic leg lifted off and observing the COP ML graph to determine when a clear trajectory towards the paretic side commenced. The mean and standard deviation of the trajectory of the COP-ML of these cut portions of the individual “stepping” events were calculated and graphed for observation of trends.

VIII RESULTS

Descriptive Summary of the Functioning of the Rehabilitation Boot Camp

All four recruited participants completed the Boot Camp. Table 2 summarizes their demographic characteristics.

Table 2: Summary of Participant Characteristics

Subject	Age	Sex	Time since injury	Duration of coma	Mechanism of ABI	Co-morbidities
01	32	male	5 years	3 months	Anoxia secondary to drug overdose	Anxiety disorder (pre-morbid)
02	45	female	17 months	7 days	Aneurysm rupture, subdural haematoma secondary to fall at time of CVA	none
03	25	female	10 months	3 months	Acute disseminated encephalomyelitis (ADEM)	none
04	23	female	7 years	2 months	Trauma secondary to MVA	none

As planned, the boot camp was run three days per week from June 2 to June 27, 2014. It was initially scheduled from 10:00 am to 4:00 pm with a 45 minute lunch break and two 15-minute washroom/socialization breaks. By the middle of the second week it was clear that participants could not meet this requirement, either due to fatigue, focal muscle soreness or child care obligations. Therefore the schedule was changed to 10:00 a.m. to 3:00 p.m. with no change to scheduled breaks.

The mean amount of RFTP per day was 89.5 minutes with a range of 82.4 – 97.91. On 5 out of the 12 boot camp days, extra assistance, as determined by therapist clinical judgement, was required. Averaged over the 12 boot camp days this amounted to an average of an extra 0.56 hours of assistance/day. Otherwise, therapy delivery was provided by one experienced therapist and one trained rehabilitation assistant for the majority of the day's therapy time (which was a total of 4.25 hours excluding lunch break). Having two staff members allowed one to always be available for one-to-one supervision while the other monitored and set up the semi-supervised stations. There were seven 25 – 30 minutes daily circuits, so each participant had approximately 32-39 minutes/ day in which they received individual therapy. These times were scheduled to be when the person was performing the most challenging balance activities. Table 3 displays the attendance and the amount of physical activity performed by the participants during the boot camp.

Table 3: Summary of Daily Attendance and Mean Amounts of Therapy Activity

Subject	01	02	03	04	Group Average Days
Days of attendance	10/12 Left early one day	11/12 Left early one day	11/12 Left early one day	10/12	10.5 days
Amount of Therapy Activities					Group Average Time
Stretch/strength (minutes)	22.2	26.91	28.64	31.30	27.26 minutes
Aerobic (minutes)	18.1	15.91	17.18	21.00	18.05 minutes
RFTP (minutes)	82.4	97.91	95.32	82.40	89.51 minutes
Daily total (minutes)	122.7	140.73	141.14	134.70	134.82 minutes
Daily average number of 1:1 circuit stations	1.8	1.0	1.3	1.1	1.3 stations
Daily approximate average 1:1 therapy time (minutes)	45 – 54	25 – 30	32 – 38	28 - 33	32 – 39 minutes

Participants were noted to sustain focus on their rehabilitation activities and to give consistently good effort. They were observed to provide each other with positive feedback and encouragement. Joking and laughing were frequently noted, despite the fact that there were objective signs that participants were fatigued and working hard. They appeared to develop a sense of camaraderie, sharing “in-jokes” and catch phrases, as well as snacks among themselves and the therapy staff.

Adverse Events

There was one unanticipated minor adverse incident. This was a fall, from an unsupported seated position to the floor. No injury was sustained, no residual discomfort was reported and no follow up medical intervention was required. Following this incident the physical set up was modified for this individual to provide more supports during any semi-supervised sitting balance activities.

Participant Perception of the Boot Camp Experience

The following summarizes the interview results of the participants’ impression of the intervention.

Perceived Effectiveness of the Boot Camp:

- Participants noted improvements in stamina, cognition, balance, endurance, confidence in physical and dual-tasking abilities.
- One person noted optimism about the ability to possibly tolerate an 8-hour workday as a result of the experience.
- All participants expressed a desire to continue or repeat the experience due to the perceived benefit.

- Functional improvements were perceived including transfer and stair-climbing ability, standing and walking stability and tolerance.
- Two participants noted that family members also remarked on improvements in participation with family activities and walking ability.

Perception of Semi-supervised Activities; Feelings of Safety versus Challenge:

- Three of the participants stated that they felt safe at all times and liked the fact that there was a range of difficulty of activities.
- One participant felt unsafe on occasion while sitting unsupported during group activities even with direct supervision. This participant mentioned that in retrospect there was not actual risk of falling, but more of a subjective anxiety related to experiencing significant ankle clonus in sitting.
- This same participant liked the availability of the standing frame for some individual, semi-supervised activities as it allowed work on good posture with a feeling of security. This person suggested availability of a body weight support system during semi-supervised activities might allow more maximal challenge.
- Three participants noted that they had to use hand support more frequently during semi-supervised activities in order to feel safe which was a drawback as they would have liked to challenge themselves to do more hands-free work.
- All participants would have liked more one-on-one attention to allow greater time to maximally challenge their balance and to ensure optimal form during all exercises.

Perceived Aspects of the Boot Camp that Worked Well:

Variety and Socialization:

- There was consensus that the boot camp was interesting and fun.
- Participants enjoyed the therapy staffs' energy and planned activities (example group warm up, daily music theme) the activity variety (group games, individual activities and computer games) as well as the bonding, motivation and competition generated by the social aspect of the program.
- The suggestion from three of the participants was for more group games, especially near the end of the day when energy levels were declining, as they found the competition and interaction were stimulating and motivating.

Intensity:

- The participants agreed that the duration, frequency and intensity of therapy activities were important, stating that they felt more benefits for the time (4 weeks) in therapy than past Physical Therapy they had received.
- Improved self-confidence related to knowing that they could tolerate that amount of activity was frequently mentioned by all participants

Frequency:

- All four liked 3 days a week in terms of being frequent enough to make improvements but allowing rest and ability to do other things
- The two participants with children liked the frequency of 3 days a week as they found arranging childcare at this rate to be manageable.

Cognitive/Dual Task Practice:

- All participants valued the added cognitive and dual-tasking challenge noting resulting increased self-confidence.

- One stated that because of this there "was always active participation" which she felt enhanced her self-confidence and performance.
- One person summed up her impression of the boot camp compared to her past experience of physical therapy by saying, "There's no comparison. There's a bit of everything, not just balance and strength".

Perceived Difficulties Related to Boot Camp Participation:

<u>Fitting into the group:</u>

- The participant with the greatest balance and mobility impairment occasionally felt self-conscious in comparison to others during group activities, due to needing to use the wheelchair in order to play some of the games.
- The sole male participant would have felt more comfortable with a more even gender representation

<u>Daily duration of activity:</u>

- One participant did feel that the day was a bit long, noting that three to four hours would have been preferable.
- Another did not mind the long day, but would have liked a longer lunch break in order to eat at a more leisurely pace and to feel recharged for activity in the afternoon.

<u>Other:</u>

- Participants relying on Handi-Transit for transportation found the day could be very long or cut short depending on drop off and pick up times (dictated by Handi-Transit's schedule).
- All of them noted fatigue and some muscle soreness at the end of day, but they all indicated that this was within an expected and acceptable level.

- One participant expressed a personal desire to have more of an upper body workout as part of the boot camp.
- Safety versus Challenge (discussed in Theme 2 above)

Impairment, Activity and Participation Outcome Measures

Participation Measure (PART-0 17):
Three out of four participants demonstrated improvement on the Part O-17. Interestingly, different domains improved for each of these individuals. Specific scores are seen in **Table 3**

Table 4: Part-O 17 Percent Change and Pre- and Post-intervention Scores

	Subject 01	Subject 02	Subject 03	Subject 04
Productivity	**0 % (N)** (0.67/ 0.67)	**20.36 % (I)** (1.33/1.67)	**0% (N)** (1.67/ 1.67)	**0% (N)** (1/ 1)
Social	**13.08 % (N)** (1.86/2.14)	**8.92% (N)** (2.86/3.14)	**37.55 % (I)** (1.43/2.29)	**0% (N)** (2 /2)
Out and About	**19.34 % (N)** (1.86/2.43)	**7.25% (N)** (1.79/ 1.93)	**53.26 % (I)** (0.5/ 1.07)	**-47.06 % (N)** (2 /1.36)
Balanced Total	**29.43 % (I)** (1.86/2.82)	**18.97% (N)** (3.63/ 4.48)	**60.85% (I)** (1.01/ 2.58)	**-37.84% (N)** (2.55/ 1.85)
Improvement versus No Improvement	**I**	**I**	**I**	**N**

% change (actual pre/post score); **I** = Improvement; **N** = No Improvement

Clinical Measures:

All participants demonstrated some improvement on at least one of the clinical measures.. Further, the SPL of COP and load data augmented the clinical observations about balance performance. For example, for 2 individuals, **the Five Times Sit to Stand** test performance declined from a clinical stand point (increased time to complete the test). However, the SPL COP ML revealed improved quality of balance control, and further examination of the paretic leg total load data demonstrated a more controlled pattern of loading that would also reflect improved balance during this demanding task. During the **Multi Directional Reach Test**, many reach directions demonstrated reduced distance. Far more of these trials demonstrated improvement in the quality of reaching, through reduction of the SPL COP ML or COP AP. This represents a strategy of reducing the extraneous sway at the cost of reach distance in some circumstances. Given that part of balance re-education is relearning safe boundaries, this may be a valuable strategy for many people depending on their residual neurological ability. The **Modified Clinical Test of Sensory Integration in Balance** only showed clinical improvement for one of the three participants who could perform it, yet there was between 32 – 75 % reductions in SPL COP ML-AP for all trials on the sponge apart from one client during the eyes closed condition.

Table 4 shows change between the pre and post assessments either as a percentage change, or, in the case of a measure with an established minimal clinical difference (MCD), as a change in score. The raw scores of clinical measures for each assessment are indicated in parentheses after the indication of change. If a test could not be successfully completed without a loss of balance or external assistance, it is indicated as “able” or “unable”.

Figures 2-5- present the variables derived from the COP data for each measure, graphically in order to show a trajectory of performance change. Tables 5- 7 show specific values of change from time 1 to time 2.

Table 5: Clinical Assessment Score Changes Pre- and Post-intervention

Assessment	Subject 01		Subject 02		Subject 03		Subject 04	
CMSA GMF subset	**↑4 points** (MCD=7 points) (36/40)	**N**	not applicable		not applicable		not applicable	
5 X STS (s)	not applicable		**↑3.1 s** (MDC =3.6 s) (10.6 /13.7)	**N**	**↑14 s** (MDC =3.6 s) (27.0 / 41.0 s)	**N**	**↑11.4 s** (MDC =3.6 s) (27.6/39.0)	**N**
MDRT (cm)	(mean of 3 trials)							
• Front	-5.26% (9.5 / 9.0)		53.7% (13.7/21.0)		17.7 (17.0 / 20.0)		-20.2 (22.3 / 17.8)	
• Back	6.98% (7.2/ 7.7)		-33.3 (12.0/ 8.0)		-3.5 (9.7 /9.3)		28.1 (19.0/24.3)	
• Right	-26.3% (12.7/9.3)		10.1 (14.8/ 16.3)		-1.4 (12.0/11.8)		-15.3 (19.7/16.7)	
• Left	33.3% (8.0/10.7)		10.8% (10.8/ 12.0)		-4.6 (11.0 / 10.5)		-32.7 (16.3/11.0)	
		I		**I**		**N**		**I**
mCTSIB (y/n)	not applicable		(y/y)	**N**	(n/y)	**I**	**(y/y)**	**N**
2 MWT (m)	not applicable		-6.7% (135 / 126 m)	**N**	19.4% (62/74 m)	**N**	-17.7% (130/ 107 m)	**N**
ST Treadmill walking (y/n)	not applicable		(able/able)	**N**	(unable/able)	**I**	(unable/able)	**I**
DT Treadmill walking (y/n)	not applicable		(able /able)	**N**	(unable/unable)	**N**	(unable/unable)	**N**
Total number improved	**1**		**1**		**2**		**2**	

Change in score time 1-2 (MCD or MDC) (actual pre/post score); **I** = Improvement; **N** = No Improvement
CMSA GMF=Chedoke McMasters Stroke Assessment Activity Impairment Gross Motor Function subset; **5 X STS**= Five Times Sit to Stand; **MDRT** = Multi-directions Reach Test; **mCTSIB** = Modified Clinical Test of Sensory Integration in Balance; **2 MWT =** Two Minute Walk Test: **ST** = Single Task: **DT** = Dual Task

1) Modified Clinical Test of Sensory Integration in Balance (mCTSIB):

Figure 2: **Core Balance Performance during the mCTSIB**

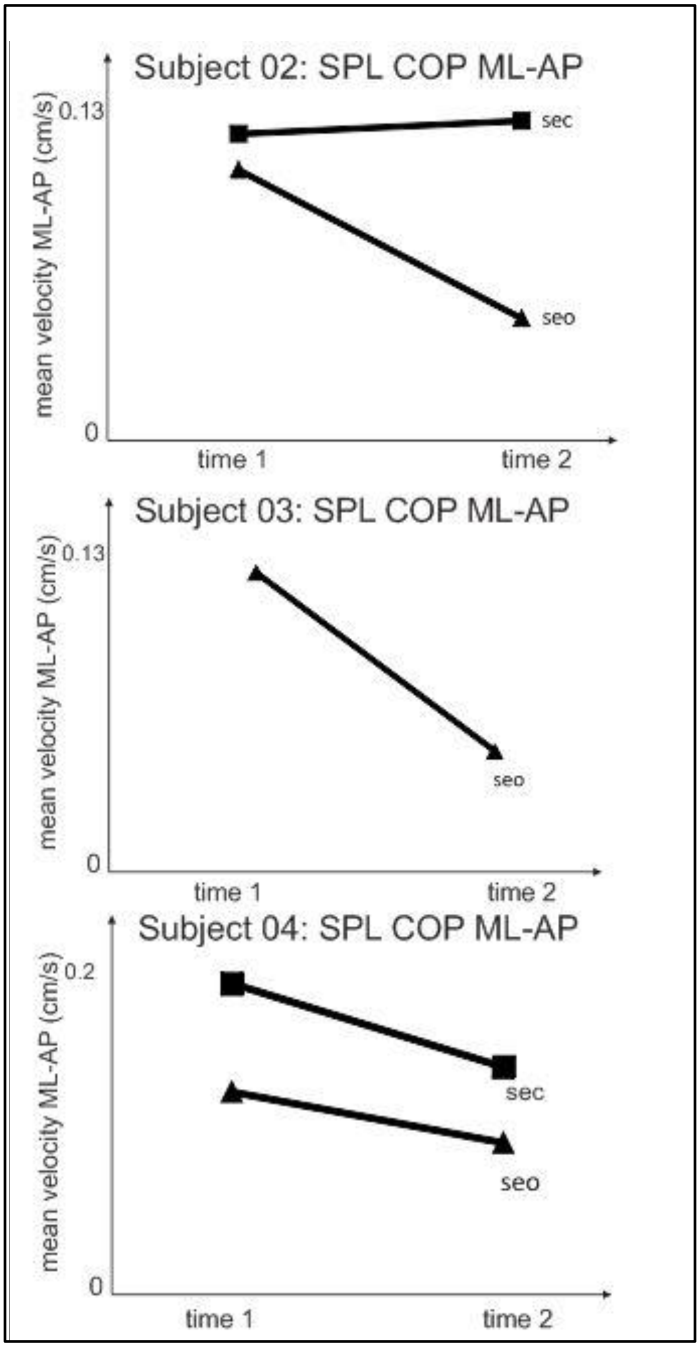


Table 6: Percent Change in SPL COP ML-AP of mCTSIB

Condition	Subject 02		Subject 03		Subject 04	
sponge eyes open	**-74.76** (0.10/0.03)	**I**	**-72.58** (0.13/0.04)	**I**	**-33.22** (0.12/0.08)	**I**
sponge eyes closed	**5.58** (0.12/0.13)	**N**	**-33.39** (0.10/0.07)	**I**	**-31.84** (0.20/0.14)	**I**

% Change time 1-2 (actual pre/post score); **I** = Improvement; **N** = No Improvement

2) Five Times Sit to Stand

Because the Sit to Stand task only requires AP movement, the physiological variable associated with an improvement in performance quality was determined to be a reduction of the amount of ML-COP movement, which would be extraneous to the desired movement (See Figure 2).

Figure 3: **Balance Control Performance during the Five Times Sit to Stand Test**

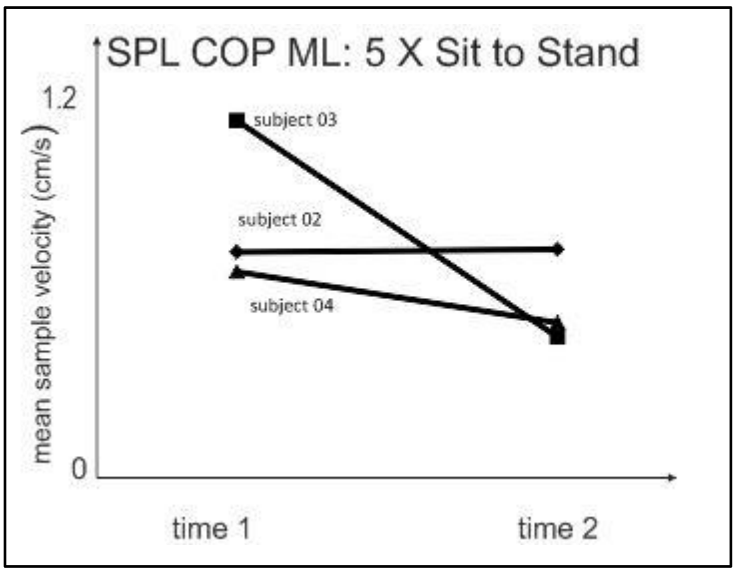


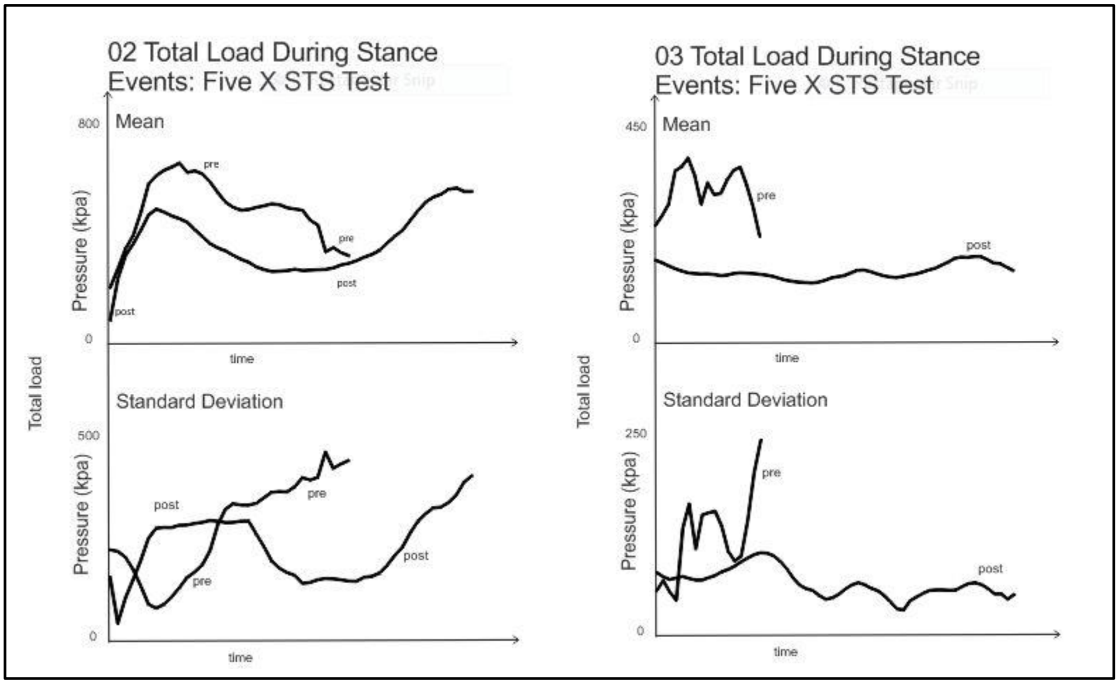
Table 7: Percent Change Balance Control Performance during the Five Times Sit to Stand Test

Variable	Subject 02		Subject 03		Subject 04	
Mean sample velocity ML COP	**1.29** (0.69/0.70)	**I**	**-62.44** (1.11/0.42)	**I**	**-26.15** (0.62/0.46)	**I**

% Change time 1-2 (actual pre/post score); **I** = Improvement; **N** = No Improvement

The average and standard deviations of the total load of the hemiparetic foot the two hemi-paretic participants, is represented in Figure 4 below:

Average and Standard Deviation of Total Load of Hemi-Paretic Foot during 5 X STS Events for Subjects 02 and 03



3) Multi-directional Reach Test (MDRT):

It was postulated that an improvement in performance would result in less extraneous movement in the direction counter to the desired movement (example for the forward reach test, improved balance performance should result in reduced movement in the ML direction relative to the movement in the AP direction.) Some improvement is seen for all participants.

Figure 4: **Balance Control Performance during Multi-directional Reach Test**

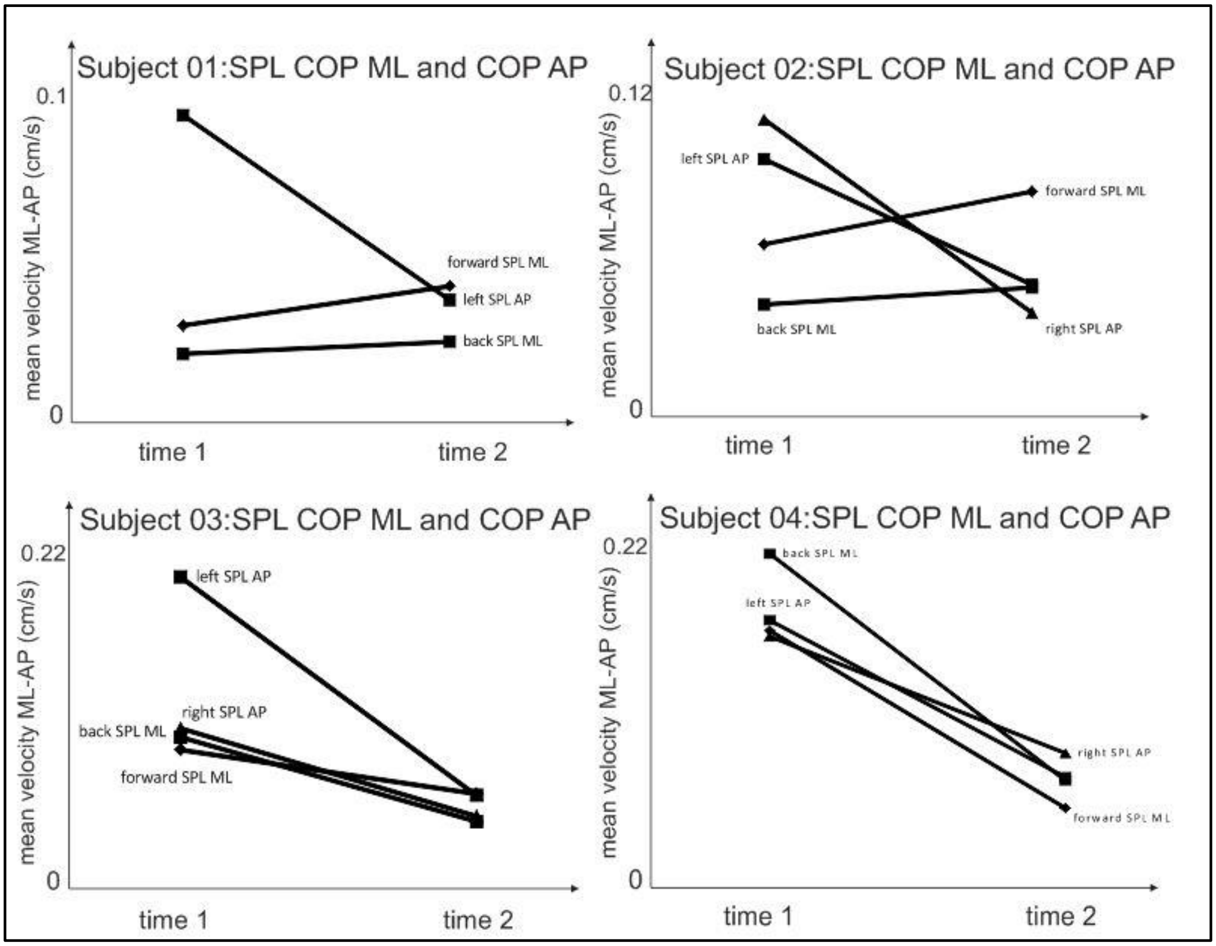


Table 8: Percent Change in Balance Control Performance during Multi-directional Reach Test

Variable	Subject 01		Subject 02		Subject 03		Subject 04	
% change in SPL COP ML and COP AP from pre- to post-intervention								
Forward (TPL COP -ML)	**-55.38** (0.02/0.03)	**I**	**-34.18** (0.07/0.09)	**I**	**-38.57** (0.08/0.05)	**I**	**-76.89** (0.17/0.04)	**I**
Back (TPL COP -ML)	**-28.28** (0.01/0.02)	**I**	**17.93** (0.04/0.05)	**N**	**-66.55** (0.09/0.03)	**I**	**-73.70** (0.23/0.06)	**I**
Right (TPL COP -AP)	LOB	**N**	**-69.21** (0.12/0.04)	**I**	**-64.92** (0.10/0.03)	**I**	**-51.91** (0.17/0.08	**I**
Left (TPL COP -AP)	**65.70** (0.07/0.02)	**N**	**52.38** (0.10/0.05)	**N**	**-76.1** (0.21/0.0	**I**	**-65.06** (0.18/0.06)	**I**

% Change time 1-2 (actual pre/post score); **I** = Improvement; **N** = No Improvement; **SPL COP**=Sway Path Length Centre of Foot Pressure; **ML** = Medial-Lateral; **AP** = Anterior-Posterior

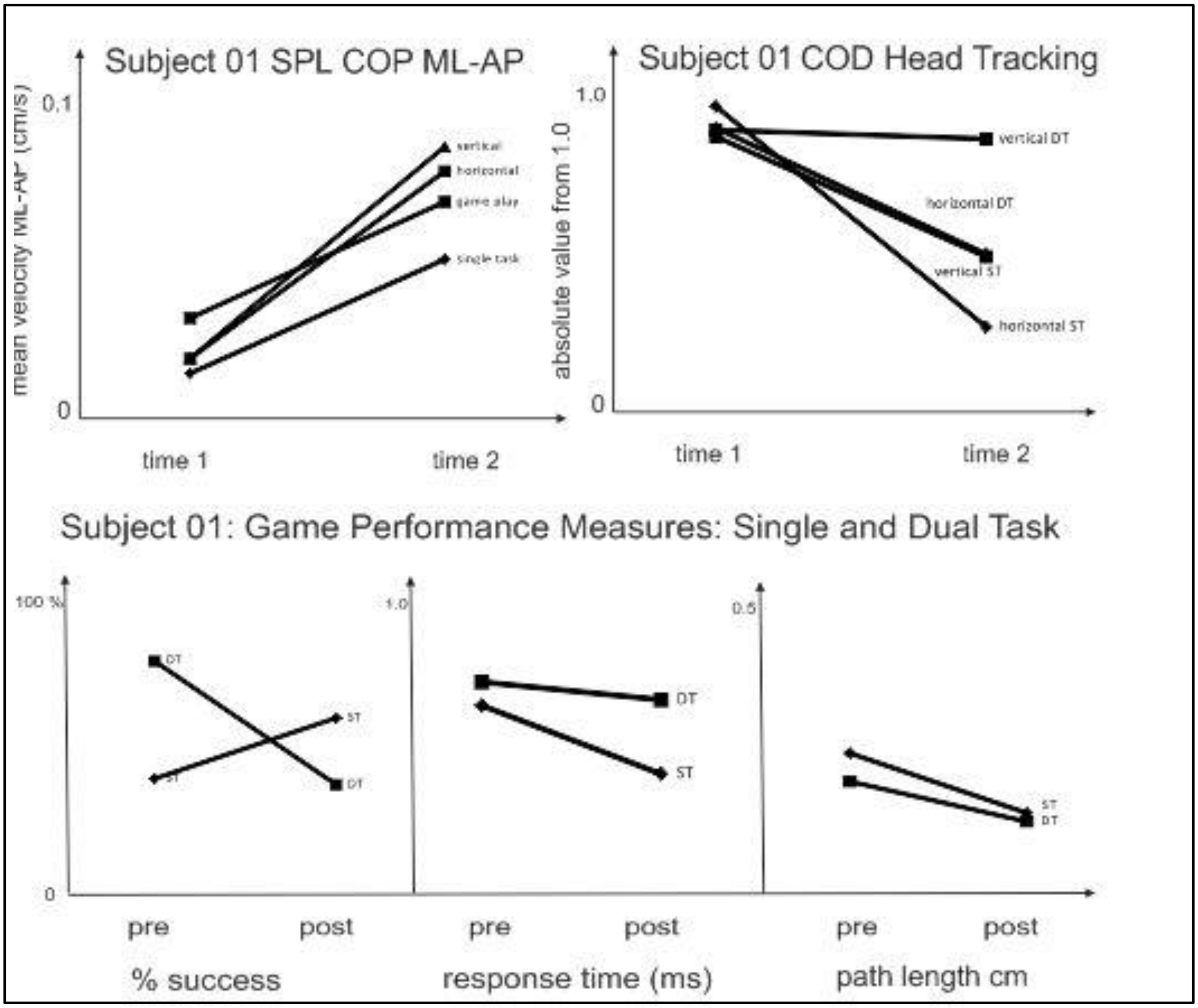
Core Balance, Walking, Visual Tracking and Cognitive Performance during Single versus Dual Task Conditions:

Core Balance Performance: At least a 25% decline in the SPL COP ML-AP for all conditions was seen for Subjects 02 – 04, indicating an improvement in balance with and without a secondary task. They simultaneously maintained or improved in some, but not all of the variables related to dual task tracking and game-playing performance, indicating some improvement in dual task ability. Subject 01 did not show improvement on the balance task but did show some improvement on most secondary task variables.

Walking Performance: Subject 02 demonstrated reduced COV SW by at least 40 % for all conditions from time 1-2. The variable Paretic/Non-Paretic SLS time demonstrated improvement for all conditions except in single task walking. Thus the participant could correct her walking performance even in the presence of a dual task. The secondary task performance was variable both for dual task conditions, thus indicating that in some conditions she sacrificed visual-cognitive performance for improved walking performance. At the pre-intervention assessment, Subjects 03 and 04 could not successfully walk hand-free on the treadmill, so although comparative data re: COV SW and P/NP SLS time is not available, this represents improvement of walking ability.

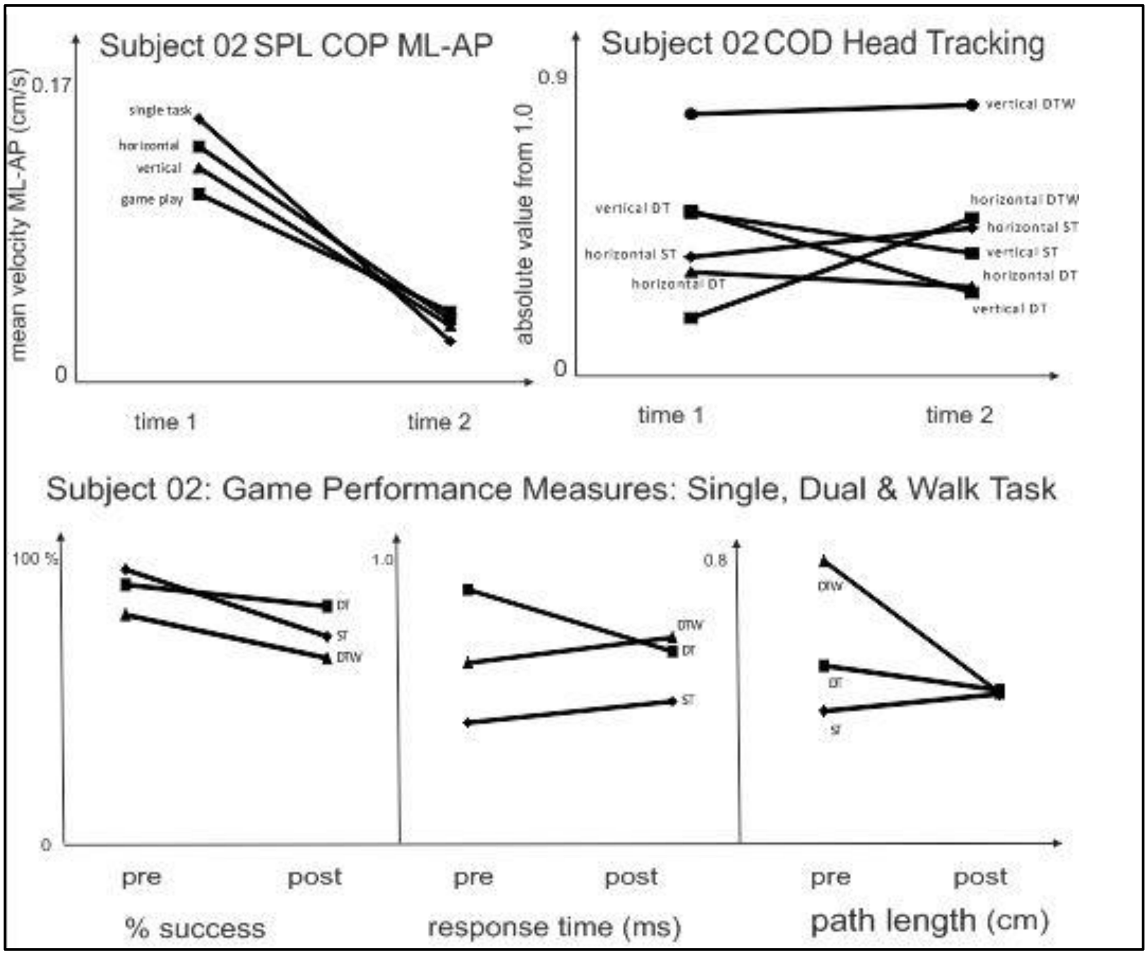
Figures 6-10 show the core balance performance, visual head tracking and cognitive performance for single task and dual task for all participants. For Subject 02, walking balance performance measures have also been shown. Table 9 shows the percent change in in performance for all variables and subjects from Time 1-2.

Figure 5: **Subject 01 Dual Task versus Single Task Performance: Core Balance, Head Tracking and Cognition**



AP = Anterior-Posterior; **COD** = Coefficient of Determination; **DT**= Dual Task; **ML** = Medial-Lateral; **SPL COP**=Sway Path Length Centre of Foot Pressure; **ST** = Single Task

Figure 6: **Subject 02: Dual Task versus Single Task Performance: Core Balance, Head Tracking and Cognition**



AP = Anterior-Posterior; **COD** = Coefficient of Determination; **DT**= Dual Task; **ML** = Medial-Lateral; **SPL COP**=Sway Path Length Centre of Foot Pressure; **ST** = Single Task

Figure 7: **Subject 02: Dual Task versus Single Task Performance during Walking**

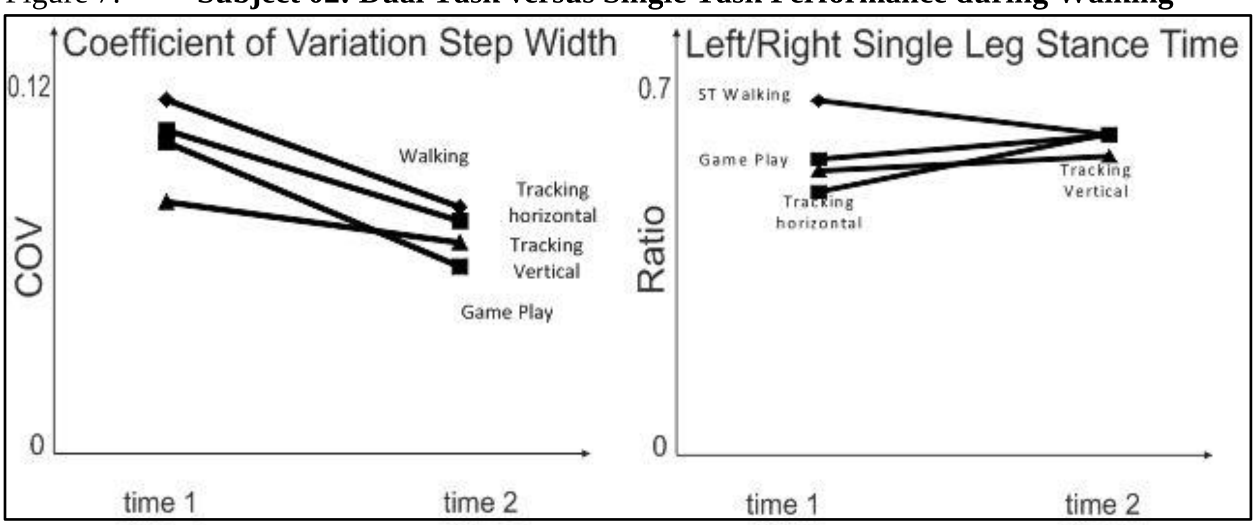
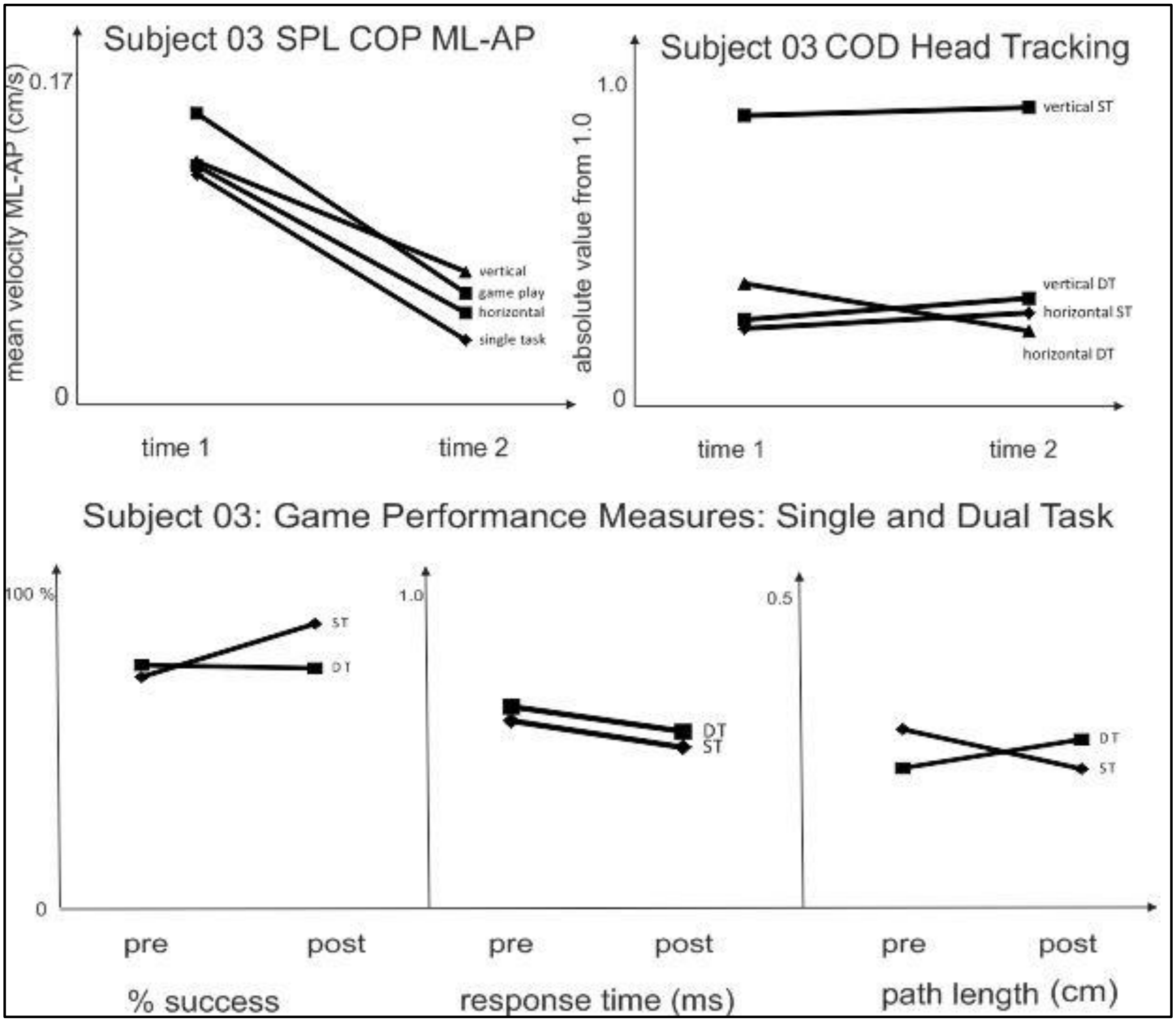
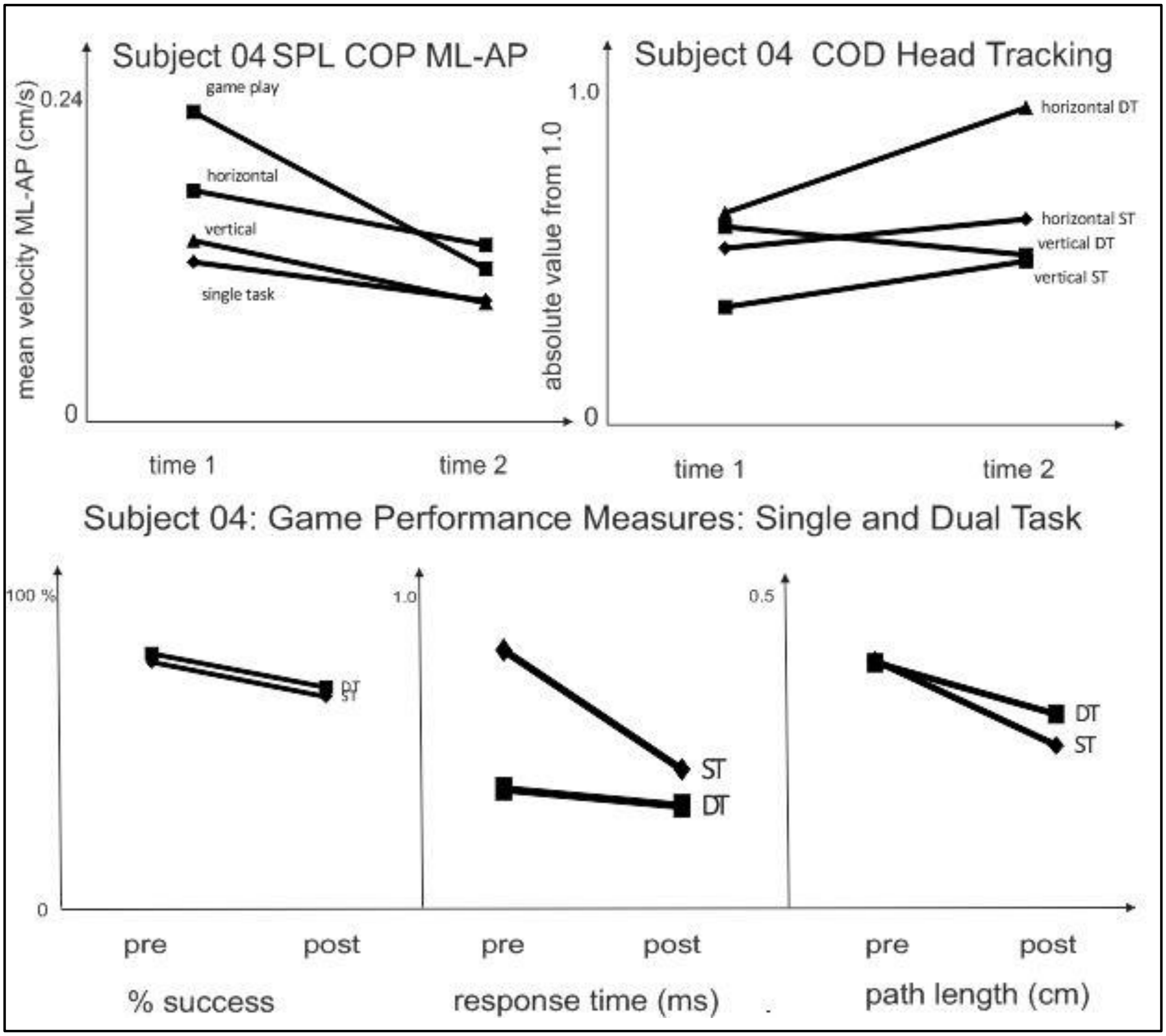


Figure 8: **Subject 03 Dual Task versus Single Task Performance: Core Balance, Head Tracking and Cognition**



AP = Anterior-Posterior; **COD** = Coefficient of Determination; **DT**= Dual Task; **ML** = Medial-Lateral; **SPL COP**=Sway Path Length Centre of Foot Pressure; **ST** = Single Task

Figure 9: **Subject 04 Dual Task versus Single Task Performance: Core Balance, Head Tracking and Cognition**



AP = Anterior-Posterior; **COD** = Coefficient of Determination; **DT**= Dual Task; **ML** = Medial-Lateral; **SPL COP**=Sway Path Length Centre of Foot Pressure; **ST** = Single Task

Table 9: Percent Change Balance and Mobility Performance from Time 1-2

Variable	Subject 01	Subject 02	Subject 03	Subject 04
Core Balance				
ST SPL COP ML-AP	**420.15 (N)** (0.01/0.04)	**-84.95 (I)** (0.16/0.02)	**-73.00 (I)** (0.13/0.04)	**-28.23 (I)** (0.12/0.08)
DT horizontal SPL COP ML-AP	**445.26 (N)** (0.01/0.06)	**-73.84 (I)** (0.15/0.04)	**-62.51 (I)** (0.14/0.05)	**-26.17 (I)** (0.18/ 0.13)
DT vertical SPL COP ML-AP	**500.36 (N)** (0.01/0.06)	**-74.02 (I)** (0.13/0.03)	**-46.05 (I)** (0.14/0.08)	**-39.47 (I)** (0.13/0.08)
DT cognitive SPL COP ML-AP	**140.99 (N)** (0.02/0.05)	**-63.07 (I)** (0.12/0.04	**-62.46 (I)** (0.17/0.06)	**-54.75 (I)** (0.24/ 0.11)
Walking Balance				
ST walk COV SW		**-51.87 (I)** (2.90/1.40)		
ST walk P:NP SLS time		**-9.74 (N)** (0.67/0.60)		
DT walk horizontal COV SW		**-49.65 (I)** (2.54/1.28)		
DT walk horizontal P:NP SLS time		**22.37 (N)** (0.49/0.60)		
DT walk vertical COV SW		**-40.54 (I)** (1.97/1.17)		
DT walk vertical P:NP SLS time		**5.27 (N)** (0.53/0.56)		
DT walk cognitive COV SW		**-59.58 (I)** (2.55/1.03)		
DT walk cognitive P:NP SLS time		**8.10 (N)** (0.56/0.60)		

%Change in score time 1-2 (actual pre/post score); **I** = Improvement; **N** = No Improvement **AP** = Anterior-Posterior; **COV** = Coefficient of Variance; **DT**= Dual Task; **ML** = Medial-Lateral; **SPL COP**=Sway Path Length Centre of Foot Pressure; **ST** = Single Task

Table 10: Percent Change Performance Visual Cognitive Performance Time 1-2

Head Tracking				
ST COD horizontal	**-87.46 (I)** (0.99/0.12)	**38.28 (N)** (0.26/0.36)	**19.84 (N)** (0.24/0.28)	**18.66 (N)** (0.51/0.61)
ST COD vertical	**-54.14 (I)** (0.87/0.40)	**-33.54 (I)** (0.42/0.28)	**2.78 (N)** (0.89/0.91)	**48.13 (N)** (0.32/0.47)
DT COD horizontal	**-54.77 (I)** (0.91/0.41)	**-24.13 (I)** (0.21/0.16)	**-38.70 (I)** (0.37/0.23)	**55.55 (N)** (0.63/0.98)
DT COD vertical	**-3.97 (N)** (0.90/0.86)	**-67.07 (I)** (0.42/0.14)	**24.44 (N)** (0.26/0.33)	**-16.02 (N)** (0.59/0.49)
DT Walk COD horizontal		**-36.60 (I)** (0.95/0.60)		
DT Walk COD vertical		**-12.97 (N)** (0.24/0.21)		
Cognitive				
ST % success	**78.88 (I)** (29.17/52.17)	**-26.09 (N)** (100/73.91)	**17.91 (N)** (80.95/95.45)	**-24.24 (N)** (73.91/56.00)
ST Response time	**-49.07 (I)** (0.44/0.22)	**19.94 (N)** (0.39/0.47)	**-16.59 (N)** (0.50/0.42)	**-46.39 (I)** (0.79/0.42)
ST Path length	**-46.58 (I)** (0.33/0.26)	**15.34 (N)** (0.34/0.39)	**-26.56 (I)** (0.44/0.41)	**-41.32 (I)** (0.69/0.41)
DT % success	**-63.46 (N)** (73.68/26.92)	**-8.93 (N)** (94.12/85.71)	**-1.04 (N)** (84.21/83.33)	**-22.22 (N)** (78.26/60.87)
DT Response time	**-10.97 (N)** (0.51/0.46)	**-25.72 (I)** (0.88/0.66)	**-14.33 (N)** (0.55/0.47)	**-14.16 (N)** (0.36/0.31)
DT Path length	**-39.98 (I)** (0.18/0.16)	**15.66 (N)** (0.47/0.40)	**25.99 (N)** (0.33/0.41**)**	**-46.39 (I)** (0.79/0.42**)**
DT walk % success		**-26.08 (N)** (82.35/65.38)		
DT walk Response time		**15.20 (N)** (0.61/0.71)		
DT walk Path length		**-50.65 (I)** (0.79/0.39)		
Number of Improved Variables	**7/10**	**6/14**	**2/10**	**3/10**

%Change in score time 1-2 (actual pre/post score) **I** = Improvement; **N** = No Improvement; **COD** = Coefficient of Determination; **DT**= Dual Task; **SPL COP**=Sway Path Length Centre of Foot Pressure; **ST** = Single Task

Individual Balance Daily Task Measures:

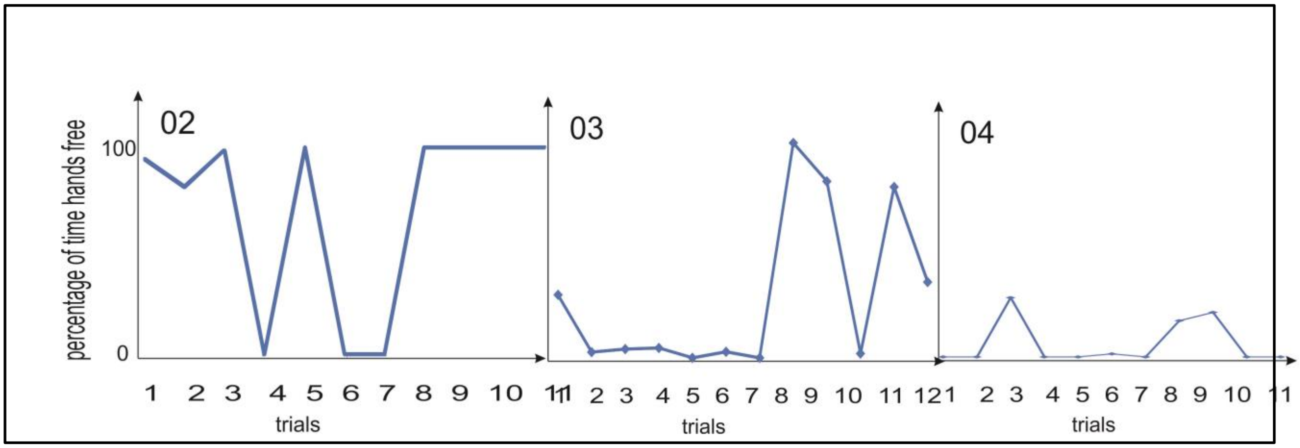
There are limitations to the use of load data with the FSA mat in this study. The nature of the FSA mat is that cells can be maximally activated before full body weight is loaded. Therefore the value of applied body weight going through the mat cannot be accurately calculated. Because the set up available for this study was with two separate mats, and therefore separate and not perfectly synchronized software interfaces, a percentage of the body weight going through the mat at a given moment in time could not be calculated. As an alternative measure, the amount of time during the trial without body weight support was extracted. This had the capability to generate a profile of performance change in three of the four participants, but for the lower functioning individual, who could not perform the task without hand support, could not. It also had a ceiling effect on participant 02 who quickly mastered performing the task hands-free, so further analysis of the COP data needed to be performed to see if she improved (COP-ML trajectory).

Table 11 shows the daily percentage of recorded samples that were hands-free for each subject and Figure 11 shows this graphically for Subjects 02 – 04.

Table 11: Percentage of Daily Balance Task Trial Time Performed Hands-free

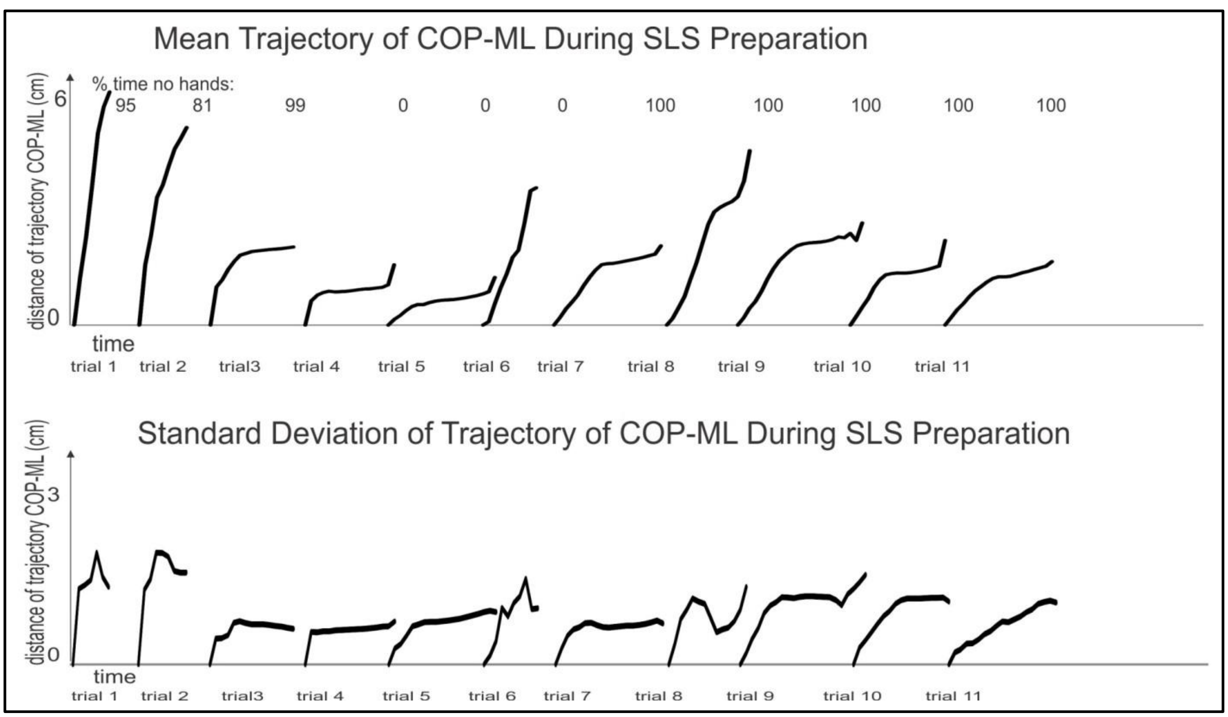
	subject 01	subject 02	subject 03	subject 04
trial 1	0.00	94.48	2.66	0.00
june04h	0.00	81.12	4.09	21.96
june06h	0.00	98.58	4.61	no data
june09h	0.00	0.00	0.00	0.00
june11h	0.00	100.00	2.81	no data
june13h	0.00	0.00	0.00	0.00
june16h	0.00	no data	no data	1.13
june18h	0.00	no data	100.00	0.00
june20h	0.00	0.00	0.00	13.42
june23h	0.00	100.00	82.10	no data
june25h	0.00	100.00	2.00	16.49
june27h	0.00	100.00	79.50	0.00
trial 2	0.00	100.00	35.25	0.00

Figure 10: **Percentage of Daily Balance Task Trial Time Performed Hands free**



As well as the change in upper limb support requirements, it was felt that other features of the daily task might be useful for future indicators of improvement, so this was explored in one of the participants. The mean and standard deviation of the trajectory of the COP-ML of these cut portions of the individual "stepping" events are shown graphically in Figure 12.

Figure 11: **Daily Balance Task Performance**



IV. DISCUSSION

Related to Hypothesis # 1: Feasibility of Intensive Group Treatment

This group of participants obtained a meaningful quantity of Repetitive Functional Task Practice. This occurred even though they had a disparity of physical abilities, and in fact their heterogeneity was advantageous, as higher functioning individuals could still do fairly challenging activities during the time while those with more profound balance impairment had direct supervision. The investigator and assistants observed well-sustained, good effort during semi-supervision, although it was noted that participants used hand support and compensatory movements more frequently when not directly supervised. All of the participants stated that their subjective experience of the intervention was positive from the point of view of having a challenging and useful experience. The fact that they all completed this rigorous intervention with overall good attendance is a testament to their satisfaction with the Boot Camp.

All participants reported that they would have liked more individual supervision during RFTP in order to a) obtain maximal balance challenge with a feeling of safety and b) receive more therapist guidance and feedback to prevent maladaptive compensatory strategies. Indeed this direct supervision would be the ideal; however it goes counter to the goal of maximizing the amount of practice with minimal increase in therapy resources. The circuit format, which allows some people to do less risky activity while one has direct supervision, partially deals with this issue, but the group setting requires that individual input will only occur for a portion of the treatment time. In fact, out of the mean 89.51 minutes of RFTP, between one third and one half (~ 35-44 minutes) was directly supervised. This compares with a typical one-hour individual treatment session in which rest breaks and activity set up occur. The remainder of the RFTP was performed semi-independently, and so possibly was not of as high a calibre regarding challenge and form correction.

Could the above benefits of individual treatment be delivered without increasing staff? For example, routine use of supportive equipment such as harnesses during semi-supervised balance activities could solve the first problem. More use of technologies that provide real-time biofeedback could supplement therapist guidance and foster greater independence in self-monitoring. The FSA technology, already present in this therapy set up, could be enhanced and utilized during standing balance activities to give clients information about symmetry and ability to control sway or improve a given spatial-temporal gait parameter. Incorporating thresholds of performance for certain mats and combining this with stimuli with which the client can interact (for example causing an annoying sound to quieten once the paretic leg is adequately loaded), could further enhance this technology. This may hearken to the days of Force Plate Training such as use of the Balance Master which has been determined to not make an impact on functional mobility in stroke survivors (Barclay-Goddard, Stevenson, Poluha, Moffatt, & Taback, 2004). The FSA system differs from this older technology, as well as the now popular Wii Board gaming system, in its ability to incorporate unstable surfaces, essential to balance challenge (Granacher, Muehlbauer, Zahner, Gollhofer, & Kressig, 2011; Lee, Park, Lee, & Roh, 2011). Thus it could be used during such activities as the above described daily balance activity, use of a mini-stepper, mini-squats and other standing activities that would more closely approximate the demands of functional mobility than mere body sway.

It could, however, be argued that progression to more independence may be one of the most important outcomes of performing some semi-supervised activities. A four-week program will not realistically optimize balance and mobility, as the neural adaptation requires much more repetition and for a longer period of time. Rather it should serve as a means to forming new practice habits that, in the long term will continue to allow positive neural adaptation. The Activities-specific Balance Confidence Scale showed increased scores in both Park (2011) and Salbach (2010) CVA group treatments. It would be hoped that after this type of intervention, participants would have the self-confidence and knowledge of correct skill execution to continue with therapeutic activities that can be performed at home or in the community, as well as to increase the amount of balance/mobility activity performed in daily life. For this to occur, balance self-efficacy, along with actual balance changes, must be improved.

As well as RFTP, other valid types of physical activity, which could be delivered without one-to-one supervision, further increased active rehabilitation to more than two hours per intervention day. Participants averaged 18 minutes per session of aerobic exercise, important for cardiac health and general physical fitness. There has been speculation that aerobic exercise may also be an important adjunct to neural adaptation, possibly due to up-regulation of brain derived neurotrophin factor and/or improved cerebral blood flow (Forrester et al., 2008b; Mang, Campbell, Ross, & Boyd, 2013; Ploughman et al., 2009) Participants also performed 27 minutes of stretch and strength exercises. There is some evidence that trunk strengthening makes a positive impact on balance in the elderly and stroke populations (Granacher, Gollhofer, Hortobagyi, Kressig, & Muehlbauer, 2013; Ko, Jung, & Bae, 2014). Although both aerobic and strengthening exercise can be safely prescribed for home, past studies have demonstrated that structured exercise has a greater likelihood of being regularly performed and generalize to subsequent, independent performance in the ABI population (Hassett, Moseley, Whiteside, Barry, & Jones, 2012; Wise et al., 2012). Thus there is value to encapsulating these activities into this group model.

Apart from the amount of physical rehabilitation delivered, there was also an important psycho-social aspect of the Boot Camp model of treatment. Subjective reports of the fun and motivating value of the group dynamic were corroborated with observed supportive interactions and the good humour amongst the participants throughout the day. Positive psycho-social input is an important aspect of brain injury rehabilitation. Negative changes in social functioning, including poor self-esteem, loss of previous friendships, and difficulty communicating with and sustaining positive family relationships are commonly seen after moderate to severe ABI (Ponsford, Kelly, & Couchman, 2014). Incidence of depression is higher than in the general population, partly due to injury-related physiological brain processes as well as reaction to associated losses (Hart et al., 2011). Interaction with other ABI survivors and families has been shown to aid in creating a new, healthier concept of self (Couchman, McMahon, Kelly, & Ponsford, 2014). Past research supports positive participant perception of social benefits in group therapy for multiple conditions including ABI (Blennerhassett, 2008; Gelsomino, Kirkpatrick, Hess, & Gahimer, 2000; Lynch et al., 2008; Schouten, Murray, Boshoff, Sherman, & Patterson, 2011; Zanker, English, Prideaux, & Luker, 2007). Improved mental health measures (Beck Depression Scale and hours of activity) have also been documented (Wise et al., 2012).

A big motivation to doing this study was to address the need for cost efficient therapy**.** Participants were treated in a group of four, with one experienced physical therapist and one trained rehabilitation aide. For the cost of 63.6 minutes of therapist time, the Boot Camp delivered 89.51 minutes or 1.4 times the absolute amount of RFTP that could be delivered if that were individual treatment. Of that time, at least one third (an estimated 32-39 minutes) was directly supervised. As noted above, it is rare to be performing RFTP throughout the entire session. For example, Lang's (2009) survey of 230 individual CVA treatment sessions related to balance and mobility found an average of 84 % of a treatment session, which would be 53.42 minutes for the same amount of therapy time, was devoted to related RFTP. Lang et al. note that this percentage is elevated, as treatment techniques that addressed more than one impairment (example walking *and* balance training) were counted twice. The Boot Camp provided a substantially greater quantity of RFTP for the same therapist time and so appears to be cost effective. Cost efficacy has been reported in other group therapies including those for a comparable diagnosis (CVA) (Blennerhassett, 2008; De Weerdt et al., 2001; English, Hillier, Stiller, & Warden-Flood, 2007; Gelsomino et al., 2000; van de Port, Ingrid GL et al., 2009). Admittedly, dosage cannot be directly compared to individual therapy sessions as semi-supervised activity is possibly not of the same level of challenge as directly-supervised. However, at least one third of the RFTP in this study was individually supervised and thus directly comparable. It must be remembered that there was correction and periods of close staff assistance during the semi-supervised circuit stations and group activities, so a portion of the "semi-supervised activity" actually had direct supervision.

Many group therapy studies stratified patients to levels of ability in order to provide treatment, whereas, in this study this was intentionally not done. In smaller centers, there may not simultaneously be sufficient numbers of appropriate clients to do this; therefore, the options are to delay intervention until there are or to cope with disparity in function. An important question of this study was to see if the latter was feasible and in this case, not only was it possible, but actually was beneficial. However, the increased treatment planning time on the part of the Physical Therapist needs to be considered as this will factor into the cost. It took approximately 2 hours (total) to create the initial treatment plan for all four participants, particularly determining the order in which rotations would need to be done to allow one-to-one supervision for the appropriate activities. Weekly upgrades to the treatment program required approximately one hour total for all participants. Despite these professional costs, this treatment is still less costly and more intense that individual treatment.

Related to Hypothesis # 2: Potential Performance Improvements

The purpose of the pre- and post-assessments was to determine if any individual improvements were noted and which ones may be most useful in future study of this model. Clinical improvements were seen in one or more of the ICF domain levels for all participants. For this reason, although no conclusions about efficacy can be made, it is reasonable to further investigate this type of intervention. The fact that the treatment is based upon principles that reflect current best practice, and has been shown to be effective in a similar population (CVA) would further support that (Bloem, Valkenburg, Slabbekoorn, & Willemsen, 2001; Yogev-Seligmann, Hausdorff, & Giladi, 2008).

Single versus Dual Task Performance: Given the volume of challenging interactive, gaming-based, dual task balance practice, meaningful improvement in one or both of the assessment tasks would be expected. The core balance performance measures improved for the three subjects who could perform this in standing. The visual cognitive performance during dual task conditions showed a mixed trajectory of change. A similar profile is seen for the Single Versus

Dual Walking for Subject 02 who demonstrated improvements in ST and DT walking performance but mainly decline in secondary task measures. Thus these participants had improvements in balance/mobility, and only inconsistently in dual tasking ability. This may reflect adopting a strategy to prioritize the balance aspect of the dual task, which would be adaptive to reduce the risks associated with falling and which is seen in normal subjects (Bloem et al., 2001; Yogev-Seligmann et al., 2008). It could, however, simply indicate not attending to the secondary task for periods of time and thus in essence reverting back to single task walking. In any case some improvements in aspects of these tasks were noted for Subjects 02-04. Subject 01 did not show improvement on the balance task but did show some improvement on most secondary task variables. This suggests neither improvement in dual task ability nor balance, rather only improvement in the visual cognitive task.

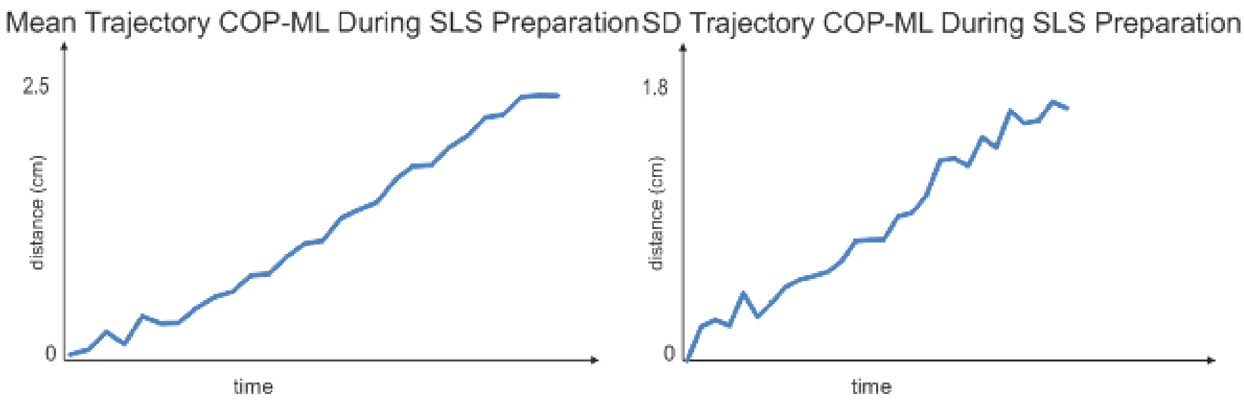
The importance of dual task training has been well established (Hayes, Donnellan, & Stokes, 2011; McCulloch, 2007; McFayden et al., 2009): practical outcome measures have not. Measures often do not monitor performance on the secondary task, thus neglecting to determine if the subjects are in fact dual tasking or just not doing the secondary task. This method of monitoring both variables would be valuable for future study in a) grading the difficulty of dual task RFTP activities; b) documenting improvement; c) predicting balance risk situations.

Regarding Hypothesis # 3: Value of Daily Measures

The Daily Measures were introduced to compensate for difficulty seeing change based on occasional assessment such as in current clinical practice. One principle of balance measurement that must be remembered is that if a task is very difficult for an individual, there will be a lot of performance variability. This will be magnified if the person’s ability is very low as there would need to be a very high amount of change in order to exceed variance and thus be consistently detected. More regular measuring allows a trajectory of change to be seen. Although there were drawbacks to the use of the load data to generating time spent hands-free during a standardized task, three of the participants did show a trend towards improvement in this type of measure. A force sensor system with 2 mats that are synchronized to one software interface would not only be more useful for determining a specific amount of upper limb support compared to body weight, but also symmetry of weight bearing between legs during a variety of tasks. Split FSA mats that allow easy determination of total load on the paretic versus non-paretic foot during all standing activities may be crucial to evaluate hemiplegic balance/mobility performance, since developing better symmetry is correlated with improved spatial-temporal gait parameters in stroke-related ABI's (Nardone, Godi, Grasso, Guglielmetti, & Schieppati, 2009).

The daily task COP-ML trajectory, which was further analysed for Subject 02 to extract the SLS preparation phase, demonstrated some interesting features that might be valuable as ongoing balance performance measures if automated. The stage of transitioning from the less affected to more affected side in preparation for single leg stance was seen to become smaller in average and standard deviation of amplitude of distance travelled and to have a smoother, slower transition on the days that the participant was using some upper limb support throughout the task. The author performed a preliminary study of this task with normal subjects and processed the data similarly. The average COP-ML trajectory was noted to be a straight slope (Figure 12) whereas Subject 02 had a hyperbolic trajectory. Trends towards a straighter line could be seen as an improvement as well as would be a reduction of the standard deviation which would reflect less variability between repetitions of the activity during each session. Thus, automatizing the extraction of this type of information would be very useful for monitoring balance performance during this crucial stage of gait.

Figure 12: **Normative COP Variables for Single Leg Stance Preparation**



Many rhythmical activities related to client goals could be generated and used as a basis of the Daily Measures. Treatment activities at some circuit stations could be routinely recorded with appropriate equipment to generate this type of profile of change over time. For example, if boot camp participants were at a level that they could perform hands-free treadmill walking, a snap shot of this performance could easily be recorded on a daily basis and the above spatial temporal variables could be analyzed. It would also be advisable to apply non-linear analysis. Non-linear variables of performance such as Frequency Analysis and Dynamics Systems Theory are recently postulated as best capturing the complexity of human walking balance and have been shown to differentiate healthy from neurologically impaired (Hausdorff, 2007; Kaipust, Huisinga, Filipi, & Stergiou, 2012) and fallers from non-fallers (Granata & Lockhart, 2008). They are generated by applying theoretical mathematical models to movement data measures such as the centre of foot pressure and motion monitors applied to the trunk, pelvis or ankle in order to capture non-linear characteristics. Because variability is expected and necessary to walking balance (Harbourne & Stergiou, 2009), looking at the quality, rather than just the quantity, of this variability can further shed light. Frequency Analysis includes the Fast Fourier Transform (FFT) which sorts signal energy into different frequency bins, to allow determination of the dominant frequencies at which movement occurs. This can then be related to the fundamental frequency of a given movement if that exists (for example, during gait or another cyclic movement) (Brach, McGurl, & Wert, 2011; Kavanagh, Barrett, & Morrison, 2005; Menz, Lord, & Fitzpatrick, 2003; Tsuruoka & Shibasaki, 2006). Detrended Fluctuation Analysis (DFA) determines if signal frequency patterns repeat over long time series (Hausdorff, 2007). Approximate Entropy (ApEn) predicts the regularity of patterns in a time series. Lower values reflect more regularity (and hence more rigidity) and higher values more variability (more flexibility) in the studied behaviour. In, Dynamics System Theory the concept of stability describes the tendency of a system to returns to its original trajectory or to join another after a perturbation (Buzzi & Ulrich, 2004; Chaudhry, Bukiet, Ji, & Findley, 2011; Dingwell & Cusumano, 2000; Granata & Lockhart, 2008)

Individualization needs to be built into this aspect of the boot camp, due to the typical heterogeneity of this population. In this group, two participants had unilateral motor control impairments, and two were bilaterally affected. One participant had cerebellar ataxia but no paresis, whereas the others all demonstrated paresis. Another participant had severe clonus that greatly perturbed balance; the others did not. The balance learning strategy would need to be different for all of these impairments: thus monitoring must be flexible and multi-faceted to be of value.

A force sensor system with two mats synchronized to one software interface would not only be more useful for determining level of upper limb support, but also for determining symmetry of weight bearing between legs during a variety of tasks. Split FSA mats that allow easy determination of total load on the paretic versus non-paretic foot during all standing activities is crucial to evaluate hemiplegic balance/mobility performance, since developing better symmetry is correlated with improved spatial-temporal gait parameters in stroke-related ABI's (Nardone et al., 2009).

Guiding Principles to Enhance Future Boot Camp Delivery:

A case series cannot inform re: treatment efficacy; rather, the value of this type of study is that it can assist in formation of principles for complex therapy interventions in populations where lack of homogeneity is the norm. Based on the above discussion, the following is recommended to optimize the combination of delivery of quality, evidence-based RFTP, safety and cost effectiveness:

Regarding Feasibility:

- The ratio of four participants to two staff, one experienced professional and one well-trained para-professional was overall successful. More iterations of the Boot Camp for staff would allow the ability to streamline processes. While staff are adapting to this model and logistics in their own facility, there should be the availability of another person on an ad hoc basis.
- The daily duration of intervention was challenging for participants but tolerated, therefore this should be maintained in the interest of driving neural adaptation and overall activity tolerance.

- Increasing the intervention to 6 weeks would have several benefits; there would be greater consolidation of motor learning and exercise habit, there may be more clinical measure change and the treatment planning/delivery ratio would be more economical. It is not unusual for out-patient therapy to be funded 3 times per week for at least 6 weeks for this population so this would be financially possible.
- The appended guidelines for treatment activity planning (Appendix 6) appeared to be successful. However, expansion of this to include creation of a bank of activity suggestions and equipment would be helpful for different therapists to provide more uniform variety of treatment. The detailing of the visual cognitive load of specific computer games is in progress and would enhance the treatment planning package.
- A guide for planning the logistics of transitioning clients from one station to another and ensuring that all get one-to-one supervision time should be detailed further, as this required a large amount of planning time on the part of the primary researcher.
- Formal documentation of therapist treatment planning time and the amount of 1:1 treatment time would assist in more accurately determining cost effectiveness.
- One adverse event did occur related to semi-supervision. The situation leading to this individual's fall was easily remedied once identified, thus the researcher believes that more in-depth physical screening and safety equipment is needed. It is recommended that the first treatment session is a one-hour individual session which allows the therapist to see performance at all stations and thus plan for available stationery supports. Use of safety harnesses such as construction workers use (body weight support systems would not be needed as the goal would not be to off load) with multiple strategic places in the treatment area to attach these should be used routinely during semi-supervision.

Regarding Efficacy:

- A larger number of participants should be recruited to allow several iterations of the Boot Camp and to allow statistical analysis of measures of efficacy
- A control intervention should be provided as part of an AB cross-over study. This will allow participants to be their own controls and thus compensate for expected heterogeneity in physical ability.
- Addition of outcome measures that determine balance self-efficacy and exercise behaviour changes would document the value of this type of intervention in transitioning participants to more self-directed therapy behaviours or to group programs that do not require as much direct professional supervision.
- All Outcome Measure testing should be blinded and performed by independent assessors
- A flexible battery of assessments is needed if participants are of multiple ability levels. The ones used in this study were selected to reflect a spectrum of balance and mobility function, but as discussed, without some gathering of COP data do not reveal the nuance of balance performance change. The most valuable for future study would be looking at symmetry of weight-bearing for hemi-paretic people during activities that demand this as well as SPL COP ML and/or AP.
- An increase of daily measures of activities as described above is recommended. The patterns of COP control or loading during these daily dynamic balance tasks could be automated to allow therapists to visually determine trends in improvement. Ideally, a bank of balance exercises and their corresponding relevant variables could be created and standardized with normative data. For higher functioning people, treadmill data could be used this way with the

two linear measures in this study as well as Frequency Analysis, in order to observe non-linear aspects of walking performance.

- Follow up use of the Part-O 17 should occur 4 to 8 weeks post intervention to prevent confounding by the actual Boot Camp participation and to better determine if benefits extend into daily life on an on-going basis.

Conclusion:

This Boot Camp model of balance and mobility treatment for people with moderate to severe ABI demonstrates potential to be successful logistically, cost-efficient and effective. As a result, serious consideration should be given to its further study. This project was useful in creating principles of treatment and performance monitoring that could be applied to a randomized control trial of efficacy. The most important principle noted was that careful planning is required to provide safety while simultaneously giving participants multiple opportunities to challenge themselves through being out of balance, with and without dual task demands.

Appendix A: Telephone Pre-screening Tool:

Subject Number: ______ Date: ________

Do you have any questions about the research project?

Review the basics of the project:
Where? Rehabilitation Hospital at the Health Sciences Centre

What?	**When**?		
Screening assessment (45-60 minutes)	In the next week		
Initial assessment (1.5 hours)	Week of March 3	OR	Week of April 14
Pre-intervention assessment (2 hours)	Week of April 7	OR	Week of May 19
Treatment (3 days a week, 4 weeks, 6 hours a day)	April 7 –May 9	OR	May 26 – June 20
Post-Intervention assessment (1.5 hours)	Week of May 12	OR	Week of June 23

When did you have your brain injury?
1-5 years ago □ □< 1 year Ago □ > 5 years ago

How long were you in a coma? (Ask if not referred by Dr. Galimova)________________

Are you still having trouble getting around? Yes □ No □
If "yes", can you stand up for short periods of time? Yes □ No □
Do you have any trouble thinking or remembering since your accident? Yes □ No □

Is your thinking and memory good enough to make your own medical decisions?
Yes □ No □

Do you think you would like to participate? Yes □ No □
Would you be available? Yes □ No □
Could you commit to coming all day 3 x/week for 4 weeks? Yes □ No □

Set up Screening Assessment appointment:
date:_________________________
time:_________________________

Appendix B: RESEARCH PARTICIPANT INFORMATION AND CONSENT FORM

Title of Study: Rehabilitation Boot Camp: an Innovative, Four-Week Program to Deliver Intensive Balance and Mobility Therapy to People with Acquired Brain Injury (ABI)

Protocol number: H2013:403

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You are being asked to participate in a research study. Please take your time to review this consent form and discuss any questions you may have with the study staff. You may take your time to make your decision about participating in this study and you may discuss it with your friends, family or (if applicable) your doctor before you make your decision. This consent form may contain words that you do not understand. Please ask the study staff to explain any words or information that you do not clearly understand.

Purpose of Study

This pilot rehabilitation study is being conducted to determine if an intensive, group rehabilitation program using functional practice, computerized games and monitoring can be an effective and efficient way to improve balance and walking. You are being asked to take part in this study because you have had a brain injury and still have difficulties with balance and mobility and possibly some cognitive (thinking) problems. A total of 12 participants are expected participate in this study.

Study procedures

1. Screening Assessment:

Once you decide to participate, you would be asked to participate in a screening assessment. This will be done to ensure that your needs and abilities are appropriate for this type of treatment program.

All tests will be conducted by a Physical Therapist in the clinical research laboratory of Dr. Szturm, 3rd floor, Rehabilitation Hospital, Health Sciences Centre. You will be asked to dress modestly with a comfortable shirt, pants, socks and shoes or runners. You will be asked to bring any braces or walking aides, such as a cane or walker, that have been prescribed and/or which you customarily use.

The screening procedure consists of the following:

An assessment of your ability to think will be performed (the MoCA or Montreal Cognitive Assessment) to ensure that you can make informed consent.

An assessment of your physical abilities to:

a) Maintain balance while sitting unsupported on the edge of a bed
b) Rise from sitting to standing
c) Maintain a standing position
d) Walk 10 meters if you are currently able to do so.
e) You will be asked to move your arms and legs in a variety of positions, and the therapist may physically move them if you are unable to move them independently through the full range of motion. Measurements of any movement restrictions will be taken and recorded to plan your individualized treatment activities

If you require assistance with any of these tasks it will be provided by the Physical Therapist.

If you have any troubles with following direction, exercise tolerance or focusing to the assessment, the researcher may ask permission to get more information about your day-to-day abilities from your health care workers or family members.

If your abilities on these tests match those required for the study you may participate in the study and you will be scheduled for assessments and the treatment group. If they do not, no further involvement will be asked of you.

2. Baseline Assessment (estimated time 1.5 hours):

This will be scheduled to occur 5 weeks prior to the start of the exercise program. It will include the following physical examination, balance and walking testing and some questionnaires about how your brain injury affects your daily function. All tests will be conducted by a Physical Therapist in the clinical research laboratory of Dr. Szturm, 3rd floor, Rehabilitation Hospital, Health Sciences Centre. You will be asked to dress modestly with a comfortable shirt, pants, socks and shoes or runners. You will be asked to bring any braces or walking aides, such as a cane or walker, that have been prescribed and/or which you customarily use. At all times the assessor will be close by, or provide hand support in order to provide physical assistance should you need it to finish the test or prevent you from losing your balance. If there are any tasks that you feel you cannot do you may choose to not attempt these.

Your ability to move around will be measured:

a) You will be asked to demonstrate how well you can move around on a bed, to transfer to and from different surfaces, and, if possible, to climb up and down a flight of stairs.
b) If you are currently able to walk without physical assistance from another person (with or without a walking aide), we will ask you to walk on an indoor course at your fastest reasonable and safe pace for 2 minutes. You will have somebody walking close to you in the event that you lose your balance. If you feel you need to rest before the 2 minutes are complete, you will be allowed to do so.

You will then be asked to do a series of balance tests. Prior to this testing, three lightweight motion sensors will be attached to your waist, chest and ankle. All of the following tests will be done with a pressure sensor mat under your feet and on any hand supports provided. These sensors will record your movements during the tests, so the quality of your movement can be analyzed.

a) Standing with your feet stationery you will be asked to reach as far as you can in 4 directions If you are unable to do this test in standing you will be asked to do it in sitting.
b) You will be asked to get from sitting to standing 5 times without the use of your arms.
c) You will be asked to stand still for 30 seconds in the following conditions (Clinical Test of Sensory Integration and Balance):
    i) On solid ground eyes open
    ii) On solid ground eyes closed
    iii) On a 4 inch thick sponge foam surface eyes open
    iv) On a 4 inch thick sponge foam surface eyes open

d) You will be asked to wear a small, head-mounted computer mouse for the following head and eye movements and measures of your head movements will be taken while sitting in a supportive chair and then either sitting on an air-filled bladder, standing on solid ground or on the sponge foam. (This will depend on your balance ability)
    i) While you rotate your head slowly left and right for 30 seconds using a metronome to help you maintain a constant rhythm,
    ii) While you perform a visual tracking task on a computer for 30 seconds. You will view a moving cursor on a computer screen and be asked to match its motion by rotating your head in left and right direction.
    iii) While playing a simple computer game for 60 seconds.
e) If you are currently walking, you will be asked to walk on a treadmill at 1.0 km/hour (0.6 mph) for 2 minutes. The treadmill is equipped with side rails and an overhead body support safety harness.
f) If you were able to walk on the treadmill for e), you will be asked to repeat the visual tracking tasks (d) i) through d) iii)) while you walk on the treadmill at 1.0 km/hour (0.6

mph) for for two minutes for each condition. If you are not walking or could not complete the walking test d), this will not be tested.

g) You will be asked to do one other balance task, which has been specifically designed for your level of ability and needs, for 2 minutes. This test will later become one of your daily exercises and will be measured every time you do it during the exercise program.

We will provide you with a clear demonstration and chance to practice each task prior to the test.

You will be asked to complete an interview/questionnaire about how your brain injury affects your day-to-day ability to function in life. This consists of 17 questions about your ability to do be productive, to do things in your home, to do things out and about in the community and to socialize.

Frequency of Testing:

This assessment will be repeated within the week before you start the program, within the week after the end of the program and 12 weeks after the program is completed (Four assessments in total). During the assessment performed in the week before the program, we will also ask you to try out (approximately 30 minutes) some computer games so we know which ones you like and are challenging.

Access to personal health information:

In addition we would ask you to provide some personal health information or to ask your physician, family member and other rehabilitation workers to provide us with this information. This would include the history of your injury, the type of treatment provided in the past, the medications that you are taking, and information about other health problems that you have. This information will be collected by the treating physical therapist (Cristabel Nett). The purpose of collecting this information is for interpretation of findings as well as to ensure your safety as you perform an exercise program.

Any analysis or publication of personal health data or study outcomes will not include your name. A coded number will be used instead of your name on all data forms that contain this personal health information. These will be placed in a file with your name, which will be kept in a locked file cabinet for the 4 weeks while you are attending, for the purpose of treatment. After this time, the information will be placed in a file that only has the identifying number, rather than your name. A list associating the number with your name will be kept in a locked file cabinet and on an encrypted computer server only.

Therapy Program

You will be asked to attend therapy sessions for six hours/day, three days/week for 4 weeks. You will attend together with other people who have similar problems. There will be a variety of exercises throughout the day. Some will be done together as a group and some will be done as part of a circuit, but they will all be based on your individual abilities and needs. Cristabel Nett will supervise all therapy sessions, although some of the therapy may be provided by a trained rehabilitation assistant or physiotherapy student. These would be completed in a four-week period at the clinical research laboratory of Dr. Szturm at the University of Manitoba, School of Medical Rehabilitation, RR345 – 800 Sherbrook Street, Winnipeg, Manitoba.

Exercises may include:

- **Balance exercises** that may be performed sitting or standing on an unstable surface or walking on a treadmill while playing computerized games. The purpose of this is to provide visual and thinking challenge which is important to help maintain your balance. It can also make the practice more fun.
- **Aerobic exercise** to improve your cardiovascular endurance. This may be with the use of a stationery leg or arm bicycle, treadmill or elliptical trainer and may also be combined with computerized games as above.
- **Stretching exercises**
- **Practice of functional movements** such as transfers, steps, reaching for objects, etc.

You will be provided with rest breaks and frequent changes of activity as required, to maintain attention and energy levels.

You will be asked to inform us of any change in symptoms and your health status or incidence of injury that may occur during the research program, even if these are not directly related to the exercise program.

You can stop participating at any time. However, if you decide to stop participating in the study, we encourage you to talk to the study staff first. Your refusal to participate or decision to stop participating will never affect future care to which you are entitled. If you are interested in the results of the study you may contact the Principle Investigator at the end of the study. We hope to present our findings to the Manitoba Brain Injury Association and will inform you of the date of any such presentation.

Risks and Discomforts

You will be asked to try standing and walking activities and so there is a risk of falling. The therapist will set things up and provide assistance in an effort to prevent this. The assessment sessions could seem strenuous. You will likely feel tired and may feel some muscle soreness and dizziness after the assessment sessions. You may find that some of the questions are emotionally upsetting. When starting the exercise program, you may experience an increase in fatigue, dizziness and muscle soreness. Some people may experience some frustration if they feel they are unable to do all the exercises well. Any underlying condition you may have may not improve or may worsen while participating in the study.

Benefits

By participating in this study, you will be providing information to the study investigators that will show the effects of group brain injury. There may or may not be direct medical benefit to you from participating in this study. We hope the information learned from this study will benefit other participants with mobility problems due to acquired brain injury.

Payment for Participation

You will receive no payment or reimbursement for any expenses related to taking part in this study.

Confidentiality

Information gathered in this research study may be published or presented in public forums; however your name and other identifying information will not be used or revealed. Despite efforts to keep your personal information confidential, absolute confidentiality cannot be guaranteed. Your personal information may be disclosed if required by law. Medical records that contain your identity will be treated as confidential in accordance with the Personal Health Information Act of Manitoba.

The University of Manitoba Health Ethics Research Board may review records related to the study for quality assurance purposes. No information revealing any personal information such as your name will leave the University of Manitoba.

Public Information about this Study

ClinicalTrials.gov is a website that provides information about federally and privately supported clinical trials. A description of this clinical trial will be available on http://www.ClinicalTrials.gov. This website will not include information that can identify you. At most, the website will include a summary of the results. You can search this website at any time.

Voluntary Participation/Withdrawal from the Study

Your decision to take part in this study is voluntary. You may refuse to participate or you may withdraw from the study at any time.

Participants who are students or employees of either The University of Manitoba or Health Sciences Centre or individuals associated professionally with any of the investigators can be assured that a decision not to participate will in no way affect any performance evaluation of potential participants. Participants who have been former clients of the Primary Investigator can be assured that a decision not to participate will in no way affect any future treatment by the Primary Investigator.

Medical Care for Injury Related to the Study

You are not waiving any of your legal rights by signing this consent form or releasing the investigator from their legal and professional responsibilities. In the event that you sustain injury while participating in this study, you will be assisted to obtain appropriate medical care.

Questions

You are free to ask any questions that you may have about your treatment and your rights as a research participant. If any questions come up during or after the study or if you have a research-related injury, contact any one of the study Co-investigators: Dr. Tony Szturm (204)787-4794 or Cristabel Nett (204)787-1164.

For questions about your rights as a research participant, you may contact The University of Manitoba, Bannatyne Campus Research Ethics Board Office at (204) 789-3389. Do not sign this consent form unless you have had a chance to ask questions and have received satisfactory answers to all of your questions.

Statement of Consent

I have read this consent form. I have had the opportunity to discuss this research study with Cristabel Nett or Dr. Szturm. I have had my questions answered by him/her in language I understand. The risks and benefits have been explained to me. I believe that I have not been unduly influenced by any study team member to participate in the research study by any statements or implied statements. Any relationship (such as employer, supervisor or family member) I may have with the study team has not affected my decision to participate. I understand that I will be given a copy of this consent form after signing it. I understand that my participation in this study is voluntary and that I may choose to withdraw at any time. I freely agree to participate in this research study.

I understand that information regarding my personal identity will be kept confidential, but that confidentiality is not guaranteed. I authorize the inspection of any of my records that relate to this study by The University of Manitoba Research Ethics Board, for quality assurance purposes.

By signing this consent form, I have not waived any of the legal rights that I have as a participant in a research study.

Participant signature________________________ **Date _____________**

Participant printed name: ____________________________

I, the undersigned, have fully explained the relevant details of this research study to the participant named above and believe that the participant has understood and has knowingly given their consent**.**

Printed Name: _________________________ **Date ____________**

Signature: ____________________________

Role in the study: ___________________________

Relationship (if any) to study team members: **_____________________**_

Appendix C: Physical Screening Assessment: Subject Number:______Date:_______

1) Transfer:

Subject to transfer to edge of high mat:

Method: Standing pivot □ squat pivot □ sliding board □

Level of assistance required: Independent □ Set up and/or cuing □

Physical assist < 50 % □ Physical assist > 50% □ mechanical lift □

2) Sitting balance: Able to sit independently at the edge of the bed

Yes □ No □

3) Arm Function:

Able to actively lift one arm to shoulder height:

Yes □ Right □ Left □ No □ Right □ Left □

Position a bedside table in front of subject at a comfortable height with drinking glass half-filled with water on table surface.

Able to successfully pick up and place down with at least one arm while sitting:

Yes □ Right □ Left □ No □ Right □ Left □

Ask subject to extend knee. Able to voluntarily move at least one leg while sitting:

Yes □ Right □ Left □ No □ Right □ Left □

4) Sit to stand: Starting in a standard arm chair or subject's wheelchair which is parked with the subject's strong side near a stable, waist-height bench:

Able to rise from sit to stand and stabilize self in a standing position with or without use of bench. Independent □ Set up and/or cuing □ Physical assist < 50 % □

Physical assist > 50% □ Unable □

5) Standing Ability:

Able to maintain unsupported standing for 30 seconds: (allow 2 tries)

Yes □ No □

Able to stand for 3 minutes without a rest: (allow 2 tries)

Yes □ No □

Needs hand support for part of this time:

Yes □ No □

1) **Walking ability**: If subject is walking: 10 m walk test time:

trial 1_______s. trial 2_____s.

Gait aide: Assistance needed: Yes □ No□ Gait abnormalities: Yes □ No □

Appendix D: Physical Assessment Sheet

Physical Assessment

Subject Number: ______ **Date**: _______

Observation Posture:

Sitting: **Standing**:

Voluntary Movement Selectivity:

S= Selective **PS**=Partially Selective **NS**=Non-selective

	S	**PS**	**NS**		**S**	**PS**	**NS**
R shoulder				L shoulder			
R Elbow				L Elbow			
R Wrist and hand				L Wrist and hand			
R hip				L hip			
R knee				L knee			
R Ankle and Foot				L Ankle and Foot			

Range of Motion/Strength (indicate abnormal values only):

Joint	**R AROM**	**R PROM**	**L AROM**	**L PROM**	**R Strength**	**L Strength**
Shoulder: Flex/ext						
Abd/Add						
IR/ER						
Elbow: Flex/ext.						
RUJ: Prono/sup.						
Wrist Flex/ext.						
RD/UD						
Hand: Fist/Open						
Hip: Flex/ext						
Abd/Add						
IR/ER						
Knee: Flex/ext						
Ankle: PF/DF						
Inv/ev						
Thoraco-Lumbar: Flex/ext						
R/L Rotation.						
Cervical: Flex/ext						
R/L Rotation						

Subject Number: **Date:**
ROM/Strength (cont) Comments:

Abnormal Tone/Reflexes:

Sensation:

Lt Touch	R U/L	L U/L	R L/L	L L/L
Proprioception	R U/L	L U/L	R L/L	L L/L

Coordination: (Repetitions in 10 Seconds**)**

FNT	R	L
RAM U/L	R	L
HST	R	L
RAM L/L	R	L

Comments:

Walking Ability:
Aide used: **Assistance needed:**
Gait Pattern:
Spatial Temporal Abnormalities:

Postural Control abnormalities:
- L/L
- Trunk
- Neck

Arm Swing

Assessor Signature:______________________

Appendix E: Individual Program Development Guidelines

Guiding principles:

- Activities for circuit training are based on impairments noted on the individual subject's initial assessments
- Neural adaptation results from RFTP that is variable and meaningful, therefore for each station a repertoire of variability must be built in. This can be done with variety of computer games, or objectives of the task that is practiced (different heights, surfaces etc.)
- Initial evaluation of ability will determine the client's starting point for each station. From there a varied repertoire will be developed for each station and attendance at that station will cycle through this repertoire rather than always performing the given task in the exact same manner. This will be influenced by the initial assessment goals.
- Weekly goal setting between the therapist and the subject will determine the level of increment for the following week. This may include increasing duration of activity, difficulty of balance demand through such things as increasing the instability of the working environment, adding or increasing the demand of the dual task activity
- Subjects who do not have deficits in certain portions of the circuit training (ex no: evidence of gaze control issues) will perform an additional station in another area of impairment (example functional mobility) instead of the original station. It is anticipated that most subjects will have some level of deficit in all areas.
- When possible, 2 subjects will work together to promote social incentives and benefits.

Defining the Activities for Circuit Training

1) **Gaze control** with computerized games (sitting or standing as possible)

The posture, with or without an unstable surface must be indicated. The subject should be in the highest posture that can be maintained on the unstable surface *without any assistance*. At least 5 different specific video games must be chosen based on the gaze control needs and preferences of the subject. In order to meet the principle of variety of task practice, interactive games will be changed within the station and from station to station.

<u>Progression of instability:</u>

Sitting on core disc → deflated Swiss ball → **Standing** on solid surface to standing on foam (firm → springy) → standing on core disc with board OR standing on stepper maintaining pedals stable.

<u>Progression of interactive gaming:</u>

- mouse in hand to mouse affixed to head.
- decreased need for precision to increased need for precision inherent in the game.

2) **Standing balance/ weight shifting activities on unstable surfaces (close supervision)**

The posture, with or without an unstable surface must be indicated. The subject should be standing on the most challenging surface possible while maintaining reasonable form. He or she may have SBA to minimal assistance and/or occasional upper limb stabilization At least 5 different specific activities must be described

Progression:

- Reduce external support provided
- Increase difficulty of standing surface (see above)
- Add need for participant to move base of support
- Add multi-tasking activity (cognitive, gaze control)

Examples: use of mini-stepper, use of Fitter, Long step on board etc.

3) **Walking activities** (treadmill or over-ground)

Five walking activities in the most challenging way possible while maintaining good form. (May have standby to occasional moderate assistance and/or use a walking aid)

Progression:

- Increase speed
- Change direction
- Walk on alternative surfaces
- Perform obstacle activities
- Multi-task → increase the cognitive demand of the game
- Reduce supportiveness of the walking aide.

4) **Cognitive games** (sitting or standing as possible)

Guidelines: This station may be used as a physical rest depending on the subject's tolerance. If he or she has adequate tolerance, these activities can be combined with balance/ambulation activities as possible. The posture, with or without an unstable surface must be indicated. The subject should be in a posture that can be maintained *without any assistance*. At least 5 different specific video games must be chosen based on the cognitive impairments as well as preferences of the subject. In order to meet the principle of variety of task practice, interactive games will be changed within the station and from station to station.

<u>Progression of instability</u>:
Sitting on core disc → deflated Swiss ball → **Standing** on solid surface to standing on foam (firm → springy) → standing on core disc with board OR standing on stepper maintaining pedals stable

<u>Progression of interactive gaming:</u>

- Increase cognitive demand of the game
- Dual tasking during more difficult physical tasks
- Mouse in hand to mouse affixed to head

5) Stretching/strengthening focal muscles

- Stretches: List those that should be performed
- Strength Training: List those that should be performed

Guidelines: Exercises based on impairments noted on initial assessment (Appendix C)

<u>Progression</u>:

- Strength training: increase resistance, repetitions, duration, lever arm length, need to stabilize other body segments
- Stretch: Increase the range through which the muscle is stretched

6) **Functional**

- Lie to sit
- Sit to stand
- Transfers
- Step ups
- Reaching for items

- Other mobility activities that the client cannot perform but needs to function optimally in life.

Guidelines: At least 5 functional tasks should be devised. Indicate the specific parameters for practice for each chosen task including the specific modifications to the task, where it is to be performed, if the height of the surface can be altered (example, seat height for practicing STS, indicate which height it should be), etc.

Progression: (any combination of the following that will more closely approximate client's functional needs)

- Start with practicing a portion of the task → progress to practicing the entire task
- Set goals to perform more repetitions
- Vary the demands of the task. (example: stepping up and down on different height steps, etc.)
- Start with practicing moving through a reduced range → practice the task in the full range/altering the height
- Start with use of an assistive device/modified strategy →practice without device or modified strategy

Appendix F: Treatment Plan and Recording Sheet

Individual Treatment Plan for Code Number: __________Week of ___________________

Station Name	Indicate time (min.) spent in activity		
	Session 1	Session 2	Session 3
1)Gaze control Posture: Instability:			
Games to be used (5)			
1)			
2)			
3)			
4)			
5)			
Comments:			
2) Standing Balance/Weight shifting exercises			
Activity #1			
• posture • instability • game to be used			
Activity #2			
• posture • instability • game to be used			
Activity #3			
• posture • instability • game to be used			
Activity #4			
• posture • instability • game to be used			

Activity #5			
• posture • instability • game to be used			
Comments:			
Station Name	Indicate time (min.) spent in activity		
	Session 1	Session 2	Session 3
3) Walking Activities			
Activity #1			
Activity #2 Activity #3			
Activity #4			
Activity #5			
Comments:			
2) Cognitive Challenge Posture: Instability:			
Games to be used (5)			
1)			
2)			
3)			
4)			
5)			
Comments:			

5)Strength and Stretching Exercises			
Comments:			
Station Name	Indicate time (min.) spent in activity		
	Session 1	Session 2	Session 3
6) Functional Task Practice			
Activity #1			
Activity #2			
Activity #3			
Activity #4			
Activity #5			
Comments:			

3) Activities to be monitored electronically:			
Comments:			

Appendix G: Focus Group Guide

Agenda

i) Primary investigator will introduce the interviewer to the participants

ii) Welcome and thanks for your participation

iii) Guiding Principles for this session

a) All opinions shall be respected by facilitators and other participants
b) We welcome participants to freely discuss any opinions that they may have even if not directly questioned
c) All data will be kept confidential and no names or identifying features will be used during transcription to protect your privacy
d) We shall encourage equal participation and representation by all participants
e) We ask that only one person speaks at a time

iv) Focus Group Questions

1) Did you find the Boot Camp helpful?

2) What about the Boot camp worked well? What did not?

3) Because of the group format the therapy staff could not always be working directly with you. At the times when you were working independently:
   a) Were the balance and mobility exercises too easy or too hard?
   b) Did you feel safe at all times?

4) What did you think about the length of the day? Would you have preferred to come more often for a shorter time?

5) What difficulties did you experience in meeting the participation commitment for the Boot Camp? (time, transportation, child care, fatigue)

6) How would you compare this experience to other physiotherapy that you have received?

7) Are there any suggestions that you might have to make the experience better or more effective?

v) Thank you and snacks/socialization

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