Evaluating the Effectiveness of an 8-week Intervention for Reducing Sedentary Time and Increasing Physical Activity Levels for People with Acquired Brain Injury

by

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Dalhousie University is located in Mi'kma'ki, the

ancestral and unceded territory of the Mi'kmaq.

We are all Treaty people.

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Abstract

Nova Scotia Health designed the Physical Activity After Acquired Brain Injury (PABI) program to improve the movement behaviours and health-related quality of life (HRQoL) of people with acquired brain injury (ABI). It was hypothesized that the PABI program would decrease sedentary time and increase physical activity, standing time, and HRQoL. The intervention (n=9) and time-matched control group (n=9) wore an activPAL for 7-days during week 0 and 8. The intervention group attended 11 educational sessions and used PiezoRx pedometers to set weekly step goals. No differences in step counts (week 0: 5791±4101 vs. week 8: 5413±3055 steps/day, p=0.34, d=-0.08), standing time (4.5±2.6 vs. 4.3±2.2 hours/day, p=0.72, d=0.08), sedentary time (10.4±2.9 vs. 10.3±2.0 hours/day, p=0.85, d=0.05), or HRQoL (47±19 vs. 52±17, p=0.68, d=0.28) were observed for the intervention group across timepoints or groups. ABI rehabilitation programming should target initial reductions in sedentary time and gradually integrate physical activity when possible.

List of Abbreviations Used

ABI = Acquired brain injury

ANOVA = Analysis of variance

HRQoL = Health-related quality of life

LPA = Light-intensity physical activity

MAP = Mean arterial pressure

MET = Metabolic equivalent of task

MPA = Moderate-intensity physical activity

MVPA = Moderate-to-vigorous intensity physical activity

NTBI = Non-traumatic brain injury

PABI = Physical activity after acquired brain injury program

PASABI = Physical activity & sport after brain injury program

QOLIBRI = Quality of life after brain injury questionnaire

SF-12 = 12-item short-form survey

SF-36 = 36-item short-form survey

VPA = Vigorous-intensity physical activity

TBI = Traumatic brain injury

♀ = female

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Chapter 1: INTRODUCTION

Acquired brain injury (ABI) encompasses a variety of medical conditions caused by an injury to the brain after birth and does not typically get worse over time (1). ABI is the second leading cause of long-term disability and death (2), with a ~13–23% mortality rate in high-income countries which is greater in low-income countries (3). People with ABI cope with a wide range of physical (e.g., migraines, paralysis), mental (e.g., depression, anxiety), and social (e.g., lack of motivation) impairments for years after their injury (4). Thus, people with ABI require additional support and resources to improve their quality of life and reduce mortality risk (1).

Physical inactivity increases the risk of most chronic diseases (5). To prevent premature mortality, the World Health Organization recommends all adults (≥18 years old) accumulate ≥150 minutes of moderate-to-vigorous aerobic physical activity (MVPA) per week, participate in at least 2 muscle-strengthening activities, and limit their sedentary time (i.e., waking time spent in reclining, sitting, or lying postures) as much as possible (6). Accelerometry data from 8,297 Canadian adults indicates only 41.5% are meeting the MVPA portion of the World Health Organization guidelines and 6.5% are limiting their sedentary time to ≤ 8 hours/day (7). Previous research has demonstrated people with ABI are more inactive and sedentary compared to healthy populations, increasing their risk of chronic disease development (8,9). For example, a systematic review of stroke (i.e., a type of ABI) survivors demonstrated they accumulate 50% fewer accelerometry-derived steps compared to age-matched controls (10). A longitudinal study of stroke survivors indicated they were sedentary for 73% of waking hours (e.g., 16-hour waking day = ~11.5 hours sedentary) three years post-injury (11). This indicates there is a

need to increase physical activity and reduce sedentary activity levels among people with ABI.

A systematic review of 38 physical activity interventions demonstrated a combination of goal setting with aerobic, balance, and strength training improved the functional capacity (e.g., physical fitness, mental health, cognitive function) and quality of life of people with ABI (12). A 12-week at-home physical activity consultation program for people with ABI was evaluated using objective accelerometry (13). Participants completed a series of modules on physical activity prescription, time management, social support, and self-efficacy (13). They determined that people with ABI increased physical activity levels by 10 minutes/day (70 minutes/week) the week following the intervention (13). However, the physical activity improvements regressed to baseline values 12 weeks post-intervention (13). While this was a negative finding, it demonstrates how people with ABI can adapt their lifestyles but often struggle to maintain these improvements habitually.

Previous literature has investigated the impacts of a lifestyle intervention on sedentary time for people with ABI. An 18-week, non-randomized control trial (2-4 sessions/week, 60 minutes/session) for people with ABI included sport-based (e.g., swimming, table tennis, and soccer group sessions) (14). The intervention compared self-reported changes in sedentary activity using the General Physical Activity Questionnaire (14). Self-reported sedentary time *increased* by 3.1 hours/day post-intervention (14), although the General Physical Activity Questionnaire has been shown to underestimate sedentary time in healthy populations by 5.8 hours/day on average (15). There is also evidence demonstrating increased self-report error in ABI populations due to cognitive impairment and memory loss (16). While the number of sessions and length of the

program are strengths of this program, it might be challenging to integrate such a high-volume program into a public healthcare system without straining resources. Due to these limitations, there remains a need for an intervention which focuses on objectively-measured reductions in sedentary time and increases in physical activity for people with ABI.

Health-related quality of life (HRQoL) is defined as the self-perception of one's physical, social, and psychological well-being across their daily life (17) and can be measured using a variety of scales, making it more challenging for researchers to definitively compare HRQoL across populations (18). For people with ABI, HRQoL is an important metric to consider when assessing the burden of their diagnosis, efficacy of treatment methods, and impact of lifestyle adaptations (19). For instance, 12-week HRQoL intervention for people with ABI included educational sessions (1 x 90-minute session per week) and standardized workbooks discussing themes of physical (i.e., setting physical activity goals) and mental wellness (i.e., coping with stress) (20). Based on the results of several HRQoL scales designed for the general population, the intervention did not impact HRQoL post-intervention (20). Evidence indicates that the additional impacts of an ABI (e.g., physical, mental, social impairments) should be considered when evaluating HRQoL (17). The Quality of Life After Brain Injury (QOLIBRI) questionnaire, an ABI-specific scale, has been shown to enhance the sensitivity of detecting changes in the HRQoL of people with ABI (17). This calls for a similar goal-oriented, educational intervention to evaluate changes in HRQoL using the QOLIBRI scale designed for ABI populations.

There are ~70,000 Nova Scotians living with long-term ABI (i.e., prolonged symptoms lasting 6 months or longer) (21). Nova Scotians with ABI who require medical

treatment are typically admitted to the Nova Scotia Rehabilitation and Arthritis Centre (21). Due to the long-term symptoms and impairments commonly associated with ABI (4), people with ABI often require additional long-term care after being released from the Nova Scotia Rehabilitation and Arthritis Centre. To provide Nova Scotians with ABI access to long-term care, Nova Scotia Health opened an ABI-specific rehabilitation clinic called the NeuroCommons in 2020 (21). The NeuroCommons administers a variety of outpatient rehabilitation programs for people with ABI to adapt their lifestyles post-diagnosis (e.g., fatigue management, emotional regulation, and community reintegration). However, no existing NeuroCommons rehabilitation program incorporates physical activity or exercise into the curriculum.

To address this gap, Nova Scotia Health designed the Physical Activity After Acquired Brain Injury (PABI) program to improve the habitual physical activity, postural behaviours (e.g., sedentary time, standing time), and HRQoL of people with ABI in Nova Scotia. The eight-week program includes 11 group-based education and exercise sessions. Part of the PABI program involves education and tracking step counts using accelerometry to establish individualized step goals. Based on the limitations of previous intervention attempts (13,14,20), the present study will objectively evaluate habitual physical activity, standing time, and sedentary time using thigh-worn accelerometry and HRQoL using the QOLIBRI scale. Determining the effectiveness of the PABI program could direct the standard of care for Nova Scotians with ABI and help healthcare providers modify and develop new rehabilitation programs for ABI populations.

1.1 Purpose & Hypotheses

The purpose of this study was to evaluate the effectiveness of Nova Scotia Health's Physical Activity After Acquired Brain Injury (PABI) Program, a new eight-

week intervention designed to improve habitual physical and sedentary activity levels in people with ABI.

It was hypothesized that the intervention group would:

1) Increase free-living step count levels, increase free-living standing time, and decrease free-living sedentary levels compared to time-matched controls.

2) Increase HRQoL levels compared to time-matched controls.

Chapter 2: REVIEW OF LITERATURE

2.1 Brain Structure and Functionality

The human brain is an organ that controls all parts of the body and is the dedicated center for the generation of emotions, memory, decision-making, and bodily movements (22). Brain cells called neurons relay information to other neurons and the rest of the body (via the spinal cord) by releasing neurotransmitters (e.g., acetylcholine, dopamine) which trigger electrical impulses known as action potentials (23). There are approximately 10^{11} neurons in the human brain, which are comprised of cell bodies (i.e., containing the nuclei) and axons (i.e., long corridors for transmitting action potentials) (24). Each neuron has approximately 1000 connections, making the brain a highly complex highway for executing bodily functions, generating thoughts, and controlling consciousness (23). The brain is typically subdivided into three major categories: the brainstem, the cerebrum, and the cerebellum (22).

2.1.1 The Brainstem

The structures of the brainstem are responsible for relaying sensory information and regulating vital autonomic functions (22). The thalamus is located deep in the brainstem and is comprised of cell bodies which filter sensory neural input (e.g., sight, hearing, taste, and touch) for the cerebellum and cerebral cortex (22). The hypothalamus is another deep brainstem structure which controls vital processes (e.g., digestion, breathing, heart rate) via smooth muscle in resistance vessels (e.g., arterioles, capillaries) (22). The brainstem serves also serves as the central pathway connecting all the nerve tracts in the spinal cord to the rest of the brain (22). Specifically, the pons is located at the top of the brainstem and is responsible for relaying sensory nerve impulses to the cerebellum and

cerebral cortex (22). While the brainstem is located deep within the brain, its centrality and widespread control means that damage to the region will cause serious dysfunction (e.g., diffuse axonal injury, vegetative state, comatose) (25).

2.1.2 The Cerebral Cortex

The cerebral cortex is the most voluminous region of the brain and is traditionally subdivided into frontal, parietal, temporal, and occipital lobes (22). The cortex is responsible for a wide variety of bodily functions, including voluntary movements, speech, vision, hearing, and memory (22). One of the most important structures is the basal ganglia, a cluster of cell bodies which are highly involved in motor control, executive functioning, and emotional control (26). While specific regions of the cortex have well-defined roles (e.g., the occipital lobe is responsible for vision), most of the cortex (i.e., the association cortex) is used to make sense of the various sensory signals using thoughts and memories (22). The cerebral cortex can also be split into grey matter (i.e., unmyelinated neural cell bodies) and white matter (i.e., myelinated axons of neurons) (22). The grey matter contains neural cell bodies where electrical impulses are generated while white matter contains neural axons wrapped in myelin cells for enhanced impulse transmission throughout the brain and spinal cord (22). The cortical ribbon is the outermost layer of grey matter (1-3 mm thick) in the cerebral cortex and due to its superficiality, is highly susceptible to damage (25).

2.1.3 The Cerebellum

The cerebellum is in the posterior brain and is responsible for coordinating musculoskeletal movements and maintaining postural balance (22). The cerebellum receives nerve impulses from the motor cortex providing specific instructions on the planned musculoskeletal movements (22). Along with afferent information from the

vestibular system, muscles, and joints, the cerebellum is tasked with coordinating movements while maintaining balance (22). Although the cerebellum does not initiate movement, it serves to refine movements, especially when dealing with complex movements using several limbs (e.g., running) (22).

2.2 What is an Acquired Brain Injury?

An ABI is defined as any diagnosable damage to the brain which occurred after birth (1). ABI is a common cause of long-term disability and death (2), with mild traumatic brain injury and other ABI (e.g., stroke, brain aneurysm, encephalitis) resulting in a mortality rate of ~13–23% in high-income countries like Canada (3). The mortality rate of ABI is greater in low-income countries, although epidemiological data is limited due to poor diagnostic procedures and access to health care (3). Despite the developments in brain research and medical treatments leading to slight improvements in post-injury prognoses over the past few decades, ABI remains a relevant health crisis (3). There are ~70,000 Nova Scotians living with ABI and ~7,500 new cases with prolonged symptoms each year (27). People with ABI cope with a wide range of impairments (e.g., migraines, fatigue, depression, anxiety, paralysis) which makes daily life more challenging (4). Therefore, there is increased importance in providing people with ABI adequate resources to maintain a high quality of life and reduce premature mortality.

ABI diagnoses are typically divided into two general classifications based on the source of the damage:

1) Traumatic Brain Injury (TBI) is caused by an external force on the brain, which can occur during motor vehicle accidents, sports injuries, combat injuries, and shaken baby syndrome (25). This is the more common form of ABI with a global prevalence rate of 403 per 100,000 (25).

2) Non-Traumatic Brain Injury (NTBI) is instigated by an internal mechanism or substance which leads to brain tissue damage (25). NTBI may be triggered by aneurysm, stroke, tumour, meningitis, or opioid overdose (25). NTBI has a global prevalence rate of 85 per 100,000.

2.2.1 Symptoms & Dysfunctionality of ABI

The permanent effects of an ABI largely depend on the severity of the mechanism. For example, an individual diagnosed with a mild ABI will likely have temporary imbalances of neurotransmitters (e.g., acetylcholine, dopamine) and axonal dysfunction but may not have permanent brain damage (25). While there are many mechanisms for triggering an ABI, there are three common types of damage to the brain during moderate-to-severe ABI (25): 1) Destruction of the cortical ribbon, 2) damage to the white matter tracts, and/or 3) damage to deep brain tissues.

Destruction of the cortical ribbon (i.e., superficial grey matter region) along with the underlying grey matter typically occurs during cardiac arrest or severe hypotension for prolonged periods (25). Loss of white matter tracts commonly occurs due to loss of adequate oxygen supply to the brain (hypoxia), extensive brain swelling, brainstem damage leading to enhanced internal pressure, or ischemia (25). These injuries can cause extensive axonal death and in serious cases lead to indefinite loss of consciousness (i.e., comatose) (25). Destruction of the cortical ribbon and loss of white matter tracts result in diffuse brain damage as both cause widespread tissue death and are common amongst severe ABI (25). The third type of damage results in damage to deep brainstem tissues (e.g., thalamus and basal ganglia) caused by contusions (i.e., TBI), hematomas (i.e., NTBI), or tumours (i.e., NTBI) (25). This causes focal damage to a specific location in the brain but may lead to damage to the surrounding tissues when hemorrhaging occurs

(25).

The wide range of ABI diagnoses results in a plethora of symptoms and recovery timelines (4). When dealing with mild ABI (e.g., concussion), people often deal with sensitivity to light, dizziness, headaches, and nausea (25). These deficits can last for an unknown period and vary largely by individual case (25). Meanwhile, people with severe ABI due to widespread tissue death struggle with major physical dysfunctions like chronic insomnia, anarthria, or paralysis (25). While these physical issues are concerning, injury to the brain causes more than just structural damage (25). People with ABI often suffer from chronic mental fatigue, which leads to decreased processing speeds, working memory, and attentional capacity when compared to unfatigued controls (28). The physical and mental dysfunctions related to an ABI diagnosis often cause negative emotional (e.g., irritability), cognitive (e.g., confusion), and behavioural changes (e.g., physical inactivity) (4). Any combination of these emotional, cognitive, and behavioural challenges result in people with ABI struggling to perform daily activities that healthy populations routinely execute (12).

2.2.2 How is an ABI Diagnosed?

The brain is a complex organ that exhibits high inter-individual variability in response to injury, making the diagnosis and prognosis of an ABI challenging (22). When diagnosing an ABI, the injury is typically categorized by (25):

1) Mechanism of injury (i.e., TBI vs. NTBI)

2) Evidence of structural damage (e.g., damage to the cortical ribbon, white matter tracts, thalamus, and/or basal ganglia)

3) Clinical severity of symptoms (e.g., memory loss, fatigue, depression) and dysfunction (e.g., paralysis, comatose)

Determining the mechanism of injury is straightforward as an ABI can either occur due to a traumatic blow or an internal non-traumatic mechanism (29). Evaluation for structural damage due to an ABI requires computed tomography scans or magnetic resonance imaging to investigate the destruction of brain tissues (25). The severity of symptoms and dysfunction are some of the most complex parts of diagnosing an ABI (30). A mild ABI diagnosis requires one of these symptoms to be present: loss of consciousness, memory loss of events immediately before or after the incident, and temporary change in mental state (i.e., disorientation, confusion, dazed), or any neurological deficit (30). For a mild classification, loss of consciousness must be less than 30 minutes and memory loss cannot exceed 24 hours (30). A moderate ABI diagnosis is defined as any of the following: loss of consciousness lasting a few minutes to a few hours, mental state changes lasting from days to weeks, and/or long-term physical, cognitive, or behavioural impairments (25). People diagnosed with a severe ABI must display low levels of consciousness for six hours or longer at the time of their accident/event, including a comatose, vegetative state, or minimally conscious state (25). Severe ABI may result in a lack of alertness or self-awareness, inability to produce spontaneous eye movements, and paralysis (25). It is important to note that time to full recovery (if possible), regardless of ABI severity, is unique to each case and cannot be accurately predicted (25).

Due to the complex nature and variability of diagnosing an ABI based on structural damage and/or symptoms (25), clinicians and researchers often classify the severity based on the person's ability to carry out daily activities (31). The Functional Independence Measure (FIM) is a standardized 18-item scale used to assess the level of independence in completing everyday tasks across six domains: self-care (e.g., bathing),

sphincter control (e.g., bowel control), transfer (e.g., bed/chair/wheelchair transfer), locomotion (e.g., walking up stairs), communication (e.g., language expression), and social cognition (e.g., problem-solving) (32). All 18 tasks are rated by a trained healthcare professional on a seven-point Likert scale with a higher score indicating better functionality (i.e., 1 = complete dependence, 7 = complete independence) (32). Scores are summed and can range from 18 (i.e., completely dependent) to 126 (completely independent) (32). The FIM must be administered by a trained healthcare professional and takes approximately 40-45 minutes to complete (33). The FIM has been validated as an accurate and reliable measure of functional capacity across a variety of diseases and impairments, including TBI and NTBI (32). This makes the FIM an ideal measure for classifying the severity of ABI in clinical settings when assessing for structural damage and symptoms is not possible and/or relevant.

2.3 Defining Physical Activity

Physical activity consists of any bodily movement that causes an increase in energy expenditure (34). This definition importantly distinguishes physical activity from exercise, which is planned or structured (34). Therefore, many habitual activities like walking to work, mowing the lawn, and cleaning the house are considered physical activities. Due to the wide range of physical activities, there are several ways to quantify physical activity (35). Classifying physical activity based on energy expenditure is commonplace among health researchers and clinicians (36). Metabolic equivalents of task (METs) quantify physical activity intensity by dividing the oxygen consumption during physical activity by oxygen consumption during rest (e.g., 15 mL/kg/min ÷ 3.5 mL/kg/min = 4.2 METs) (36). Absolute thresholds (i.e., standardized values which do not

consider maximal aerobic fitness level) have been developed to sort physical activity into three main categories based on METs: light-intensity physical activity (LPA) = 1.5-2.9 METs, moderate-intensity physical activity (MPA) = 3-5.9 METs, and vigorous-intensity activity (VPA) ≥6 METs (35). This concept has been adopted by the World Health Organization guidelines which recommend ≥150 minutes/week of moderate-to-vigorous physical activity (MVPA) for all adults (6).

Though the global guidelines have adopted absolute intensity-derived thresholds, most of the general population is still unfamiliar with quantifying physical activity by intensity (37). In many settings, it is common to use step counts to report physical activity levels because the metric is simple for the public to understand and track (35). A review of step count monitoring interventions determined that providing people with basic step count measures (i.e., via pedometers) was more effective for increasing physical activity levels than using complex tracking devices (i.e., MVPA via accelerometers) (38). While engaging in higher intensity physical activity results in health benefits (39), this research suggests that informing people to engage in 150 minutes/week of MVPA is more difficult to interpret than basic feedback on step counts and setting daily step goals (38).

2.3.1 Benefits of Physical Activity

The benefits of regularly maintaining weekly physical activity levels are plentiful (5). There is an inverse relationship between physical activity levels and the risk of cardiovascular disease, coronary heart disease, stroke, and all-cause mortality (i.e., more physical activity = reduced risk) (40). Meta-analysis results linking steps/day and all-cause mortality indicate that people who accumulate 8000+ steps/day reduce their risk of all-cause mortality by 50-60% compared to people who accumulate <5000 steps/day (39).

This demonstrates that more physical activity can prevent disease or premature death (41). There is also substantial evidence indicating that routine physical activity can boost overall mental health and reduce the risk of suicide (42). While physical activity is an excellent preventative mechanism, it is also an effective treatment for many diseases and injuries (5). A systematic review presented physical activity as a viable treatment option for common chronic diseases including cancer, osteoporosis, and diabetes (43). Despite the benefits associated with frequent physical activity, accelerometry data from the Canadian Health Measures study indicates only 41.5% of adults are meeting the MVPA guidelines (7). Therefore, there remains a need for more physical activity education, facilities, and community programming to promote healthy, physically active lifestyles.

2.3.2 Measuring Physical Activity

Habitual physical activity levels can be estimated by self-report questionnaires and objective activity monitors (44). While self-report measures are time- and cost-efficient and can obtain more details regarding specific physical activities (e.g., weight-training, cycling, walking), they are susceptible to recall bias (i.e., under/over-reporting physical activity levels) (45). Objective monitors (e.g., accelerometers, pedometers) can reduce the error associated with self-report, however, they are typically limited to quantifying stepping-based activities (e.g., walking, running) (44). Thus, self-report and objective physical activity measures often provide different estimates of physical activity (44). For instance, 2372 Canadians who completed the Physical Activity Adult Questionnaire overestimated their MVPA levels by 182 mins/week compared to accelerometry (44). While both self-report and objective measures of physical activity are useful ways to estimate physical activity, they cannot be used interchangeably due to their unique limitations (44).

2.3.3 Using the PiezoRx Accelerometer to Measure Physical Activity

The PiezoRx (StepsCount Inc., Deep River, ON, Canada) is a portable tri-axial accelerometer worn on the waist (Figure 2.1). One of the benefits of the PiezoRx is it has a digital display that provides the wearer with cumulative step count and step-rate threshold-based physical activity data. Piezoelectric monitors implement a horizontal cantilevered beam with a weight on the end that compresses a piezoelectric crystal when subjected to acceleration, which generates a voltage oscillation used to identify each step taken (46). The PiezoRx was within ±2.2% of manually counted steps during a progressive, 6-speed treadmill protocol (2.4-7.2 km/hr) in younger adults (39±15 years) (47) and ±3.0% of manual step counting during a progressive, 5-speed treadmill protocol in older adults (69±2 years) (48). The PiezoRx was strongly correlated to the previously validated ActiGraph GT3X accelerometer (ActiGraph, FLA, USA) when measuring step counts in free-living conditions as well (46). Based on existing findings (46–48), the PiezoRx is a valid measure of step counts across a variety of walking and jogging/running speeds for all adults. Thus, the American Heart Association has specifically advocated for the PiezoRx to be used in the routine assessment of physical activity and rated it an adequate tool for behavioural change (e.g., setting physical activity goals) (49). Despite the effectiveness of wearable devices like the PiezoRx, a systematic review of community-dwelling people with ABI indicated that PiezoRx devices have yet to be routinely integrated by ABI rehabilitation programs (50). This calls for more community

programs to provide access to wearable devices and education on how to effectively use them.

Figure 2.1. A PiezoRx monitor (StepsCount Inc., Deep River, ON, Canada) clipped to the right side of the waist-band.

2.3.4 Using the PASB-Q to Estimate MVPA

The Physical Activity & Sedentary Behaviour Questionnaire (PASB-Q) is a questionnaire developed by the Canadian Society for Exercise Physiology to quickly estimate physical activity levels using two questions derived from the Physical Activity Vital Sign (51). The PASB-Q is commonly used in clinical settings to assess the physical activity levels of patients, including at the Nova Scotia Rehabilitation and Arthritis Centre and Nova Scotia Health's ABI NeuroCommons. The Physical Activity Vital Sign included in the PASB-Q asks the following two questions:

1) "In a typical week, how many days do you do moderate-intensity (like brisk walking) to vigorous intensity (like running) aerobic physical activity?", and

2) "On average for days that you do at least moderate-intensity aerobic physical activity (as specified above), how many minutes do you do?"

The Physical Activity Vital Sign questions underestimated MVPA levels by 50 minutes/week compared to ActiGraph GT3X accelerometry in a sample of 35 older adults (ActiGraph, Pensacola, Fla., USA) (51). However, further evidence in a sample of 140 younger adults demonstrated the Physical Activity Vital Sign questions severely underestimated MVPA levels by 180 minutes/week (52). Even though the Physical Activity Vital Sign has displayed poor validity (51,52), a review of physical activity questionnaires for older adults specified the Physical Activity Vital Sign was the best available self-report measure of MVPA (53). Existing evidence is limited to healthy younger and older adults, indicating further investigation into the validity of the Physical Activity Vital Sign validity for people with ABI is necessary.

2.3.5 Using the activPAL to Measure Physical Activity

As shown in Figure 2.2, the activPAL activity monitor (PAL Technologies Ltd., Glasgow, Scotland) is a thigh-worn accelerometer capable of quantifying free-living step counts, physical activity levels, and time spent in postures (e.g., standing, stepping) (54). The activPAL includes a triaxial piezo-capacitive accelerometer with a sensing range of ±2*g* (55). The piezo-capacitive monitor contains a cantilever beam and a proof mass (56). When the proof mass is shifted by motion, it is detected as acceleration (56). Piezoresistors translate this applied acceleration into a proportional voltage reading (56). This allows the activPAL to detect both static acceleration (i.e., acceleration due to

gravity) and dynamic acceleration (i.e., acceleration due to movement) for quantifying stepping-based physical activity (55).

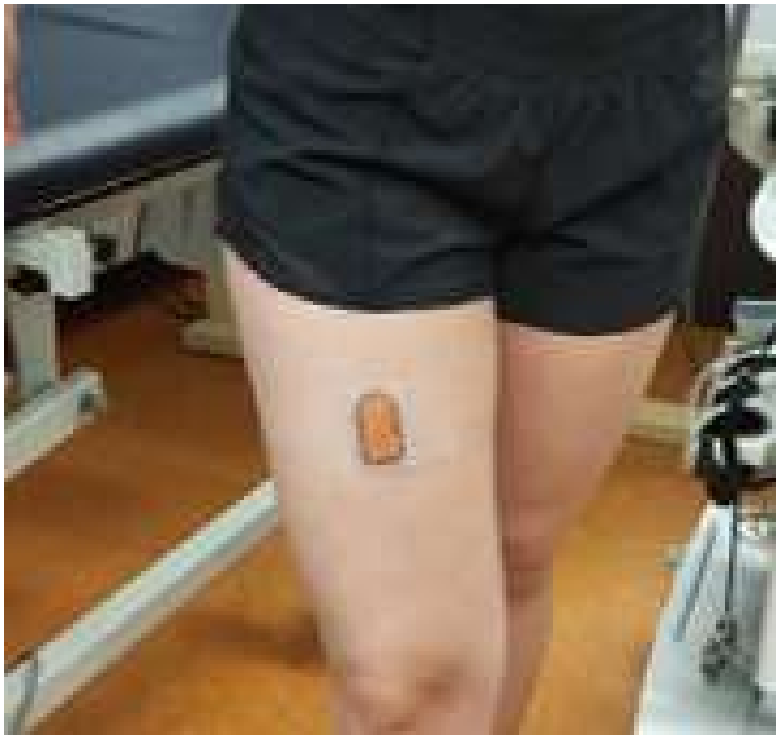

Figure 2.2. The activPAL device (PAL Technologies Ltd., Glasgow, Scotland) adhered to the thigh of a participant using Tegaderm^{TM} medical adhesive.

A systematic review of the validity of the activPAL for measuring free-living physical activity concluded it was a valid measure of free-living step counts and time spent stepping, however, it overestimates LPA and underestimates MVPA (57). The activPAL includes standardized step-rate thresholds for estimating time spent in MPA (74-211 steps/min) and VPA (≥212 steps/min) (58,59). However, research shows that using relative thresholds based on aerobic fitness or anthropometrics (e.g., height, BMI) can improve the estimation of physical activity intensity (59–61). It is often impractical to measure aerobic fitness levels due to time and resource constraints, making it more convenient to collect anthropometrics. Step-rate thresholds using BMI for healthy adults ≥ 55 years (59) and height for adults < 55 years (62) have been shown to more accurately

classify MPA (e.g., 90-130 steps/min) and VPA (e.g., ≥130 steps/min) compared to the standardized activPAL step-rate thresholds. Therefore, applying these anthropometric adjustments to the activPAL data is recommended for estimating the intensity of physical activity.

The activPAL differs from many other physical activity monitors because it is also a thigh-worn inclinometer, which allows it to use programmed acceleration processing algorithms and thigh angles to determine lower-limb posture (63). The activPAL considers the thigh to be in an upright posture (i.e., standing, stepping) if the orientation angle is ≥20° from horizontal (0°) (55). The activPAL can then distinguish standing and stepping postures using dynamic accelerometry counts (54) and has been shown to be a valid measure of time spent in sedentary and upright postures (64). The activPAL monitor does not display in-progress data like the PiezoRx, making it ideal for evaluating habitual physical activity without providing biofeedback and thus influencing behavioural patterns. The combination of tri-axial accelerometry and thigh inclinometry makes the activPAL an effective measure of step counts, stepping time, and physical activity.

2.3.6 Physical Activity Levels in ABI Populations

There is evidence to support that physical activity is an effective method for improving mental health, brain function, and managing cognitive impairment (e.g., dementia) (65). However, existing literature indicates that people with TBI (40) and NTBI (66) are less physically active than healthy populations. For example, a review of 26 physical activity monitoring studies observed that accelerometry-based step counts were 50% lower in people with stroke (i.e., NTBI) when compared to age-matched controls (10). In a sample of 180 individuals diagnosed with mild TBI at least three

months prior, self-reported MVPA levels (via the Godin Leisure-Time Exercise Questionnaire) decreased 75% from their pre-injury levels (67). Thus, increasing the physical activity levels of people with ABI is of great importance.

Existing evidence demonstrates physical activity is crucial for rehabilitation in people with NTBI (68). However, literature on TBI rehabilitation has debated the safety of returning to physical activity post-injury (9,40,67). For people with TBI, a common symptom is physical activity intolerance (i.e., reduced/no capacity to be active without experiencing negative symptoms) (69). Due to this, people with TBI often avoid physical activity or are told to refrain from exercising until they are asymptomatic (69). However, a retrospective study of 430 people with TBI determined those who self-reported more physical activity also reported a reduction in symptom severity, better mental health outcomes, and increased community involvement (9). Therefore, increasing physical activity should be a part of the rehabilitation process for people with ABI, regardless of the severity of symptoms and/or level of impairment.

2.3.7 Physical Activity Interventions for People with ABI

Despite the benefits of physical activity in ABI rehabilitation, few studies have investigated the effectiveness of programming for increasing habitual physical activity (66). The efficacy of a 12-week at-home consulting program on physical activity levels in people with ABI (n=23) was evaluated using Actigraph GT3X accelerometry (13). Participants completed a series of modules discussing motivation, time management, social support, self-efficacy, and structured physical activity prescription (i.e., intensity, type, frequency, and time) (13). They determined people with ABI increased their physical activity levels by 10 minutes/day (i.e., 70 minutes/week) post-intervention compared to baseline values and time-matched controls (13). Despite the positive

outcomes of the program, the improved physical activity levels of the intervention group regressed to baseline values 12 weeks post-intervention (13). Although physical activity returned to baseline, this study emphasizes the importance of providing participants with the knowledge and skills to implement physical activity into their daily lives. A systematic review of interventions in ABI populations mentioned that few studies have focused on the social and educational aspects of habitual physical activity (1). To elicit more long-term adaptations to physical activity levels, providing people with the resources (e.g., accelerometers) and education (e.g., group classes) to integrate habitual physical activity appears to be necessary.

2.4 Defining Postural Activities

Sedentary time includes all waking behaviours in a sitting, lying, or reclined posture with low (≤1.5 MET) energy expenditure (70). Desk-based jobs, school, transportation methods (e.g., driving a car), and television watching are common examples of sedentary activities that consume most adults' waking hours (70). Standing time includes all waking behaviours spent in a stationary, upright position with low (≤2 MET) energy expenditure (70). Canada's newly published 24-hour movement guidelines recommend all adults limit their sedentary activity to ≤8 hours/day to maintain good health and prevent the development of chronic disease (5). Additionally, Canada's 24-hour movement guidelines urge people to break up sedentary bouts as frequently as possible and limit their daily screen time to ≤3 hours (5). A prolonged sedentary bout is typically characterized as ≥1-hour of continuous sitting/lying, which can occur at work (e.g., sitting in a meeting), transporting (e.g., long car ride), or at home (e.g., watching a movie) (71). Although the sedentary guidelines are based on a large body of "low-

quality" evidence (assessed using the Grading of Recommendations Assessment, Development, and Evaluation framework) (5), it appears that to maintain good health, reducing the time spent in sedentary postures is highly relevant (70).

2.4.1 Consequences of Sedentary Lifestyles

While the importance of physical activity has been well integrated into movement recommendations, emerging evidence suggests that limiting time spent in sedentary postures may be of equal importance (72). Data from the 2019 Canadian Health Measures Survey determined Canadian adults are spending a daily average of 9.4 hours participating in sedentary activities (73). Accumulating excess sedentary time has been shown to increase the risk of cardiovascular disease and all-cause mortality, especially when accrued in prolonged bouts (74). Furthermore, evidence from a longitudinal analysis of 201,129 adults demonstrates that replacing sedentary time with sleep, standing time, or physical activity can reduce the risk of all-cause mortality (75). In a technologically- and economically-driven world, most people are struggling to limit their sedentary activity regardless of their physical activity levels (76). For example, high-volume TV watchers (i.e., several hours per day) were at a 33% increased risk of all-cause mortality compared to low-volume TV watchers (i.e., little to no TV watching) (77). Moreover, evidence from a meta-analysis of over 44,000 people indicates that the increased risk of all-cause mortality of a sedentary lifestyle can be attenuated by accumulating 30-40 minutes of MVPA per day (i.e., 210-280 minutes/week) (78). Therefore, it is important to consider physical activity, standing time, and sedentary activity independently.

2.4.2 Measuring Postures in Free-Living Conditions

Similar to physical activity, habitual sedentary activity can be approximated using objective measures and self-report questionnaires (79). However, a systematic review of 55,199 people demonstrates that self-report measures underestimate sedentary time by 1.7 hours/day compared to accelerometry (79). Objectively measuring sedentary activity requires the device to classify specific postures as sedentary (e.g., sitting, lying down) and upright (e.g., standing, walking, jogging) (80). Due to their position on the waist or wrist, many accelerometers that monitor movement behaviours are limited to estimating "stationary" time (i.e., non-stepping time), meaning they cannot distinguish between standing and sedentary time (81). To overcome this limitation, activity monitors have included inclinometers to approximate the orientation angle based on the force of gravity on the device (82). The location of the device has also been shown to have an impact on postural time estimates (e.g., waist-worn vs. thigh-worn) as the orientation of the thigh denotes the posture (82). Evidence indicates that waist-worn devices cannot detect sedentary time as well as thigh-worn devices, suggesting that researchers interested in accurately estimating sedentary time should implement thigh-worn devices containing accelerometers and inclinometers (82).

2.4.3 Using the PASB-Q to Measure Sedentary Time

As discussed in section 2.3.4, the PASB-Q is frequently used to approximate physical activity and sedentary time in clinical settings, including at the Nova Scotia Arthritis & Rehabilitation Centre and ABI NeuroCommons. The PASB-Q estimates daily sedentary activity levels using two questions (51):

1) On a typical day, how many hours do you spend in continuous sitting: at work, in meetings, volunteer commitments and commuting (i.e., by motorized transport)?

2) On a typical day, how many hours do you watch television, use a computer, read, and spend sitting quietly during your leisure time?

For both questions, respondents are given eight pre-selected options ranging from "none" to ">6 hours" and the two questions can be summated to estimate daily sedentary time (51). In a sample of 35 older adults, the PASB-Q underestimated sedentary time by 5.8 hours/day (51). Self-report measures consistently underestimate sedentary time compared to objective devices like the activPAL (79). The poor validity of the PASB-Q for estimating sedentary activity emphasizes the importance of including an objective measure of sedentary time for evaluating an intervention for people with ABI.

2.4.4 Using the activPAL to Measure Free-Living Postures

As mentioned in section 2.3.4, the activPAL monitor (see Figure 2) is a thigh-worn, triaxial piezo-capacitive accelerometer which also includes an inclinometer (54). The activPAL can produce valid estimates of sedentary activities because it uses postural angles to distinguish time spent sedentary, standing, and stepping (80). The activPAL considers the thigh to be in a sedentary posture if the orientation angle is <20° from horizontal (0°) and dynamic acceleration data indicates the thigh is stationary (55). This information is typically processed into 15-second summary epochs to classify the posture and/or movement of the thigh four times per minute (63). Furthermore, the activPAL provides the length of each postural bout based on these epoch summaries (63). This allows for tracking of the total time spent in each posture and the number of bouts in each posture (e.g., 8.9 hours/day of sedentary time accumulated in 35 sedentary bouts/day). The activPAL device has been previously validated for measuring the frequency and duration of postural activities, including total time spent sedentary, standing, and stepping

(64,80). This makes the activPAL the ideal monitor for accurately estimating time spent in various postures (63).

2.4.5 Time Spent in Free-Living Postures Among ABI Populations

Like physical activity recommendations, there is evidence to support limiting sedentary activity across all populations (72). For people with ABI, evidence from a systematic review of ABI self-management programs indicates they are more sedentary than healthy populations, but to what extent is still unknown (1). The activPAL was used to determine that 74 stroke survivors (i.e., a specific type of ABI) were sedentary for 73% (e.g., 16 waking hours = 11.7 hours sedentary) and standing for 18% (e.g., 16 waking hours = 2.9 hours standing) of an average day three-years post-stroke (11). While this is lower than the 94% sedentary time and 4% standing time during their time in the hospital, the increased sedentary behaviours linger for years after being discharged (11). A sample of 150 people with mild TBI self-reported being sedentary for 9.7 hours/day, which was 3.3 hours/day higher than self-report estimates pre-injury (67). This additional sedentary time is likely due to diminished motivation (11), impaired physical function (83), and increased mental fatigue (28), commonly associated with ABIs. While people with ABI are more sedentary than the ~9.4 hours/day observed in the general population, very few interventions have focused on reducing sedentary activity levels in people with ABI (83). Therefore, it remains pertinent to further investigate the sedentary activities of people with ABI and design interventions to decrease sedentary activity levels.

2.4.6 Sedentary Reduction Interventions in People with ABI

No study to date has objectively evaluated the changes in sedentary activity across a movement intervention for people with ABI. However, one physical activity intervention did explore the self-reported changes in sedentary activity of people with

ABI (14). The Physical Activity, Sport, and Acquired Brain Injury (PASABI) program was an 18-week non-randomized control trial for 34 people with ABI (14). The PASABI program's sport-based group sessions (e.g., swimming, table tennis, and soccer) aimed to reduce the sedentary time of the intervention group (14). A strength of the PASABI intervention was it included two to four sessions (60 minutes per session) per week for 18 weeks, a much greater volume compared to other ABI interventions (14). The program *increased* sedentary activity levels by 3.1 hours/day but sedentary activity was measured using the Global Physical Activity Questionnaire (14). The Global Physical Activity Questionnaire has been shown to underestimate sedentary time by 5.8 hours/day with poor test re-test reliability (r=−0.02; p=0.92) compared to ActiGraph G3TX accelerometry, severely limiting any findings from this study (15). Furthermore, the high volume, sports-based, intervention may not be viable for people dealing with advanced health deficits (e.g., paralysis, cognitive impairment) in a public health care setting (e.g., budget, staff restraints). There remains a need for a group-based educational intervention which evaluates sedentary time changes in people with ABI using objective activity monitoring.

2.5 Health Related-Quality of Life

While it is critical to maintain physical health, overall well-being extends beyond movement behaviours (84). HRQoL is defined as the perception of one's physical, social, and psychological well-being across their daily life (17). Subjective factors of HRQoL include, but are not limited to pain, mood, fatigue, and interpersonal relations (17). It is often valuable to evaluate HRQoL in clinical populations as it provides useful insight into the burden of disease (84). People with ABI often experience a plethora of physical (e.g., headaches, paralysis), mental (e.g., anxiety), and social (e.g., lack of motivation) deficits

which negatively impact their HRQoL (1). Obtaining a measure of HRQoL in people with ABI is an important metric when assessing the burden of their diagnosis, efficacy of treatment methods, and the impact of lifestyle adaptations (19).

2.5.1 Measuring HRQoL

HRQoL is evaluated by self-report scales which ask about several components of an individual's daily life (84). While most measures of physical health can be objectively measured or assessed by trained healthcare professionals, HRQoL can only be collected through self-report measures (84). Despite regular use in health research, there is no universal scale for HRQoL, making it more challenging for researchers to definitively compare HRQoL across populations (18). Generic questionnaires like the 12-Item Short Form Survey (SF-12) and 36-Item Short Form Survey (SF-36) are commonly used to assess HRQoL (85). The SF-12 and SF-36 have been validated for summarizing the physical and mental components of HRQoL across the general population (85). In clinical populations, it may be better to use an HRQoL measure that targets the population of concern. The additional physical (e.g., migraines, fatigue, paralysis), mental (e.g., depression, anxiety), and social deficits (e.g., loneliness, emotional dysfunction) associated with ABI should also be considered when evaluating HRQoL (4). Measuring HRQoL using an ABI-specific scale may provide a more comprehensive outlook on how their injury impacts their daily life.

2.5.2 HRQoL Interventions for People with ABI

A systematic review of the impact of 38 physical activity interventions for people with ABI acknowledged that physical activity of any type (e.g., aerobic, resistance) can improve HRQoL (12). For example, the non-randomized control trial of the 18-week sports-based group PASABI program successfully improved the physical and mental

domains of HRQoL in 34 people with ABI, according to the generic SF-36 (14). Another 12-week intervention was developed to help improve the physical activity and HRQoL levels of 37 people with ABI (20). Using 12 educational sessions (1 x 90-minute session per week) and workbooks focused on increasing physical (i.e., setting physical activity goals) and mental wellness (i.e., coping with stress), participants were provided with resources on how to cope with their ABI (20). Based on results from the Health-Promoting Lifestyle Profile II, Perceived Wellness Survey, and SF-12, the intervention group did not alter HRQoL post-intervention (20). While these interventions had conflicting impacts on HRQoL, neither study implemented an ABI-specific scale for assessing changes in HRQoL (14,20). An education-based intervention which evaluates changes in HRQoL using an ABI-specific scale remains necessary.

2.5.3 Measuring HRQoL with the QOLIBRI

When measuring HRQoL in people with ABI, existing literature has relied on general questionnaires like the SF-12 and SF-36 (14,20). However, the Quality of Life After Brain Injury (QOLIBRI) questionnaire (see Appendix B) was designed to assess the HRQoL of people diagnosed with an ABI (17). The QOLIBRI assesses HRQoL across six categories: cognition, emotions, daily life/autonomy, social relationships, mental impairments, and physical impairments (17). Each category includes a series of questions using a five-point Likert scale to indicate the frequency of signs and symptoms. The QOLIBRI was shown to be a concurrently valid measure of HRQoL in people with ABI when compared to the more commonly implemented SF-36 questionnaire (17). However, the QOLIBRI had a higher sensitivity for detecting differences in HRQoL based on the diagnosis of ABI (i.e., TBI versus NTBI) and identifying changes in mental health (17) compared to the SF-36. Thus, the QOLIBRI questionnaire may be a more effective

measure of HRQoL in ABI populations (17).

2.6 Standard of Care for ABI Populations in Nova Scotia

People who are receiving medical treatment for an ABI in Nova Scotia attend the ABI unit of the Nova Scotia Rehabilitation and Arthritis Centre (21). This healthcare centre is home to a team of specialized healthcare professionals who are experienced in treating ABI (21). The wide range of ABI diagnoses and severities requires the clinic to have a diverse team of physicians, nurses, physiotherapists, occupational therapists, and social workers (21). Due to the long-term symptoms and impairments commonly associated with ABI, people with ABI often require additional long-term care after being released from the Nova Scotia Rehabilitation and Arthritis Centre.

To provide Nova Scotians with ABI access to long-term care, Nova Scotia Health opened an ABI-specific rehabilitation clinic called the NeuroCommons in 2020 (21). Since its inception, this dedicated rehabilitation site has developed a series of rehabilitation programs to help people with ABI become more knowledgeable about ABI, engage in activities in the community, establish their capabilities, and develop strategies to cope with their symptoms (21). The NeuroCommons clinic provides care to hundreds of people with ABI annually. People with ABI must have their primary physician submit a standardized referral form (see Appendix C) that indicates they have been diagnosed with an ABI and can consent to participating in clinic programming (21). After referral, people with ABI complete an intake interview with the ABI Day Program coordinator to determine program eligibility. The FIM is conducted to evaluate motor and cognitive independence on a scale from 1 (no independence) to 7 (fully independent) (32). A score of 5 (independence with supervision) or higher in each of the categories is necessary to be eligible for ABI Day programming. Once accepted, new admissions at the

NeuroCommons complete a six-week (two 150-minute sessions per week) core program which focuses on ABI education and provides an overview of other programs offered at the clinic (86). After completing the core series, they are allowed to sign up for specific programs designed to target different aspects of the ABI rehabilitation process (86). The existing ABI Day Program includes series on fatigue management, memory, emotional regulation (i.e., anger, frustration), relaxation strategies, recreation/leisure participation, and community living skills (86). No existing Nova Scotia Health ABI Day Program series has focused on improving the habitual physical activity and sedentary activity levels of people with ABI.

Previous studies have attempted to modify the physical, social, or emotional behaviours of people with ABI (13,14,20). While these studies have focused on improving objectively-measured physical activity levels (13) and HRQoL measured by scales designed for the general population (14,20), no study has objectively measured the changes in sedentary activity and changes in HRQoL via the QOLIBRI throughout an intervention. This remains a concern as evidence suggests sedentary time increases after an ABI diagnosis (87) and remains for years post-injury (11). In a population that is dealing with a combination of physical, emotional, and mental impairments (1), altering sedentary activity and HRQoL may be more viable than increasing physical activity (88). Therefore, it remains necessary to design a movement intervention for people with ABI that comprehensively evaluates HRQoL and encourages physical activity while reducing sedentary activity.

To address the gap in community programming and the existing literature, Nova Scotia Health has recently designed an eight-week intervention called the Physical Activity After Acquired Brain Injury (PABI) program to guide people with ABI to a more

physically active, less sedentary life. A team of healthcare providers (e.g., physiotherapists, occupational therapists, social workers, dietitians, neurologists) specializing in ABI populations created a series of 11 educational sessions on themes including brain health, aerobic physical activity, resistance training, balance, coordination, nutrition, warm-up, cool-down, and goal setting strategies. All participants receive a PiezoRx accelerometer to track their step counts throughout the program. Part of the program includes creating weekly physical activity goals (e.g., step goals) with the help of the ABI Day Program Leader (i.e., licensed physiotherapist). It was unknown how the implementation of the PABI program would impact the standard of care for people with ABI in Nova Scotia.

2.7 Purpose & Hypothesis

The purpose of this study was to evaluate the effectiveness of Nova Scotia Health's Physical Activity After Acquired Brain Injury (PABI) Program, a new eight-week intervention designed to improve physical and sedentary activity levels in people with ABI.

It was hypothesized that the intervention group would:

1) Increase free-living step count levels, increase free-living standing time, and decrease free-living sedentary levels compared to time-matched controls.
2) Increase HRQoL levels compared to time-matched controls.

Chapter 3: METHODOLOGY

3.1 Participants

The study included 26 adults (18 years and older) who were previously diagnosed with an ABI. Nine of 11 recruited (18% dropout rate) participants completed the PABI program while nine of 17 (47% dropout rate) recruited participants completed the control group (Figure 3.1). The PABI program was delivered in two cohorts, September-October 2022 and January-February 2023.

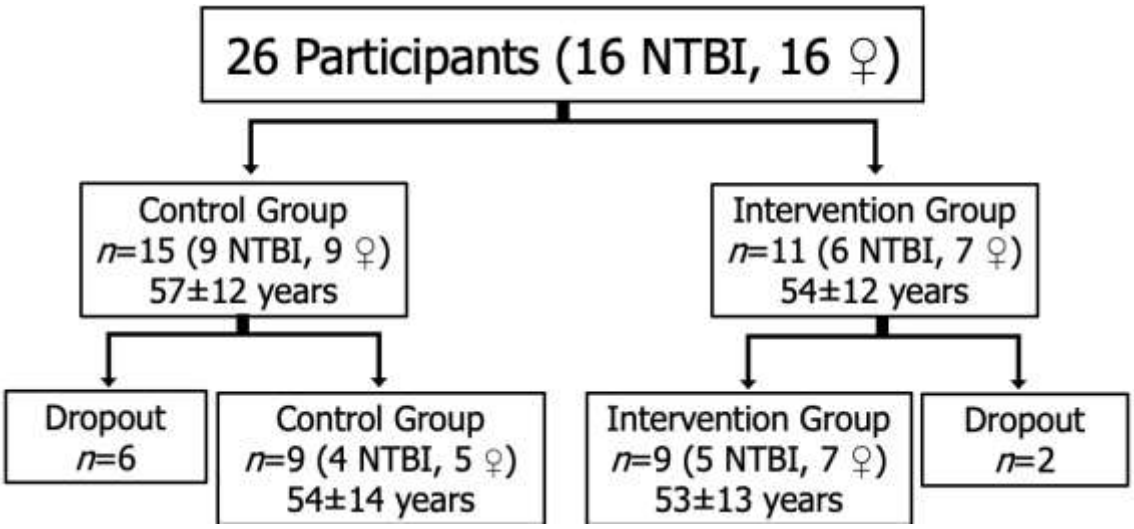

Figure 3.1. Diagram depicting the sample size for the pooled sample, control group, and intervention group, including number of dropouts. NTBI, non-traumatic brain injury; ♀, female.

The included sample comprised of 9 people with TBI (e.g., concussion) and 9 with people NTBI (e.g., stroke). Based on the medium-to-large effect size (d=0.69) previously observed for MVPA (13), a minimum of 18 participants (9 per group) were estimated to achieve β=80% power at α=0.05 (G*Power, v3.1.9.7) (89). People were recruited from Nova Scotia Health's ongoing ABI Rehabilitation Day Program, with physician-referred people with ABI ready to begin rehabilitation programming. All

participants had previously completed Nova Scotia Health's ABI Day Program core series but had not received previous physical activity programming. Prospective participants were excluded from the study if they were:

- <18 years of age.
- Had not completed the ABI Day Rehabilitation core series before providing informed consent.
- Scored <90 on the FIM (or <5 on any of the 18 assessment categories).
- Could not safely engage in MVPA as specified by a primary care provider on the referral form (see Appendix C).
- Had a known allergy to Tegaderm™ clear, medical adhesive dressing.
- Were unable to provide written or verbal informed consent (i.e., could not complete the necessary forms and questionnaires). If present, caregivers were allowed to provide informed consent when deemed necessary by the principal investigator.

Due to this study evaluating a public health care program, the intervention group was formed by the ABI Day Program waitlist on a first-come, first-serve basis (i.e., randomization was not possible). People on the waitlist who were not participating in any of the ABI Day Program series at the clinic were invited to the time-matched control group. The control group was allowed to enter the treatment group during a future program iteration (three participants completed the control group before completing the intervention). This ensured that everyone had the opportunity to complete the physical activity programming. Research ethics approval was granted by Nova Scotia Health's Research Ethics Board (REB #39067) before data collection.

3.2 Study Design

The PABI program was conducted at the NeuroCommons ABI Day Rehabilitation clinic in Bedford, Nova Scotia. A pre-screening interview with the ABI Day Program Coordinator was conducted to confirm ABI Day Program eligibility and to complete the FIM before being put on the waitlist. Figure 3.2 summarizes the study protocol from week 0 to week 8. Participants were recruited off the ABI Day Program waitlist and placed into one of two groups: a time-matched control group and an intervention group. Both groups completed a standardized assessment during week 0 and week 8. The control group maintained their habitual activities for eight weeks while the intervention group completed the eight-week PABI program.

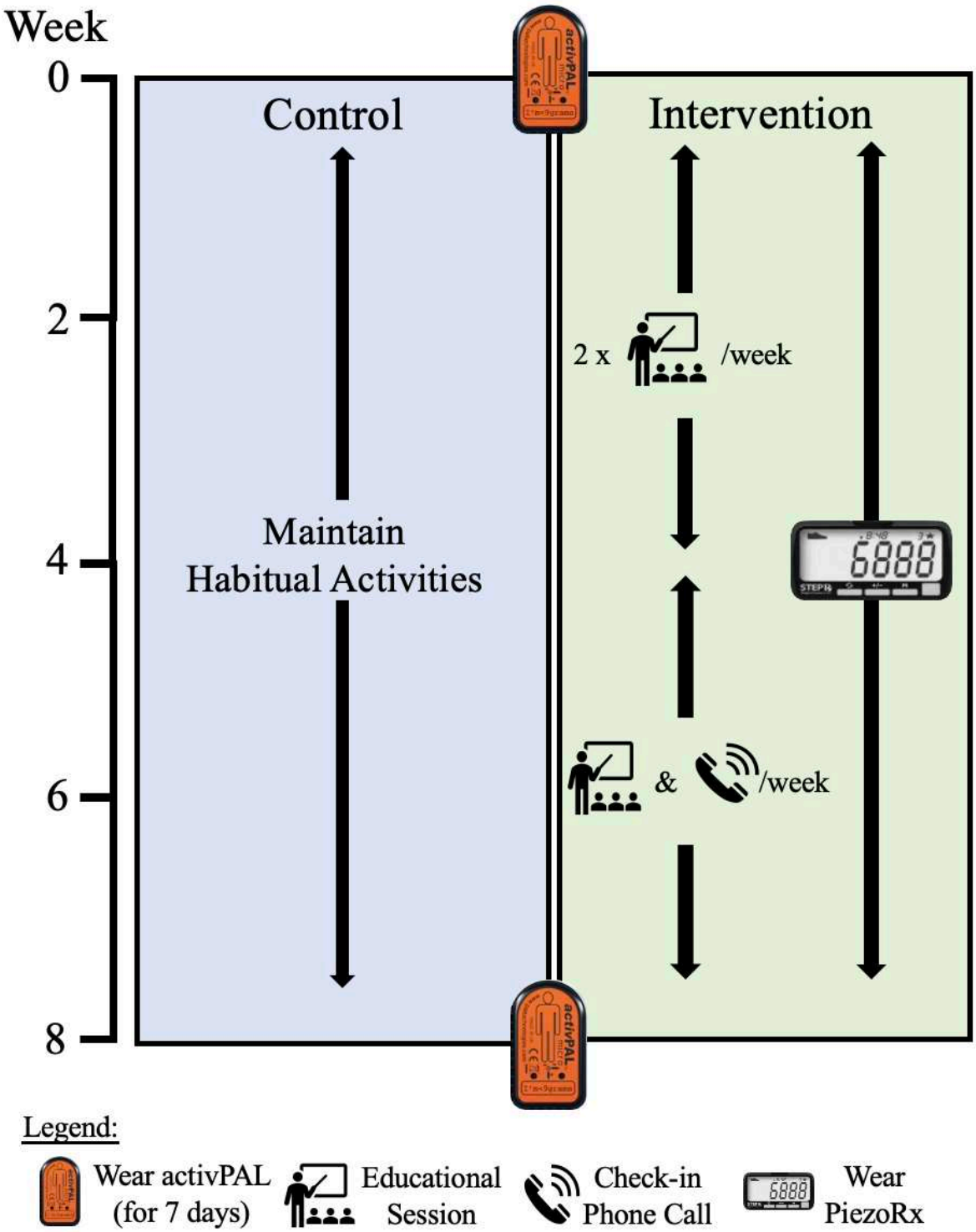

Figure 3.2. Standardized Protocol for completion of the Physical Activity After Brain Injury (PABI) Program. QOLIBRI, Quality of Life After Brain Injury; PASB-Q, Physical Activity Sedentary Behaviour Questionnaire.

3.2.1 Week 0 & Week 8 Assessments

Prior to the week 0 assessment, participants were encouraged to read all study explanation materials beforehand to ensure they were interested. Participants were then contacted by the ABI Program Leader to review the program requirements and determine if they were willing to participate. When participants arrived at the NeuroCommons clinic for their week 0 assessment, they were introduced to the research staff and were given another opportunity to ask questions or concerns. The week 0 assessment took approximately one hour to complete. Participants were given the option to complete the consent form privately or have it verbalized during their initial visit.

After obtaining informed consent, participants were asked to change into comfortable attire (e.g., shorts, loose pants) in a private changing room for the application of the activPAL. Demographic (e.g., age, sex), medical (e.g., ABI diagnosis, existing health conditions, medications), and anthropometric (e.g., height, weight) data were recorded. Participant self-reported their age, sex, history of health conditions, and current medications. Height (cm) and weight (kg) were measured using a calibrated stadiometer (Health-O-Meter, McCook, IL, USA). Body mass index (BMI) was calculated by dividing body mass by height squared (kg/m^2). Blood pressure and heart rate while sitting were collected via electronic blood pressure monitoring (Omron HEM-907XL, Kyoto, Japan) after five minutes of seated rest. Mean arterial pressure (MAP) was calculated as $1/3 \times$ systolic blood pressure $+ 2/3 \times$ diastolic blood pressure (90).

Participants were asked to fill out two questionnaires during the week 0 visit: the PASB-Q (estimating sedentary and physical activity) and the QOLIBRI (measuring HRQoL). Participants had the choice of filling out the questionnaires privately or having

them verbalized. The PASB-Q provided an estimate of MVPA in minutes/week and daily sedentary time in hours/day. The QOLIBRI questionnaire responses were obtained via a five-point Likert scale from Parts A-D (see Appendix B) were assigned numerical values (e.g., "not at all" = 0, "very" = 5). QOLIBRI responses from Parts E-F were inversely scored (e.g., "not at all" = 5, "very" = 0). The mean score for each section was calculated (e.g., sum of section A values/# of questions in section A) and the six section means (A-F) were summed to calculate a total mean (sum of section mean scores/6). The total mean (e.g., 3.8 out of 5) was converted to a 0-100 scale ([0] = no HRQoL, [100] = perfect HRQoL). This conversion was done by subtracting one from the total mean and multiplying by 25 (e.g., [3.8 – 1] × 25 = 70). A higher QOLIBRI score indicates better HRQoL.

After completing the questionnaires, one activPAL (Version 4) was sealed inside a waterproof sleeve and applied to the anterior right thigh using transparent Tegaderm™ medical dressing (3M Canada, London, ON, Canada) (Figure 2.2). Participants wore the activPAL 24 hours/day for seven days to assess their habitual movement behaviours (e.g., step counts, standing time, and sedentary time). Participants self-reported the time they fell asleep and woke up each day (Appendix D) to aid analysis of waking time only. Participants were able to shower, swim, and engage in regular activities while wearing the activPAL. Participants were asked to maintain their normal routine during the week 0 activPAL assessment. After seven days, participants removed the activPAL and returned the device to the NeuroCommons clinic.

The raw activPAL data collected was exported into PAL Analysis (version 5.8.5) for data processing. The PAL Analysis program produced a range of activity summaries,

including a 15-second epochs file (i.e., raw acceleration data was summarized into 15-second intervals) and an event summary file (i.e., classified raw acceleration data into sedentary, standing, or stepping bouts). The 15-second epoch files and event files were analyzed using a customized MATLAB program (MathWorks, Portola Valley, CA, USA) that summarized daily averages of time awake, time spent standing, and time spent sedentary (54). Prolonged sedentary bouts (e.g., bouts >1 hour in sitting/lying postures) and upright bouts (e.g., bouts of >10 minutes in standing/stepping postures) were also derived using this program. An additional LabVIEW program (National Instruments, Austin, TX, USA) used anthropometrically determined step-rate thresholds based on BMI for healthy adults ≥55 years old (59) and height for adults <55 years old to calculate weekly LPA and MVPA (62).

All participants attended the clinic for a second assessment eight weeks later. The week 0 protocol was replicated except for obtaining informed consent and medical information (e.g., ABI diagnosis, existing health conditions, medications). Participants were also asked to fill out a voluntary survey providing feedback on their experience during the program (Appendix E).

3.2.2 PABI Program

The PABI program was completed over eight weeks with eleven 120-minute sessions with unique themes were completed. There were eight sessions in the first four weeks and three sessions in the final four weeks (see breakdown below in Table 3.1). Upon arrival for the first program session (week 1), intervention participants were provided with a PiezoRx accelerometer. The waist-worn PiezoRx had an LED screen which provided real-time feedback on daily step count and physical activity levels.

PiezoRx-derived step counts were recorded for six weeks (weeks 2-7) and averaged each week. Part of the intervention included tracking step counts and setting goals based on previous weeks, making the PiezoRx the ideal device due to its convenient display and accuracy. Intervention participants were required to attend nine of 12 sessions to maintain eligibility for study inclusion (minimum of 75% adherence rate).

Table 3.1 displays a schedule and brief overview for each session. Specific themes were presented during each session to provide education on different aspects of health and physical activity. Step count goals, sample exercises and intensity for each session were dependent on the physical, mental, and social capabilities of each participant. During the final four weeks of the program, participants received check-in phone calls from the ABI Program Leader (i.e., licensed physiotherapist). These phone calls were ~10-15 minutes in duration and were designed to facilitate the creation of weekly step goals and prompt physical activity.

Table 3.1. Overview of the Physical Activity After Brain Injury program including session details.

WEEK	Session 1	Session 2
1	**Introduction to physical activity** – including the rationale and importance of physical activity. Provided participants with a progress tracking calendar and instruct them to start tracking steps daily. Provided education on breathing exercises to improve and support respiratory muscle strength.	**Lifestyle adaptation** – Discussed the potential barriers and possible solutions to physical inactivity and sedentary behaviour. Provided education on the way to successfully change their lifestyle to become more active and healthier. Participants were allowed to create a weekly PA schedule to help maintain an active lifestyle post-intervention.
2	**Warm-up and cooldown** – Emphasized the significance of implementing proper warm-up and cooldown techniques (e.g., stretching, light-intensity exercises) to prevent injury and improve performance.	**Introduction to aerobic training** – Provided education on the necessity for aerobic physical activity, emphasizing the need for variability in intensity and volume.
3	**Introduction to strength training** – Discussed why participating in different types of physical activity is needed and the benefits of building/maintaining muscle. Explained what exercise prescription means (e.g., what does 1-3 sets of 10-15 reps (8-10 different exercises) mean?).	**Introduction to balance training –** Education about the relevance and mechanisms of maintaining good posture and balance.
4	**Introduction to coordination training** – Provided education on the relationship between the brain and coordination. Discussed how it can be re-developed/maintained after ABI and what types of physical activity can be implemented to impact coordination.	**Recreation opportunities** – Participants were provided information on different community programs and recreational activities to make it more convenient to engage in physical activity safely and efficiently.

5	**Check-in Phone Call**	**Nutrition** – Provided information on diet planning and goal-setting. Also, discussed the importance of a balanced diet, how it contributes to physical and mental well-being.
6	**Check-in Phone Call**	**Physical activity and the brain**– explained the link between physical fitness and brain health was presented by a neurology expert. This was a pre-recorded session shown to all participants.
7	**Check-in Phone Call**	**Wrap-up** – Debrief on the intervention experience and how to implement the knowledge learned into daily life. Discussed the long-term health benefits of staying physically active after the intervention.
8	**Check-in Phone Call**	**Post-program Assessment**

3.2.3 Time-Matched Control Group

The control group did not attend any intervention sessions nor receive PiezoRx accelerometers. Control group participants were not allowed to participate in other ABI Day Program series while participating in the study. All control group participants were given the option to be a part of the intervention group after completing the control phase.

3.3 Statistical Analysis

All dependent variables were assessed for normality using a Shapiro-Wilk test. Results from Shapiro-Wilk testing indicated all continuous variables met parametric assumptions except for the time interval between assessments ($p<0.01$), weight ($p<0.01$), resting heart rate ($p=0.02$), number of co-morbidities ($p=0.03$), MVPA ($p<0.01$), self-reported MVPA ($p<0.01$), prolonged sedentary time ($p=0.04$), self-reported sedentary time ($p=0.01$), prolonged standing time ($p<0.01$), and HRQoL ($p=0.03$).

Pairwise comparisons between control and intervention groups for average MPA step-rate threshold, VPA step-rate threshold, and height were completed using independent-sample t-tests. For the time interval between week 0 and 8 assessments, the non-parametric Mann-Whitney U test was used to complete pairwise comparisons. Parametric variables (e.g., step counts, standing time, sedentary time, HRQoL) assessed at week 0 and 8 timepoints were compared using a two-way, between-group (i.e., control vs. intervention) and within-group (i.e., week 0 vs. week 8) repeated measures analysis of variance (ANOVA). Mauchly's test of sphericity was used to assess variance of differences and when violated, the Greenhouse-Geisser correction to the degrees of freedom was applied. Bonferroni *post-hoc* testing was completed for statistically significant ANOVAs. Non-parametric variables (e.g., MVPA, prolonged sedentary time)

were analyzed for between-group effects (i.e., control vs. intervention) using a Mann-Whitney U test and within-group effects (i.e., week 0 vs. week 8) using a Wilcoxon signed-rank test. Cohen's *d* effect sizes were reported for within-group effects (i.e., week 0 vs. week 8 in the intervention group) and between-group effects (i.e., control vs. intervention at week 8). Age, BMI, and number of comorbidities were entered into bivariate correlational analyses (i.e., Pearson Product-Moment for parametric variables, Spearman Rank for non-parametric variables) to explore whether they influenced the change (week 8 – week 0) in step counts, standing time, sedentary time, and HRQoL across time points. Sex (female = 0, male = 1) and type of ABI (TBI = 0, NTBI = 1) were entered into point biserial correlational analyses to explore whether they influenced the change (week 8 – week 0) in step counts, standing time, sedentary time, and HRQoL across time points. All statistical analyses were performed using SPSS software (Version 28, IBM, Armonk, NY, US) with significance set *a priori* at $p<0.05$.

Chapter 4: RESULTS

4.1 Sample Characteristics

The time interval between week 0 and week 8 assessments was longer (d=0.98, p=0.03) for the control group (62±7 days) than the intervention group (56±5 days). The average anthropometrically-derived MPA thresholds were similar (d=0.00, p=0.78) for the control (107±5 steps/minute) and the intervention group (107±5 steps/minute). The average anthropometrically-derived VPA thresholds were similar (d=0.00, p=0.56) for the control (132±5 steps/minute) and the intervention group (132±7 steps/minute). Table 4.1 presents the participant characteristics for control and intervention groups at week 0 and week 8. The average age (control: 56±12 years vs. intervention: 53±13 years, d=0.23, p=0.63), number of co-morbidities (2.3±1.4 vs. 2.2±1.3, d=0.07, p=0.86), and number of medications (3.4±3.1 vs. 5.7±3.9, d=0.63, p=0.20) were not different between the control and intervention groups. See Appendix F for a complete list of self-reported co-morbidities (Table S1) and medications (Table S2).

Table 4.1. Comparing the self-reported participant characteristics, physical functioning, and habitual physical activity levels between groups and timepoints.

Variable	Control (*n = 9, 5*♀)		Intervention (*n = 9, 7*♀)		Within-Group Cohen's *d*	Between-Group Cohen's *d*
	WEEK 0	WEEK 8	WEEK 0	WEEK 8		
Height (cm)	167.6 ± 8.4		167.4 ± 8.9		-	0.12
Weight (kg)	88.3 ± 16.1	90.2 ± 19.0	84.6 ± 22.2	86.3 ± 19.8	-0.05	0.21
BMI (kg/m^2)	31.3 ± 4.5	31.9 ± 10.5	30.0 ± 5.9	30.7 ± 5.6	-0.12	0.14
Systolic BP (mmHg)	121 ± 15	126 ± 16	130 ± 20	129 ± 17	0.05	-0.18
Diastolic BP (mmHg)	74 ± 9	77 ± 8	82 ± 69	82 ± 8	0.00	-0.63*
MAP (mmHg)	90 ± 9	93 ± 10	98 ± 12	98 ± 9	0.00	-0.52
Resting HR (bpm)	77 ± 15	75 ± 15	80 ± 13	79 ± 17	0.07	-0.25

Note: For parametric variables, Group × Time interaction effects were assessed using a repeated measures analysis of variance with Bonferroni pairwise comparisons determined within and between group differences. For non-parametric variables (i.e., weight, BMI, diastolic BP, resting HR), between-group differences (i.e., control vs. intervention) were assessed using a using a Mann-Whitney U test and within-group differences (i.e., week 0 vs. week 8) were assessed using a Wilcoxon signed-rank test. Cohen's *d* effect sizes are reported for between-group (control-intervention at week 8) and within-group (i.e., week 0-week 8 for the intervention group). BMI, body mass index; BP, blood pressure; MAP, mean arterial pressure; HR, heart rate. Data presented as means ± SD or proportions. *, indicates statistical significance of $p \leq 0.05$. The average Diastolic BP of the intervention group was significantly higher than the control group at week 8 only ($p=0.05$). No other significant differences were observed for group, time, or group-time interactions (all, $p \geq 0.14$).

Table 4.2 presents the distribution of ABI diagnoses across the groups. All participants were diagnosed with their ABI at least 6 months prior to enrolling in the study.

Table 4.2. Distribution of Acquired Brain Injury diagnoses across the pooled sample, control group, and intervention group.

	Pooled Sample *n* (%)	Control Group *n* (%)	Intervention Group *n* (%)
Non-Traumatic Brain Injury	9 (50)	4 (44)	5 (56)
Stroke	7 (38)	3 (33)	4 (44)
Brain Aneurysm	1 (6)	0 (0)	1 (12)
Encephalitis	1 (6)	1 (11)	0 (0)
Traumatic Brain Injury	9 (50)	5 (56)	4 (44)
Concussion	8 (44)	4 (44)	4 (44)
Other	1 (6)	1 (11)	0 (0)
>6 Months Since Diagnosis	18 (100)	9 (100)	9 (100)

4.2 Physical Activity Outcomes

There was no effect of time (intervention [week 8–week 0]: d=-0.08, p=0.98), group (week 8 [intervention–control]: d=0.12, p=0.99), or interaction between group-time (p=0.34) on step counts (Figure 4.1). At week 0, step counts were 5396±2288 steps/day for the control group and 5791±4101 steps/day for the intervention group. At week 8, step counts were 5762±2345 steps/day for the control group and 5413±3055 steps/day for the intervention group. Changes in step counts from week 0 to week 8 were not correlated to age (p=0.64), sex (p=0.95), BMI (p=0.42), co-morbidities (p=0.40), or type of ABI (p=0.07) for the intervention group.

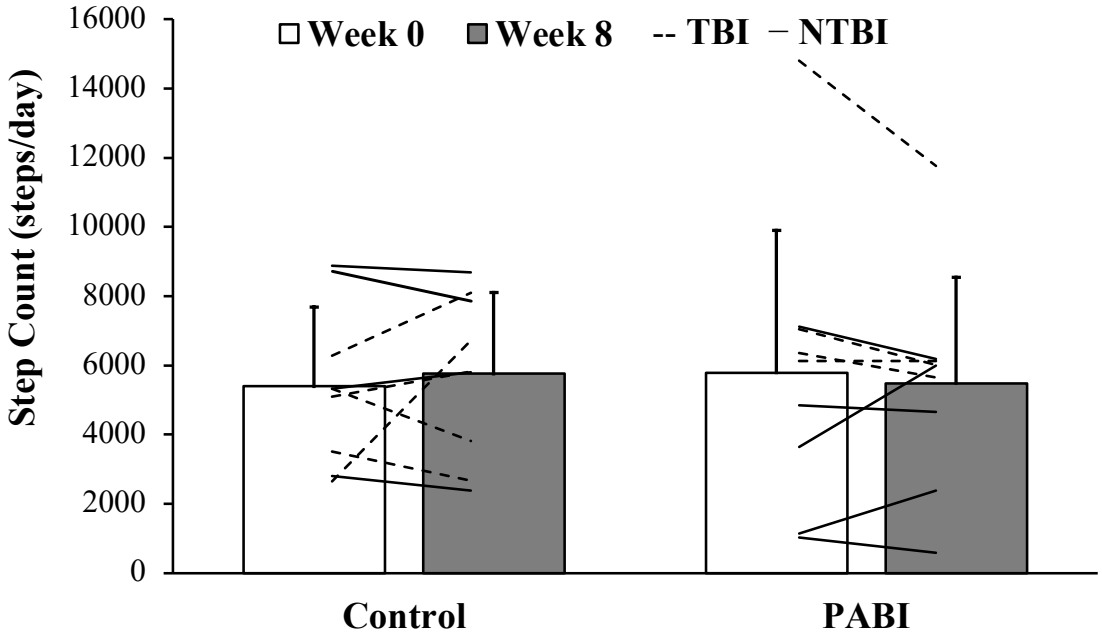

Figure 4.1. activPAL-derived daily step counts across groups and timepoints. Note: individual data points for people with traumatic brain injury (TBI) are dashed and for people with non-traumatic brain injury (NTBI) are solid.

Figure 4.2 provides a summary of the average step counts for each participant throughout the intervention, including in-progress step counts collected using the PiezoRx. Minimal fluctuations in step counts were observed for all participants.

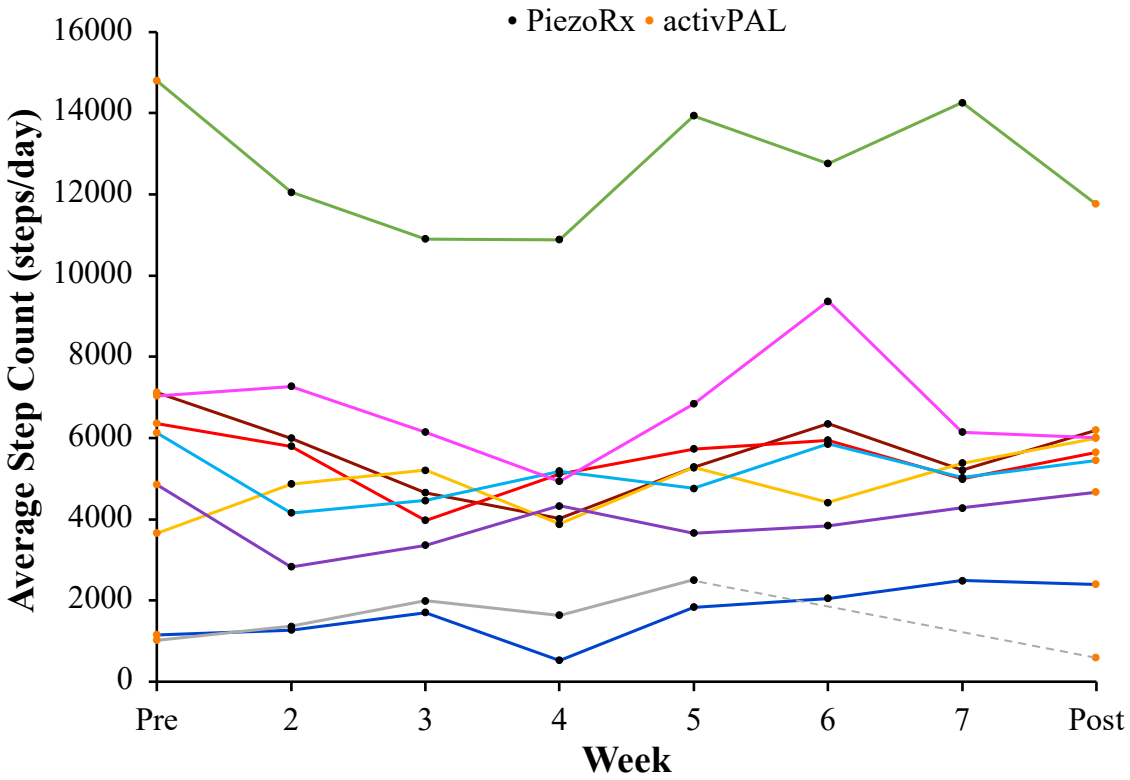

Figure 4.2. Individual average step counts (steps/day) throughout the intervention. Note: Each coloured line represents one intervention participant. Note: No step count data was collected during week 1. Orange markers indicate data collected by the activPAL and black markers indicate data collected by the PiezoRx. The dashed grey line indicates no step count data was collected during weeks 6 and 7 due to illness.

Table 4.3 contains additional physical activity outcomes for the control and intervention groups at week 0 and week 8 timepoints. LPA, MVPA, and self-reported MVPA were not different across any groups or timepoints (all, $p \geq 0.07$). Self-reported MVPA was lower than activPAL-derived MVPA at week 0 ($d=0.87$, $p=0.01$) but not at week 8 ($d=0.57$, $p=0.14$).

Table 4.3. Additional physical activity outcomes collected via the activPAL and self-report across groups and timepoints.

	Control (*n* = 9, 5♀)		Intervention (*n* = 9, 7♀)		Within-Group Cohen's *d*	Between-Group Cohen's *d*
	WEEK 0	**WEEK 8**	**WEEK 0**	**WEEK 8**		
LPA (min/week)	495 ± 185	444 ± 197	487 ± 274	487 ± 225	0.00	0.20
MVPA (min/week)	42 ± 49	52 ± 55	64 ± 90	56 ± 73	-0.09	0.06
Self-Reported MVPA (min/week)	295 ± 338	143 ± 217	194 ± 268	104 ± 92	-0.45	-0.23

Note: For parametric variables, Group × Time interaction effects were assessed using a repeated measures analysis of variance with Bonferroni pairwise comparisons determined within- and between-group differences. For non-parametric variables (i.e., MVPA, self-reported MVPA), between-group differences (i.e., control vs. intervention) were assessed using a Mann-Whitney U test and within-group differences (i.e., week 0 vs. week 8) were assessed using a Wilcoxon signed-rank test. Cohen's *d* effect sizes are reported for between-group (control-intervention at week 8) and within-group (i.e., week 0-week 8 for the intervention group). LPA, light-intensity physical activity; MVPA, moderate-to-vigorous-intensity physical activity. Data presented as means ± SD or proportions. No significant differences were observed for group, time, or group-time interactions (all, $p \geq 0.07$).

4.3 Standing Time & Upright Postural Outcomes

There was no effect of time (d=-0.08, p=0.78), group (d=-0.16, p=0.88), or interaction between group-time (p=0.72) on standing time (Figure 4.3). At week 0, standing time was 4.5±1.5 hours/day for the control group and 4.5±2.6 hours/day for the intervention group. At week 8, standing time was 4.6±1.4 hours/day for the control group and 4.3±2.2 hours/day for the intervention group. Changes in standing time from week 0 to week 8 were not correlated to age (p=0.75), sex (p=0.97), BMI (p=0.64), co-morbidities (p=0.93), or type of ABI (p=0.13) for the intervention group.

There was no effect of time (d=-0.10, p=0.78), group (d=-0.17, p=0.89), or interaction between group-time (p=0.35) on upright time. At week 0, upright time was 5.8±1.9 hours/day for the control group and 5.8±3.4 hours/day for the intervention group. At week 8, upright time was 5.9±1.8 hours/day for the control group and 5.5±2.8 hours/day for the intervention group. There was no effect of time (d=0.13, p=0.93) or group (d=0.30, p=0.99) on prolonged standing time ≥10-minutes. At week 0, prolonged standing time ≥10-minutes was 92±87 minutes/week for the control group and 42±39 minutes/week for the intervention group. At week 8, prolonged standing time ≥10-minutes was 61±39 minutes/week for the control group and 48±48 minutes/week for the intervention group.

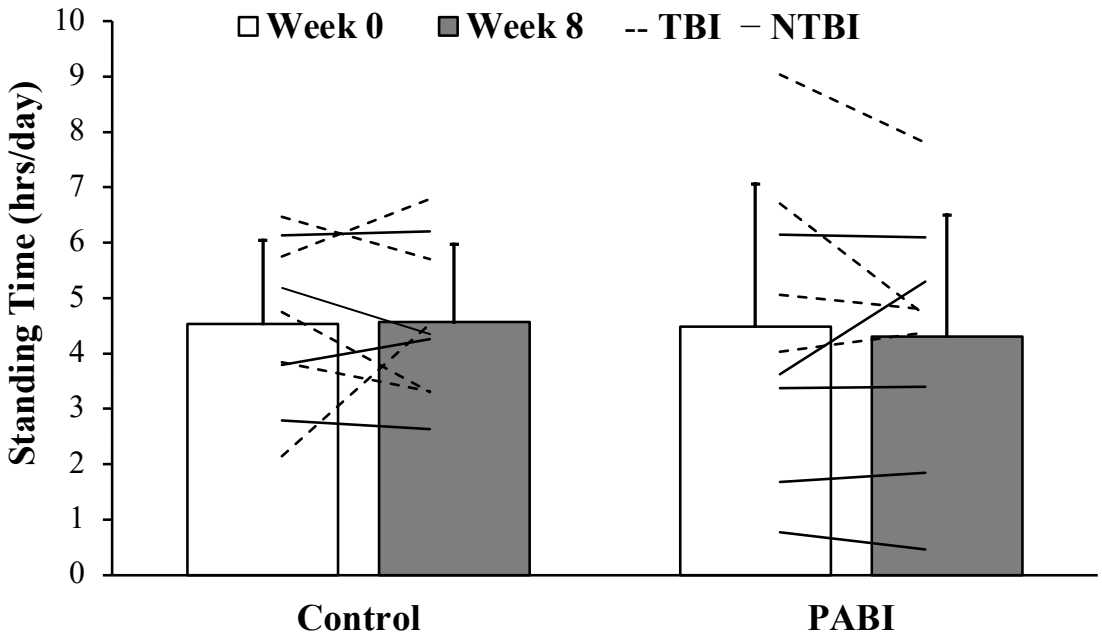

Figure 4.3. activPAL-derived daily standing time across groups and timepoints. Note: individual data points for people with traumatic brain injury (TBI) are dashed and for people with non-traumatic brain injury (NTBI) are solid.

4.4 Sedentary Time & Postural Outcomes

There was no effect of time (d=0.05, p=0.91), group (d=0.23, p=0.67), or interaction between group-time (p=0.83) on sedentary time (Figure 4.4). At week 0, sedentary time was 10.7±1.6 hours/day for the control group and 10.4±2.9 hours/day for the intervention group. At week 8, sedentary time was 10.7±1.3 hours/day for the control group and 10.3±2.0 hours/day for the intervention group. Changes in sedentary time from week 0 to week 8 were not correlated to age (p=0.84), sex (p=0.79), BMI (p=0.87), co-morbidities (p=0.94), or type of ABI (p=0.06) for the intervention group.

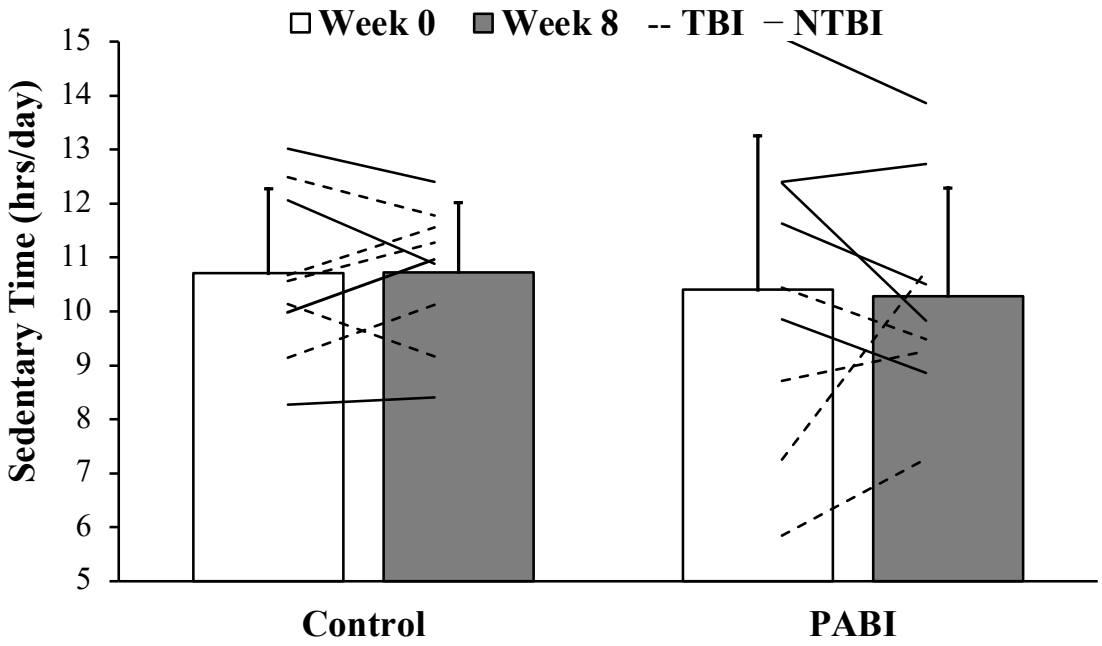

Figure 4.4. activPAL-derived daily sedentary time across groups and timepoints. Note: individual data points for people with traumatic brain injury (TBI) are dashed and for people with non-traumatic brain injury (NTBI) are solid.

Table 4.4 contains additional sedentary activity outcomes for the control and intervention groups at week 0 and week 8 timepoints. Prolonged sedentary time ≥1-hr, sedentary break frequency, and self-reported sedentary time were not different for any within-group, between-group, or interactions of group-time comparisons (all, $p \geq 0.34$). Self-reported sedentary time was lower than the activPAL-derived sedentary time at week 0 ($d=1.44$, $p<0.001$) and week 8 timepoints ($d=1.30$, $p<0.001$).

Table 4.4. Additional sedentary outcomes collected via the activPAL and self-report across groups and timepoints.

	Control (*n = 9, 5*♀)		Intervention (*n = 9, 7*♀)		Within-Group Cohen's *d*	Between-Subjects Cohen's *d*
	WEEK 0	**WEEK 8**	**WEEK 0**	**WEEK 8**		
Prolonged Sedentary Time ≥1-hr (hr/day)	5.0 ± 2.6	5.2 ± 1.8	4.9 ± 3.3	5.7 ± 3.3	-0.24	-0.18
Sedentary Break Frequency (breaks/hr)	2.3 ± 0.6	2.5 ± 0.6	2.5 ± 0.9	2.4 ± 0.9	-0.11	0.13
Self-Reported Sedentary Time (hr/day)	6.2 ± 2.4	6.7 ± 2.7	7.6 ± 3.2	4.9 ± 3.2	0.84	0.61

Note: For parametric variables, Group × Time interaction effects were assessed using a repeated measures analysis of variance with Bonferroni pairwise comparisons determined within- and between-group differences. For non-parametric variables (i.e., self-reported sedentary time), between-group differences (i.e., control vs. intervention) were assessed using a Mann-Whitney U test and within-group differences (i.e., week 0 vs. week 8) were assessed using a Wilcoxon signed-rank test. Cohen's *d* effect sizes are reported for between-group (control-intervention at week 8) and within-group (i.e., week 0-week 8 for the intervention group). Data presented as means ± SD or proportions. No significant differences were observed for group, time, or group-time interactions (all, $p \geq 0.34$).

4.5 Health-Related Quality of Life

There was no effect of time (d=0.28, p=0.21) or group (d=-0.14, p=0.86) on HRQoL derived from the QOLIBRI (Figure 4.5). At week 0, HRQoL was 49±12 for the control group and 47±19 for the intervention group. At week 8, HRQoL was 54±12 for the control group and 52±17 for the intervention group. Changes in HRQoL from week 0 to week 8 were not correlated to age (p=0.87), sex (p=0.79), BMI (p=0.21), co-morbidities (p=0.93), or type of ABI (p=1.00) for the intervention group.

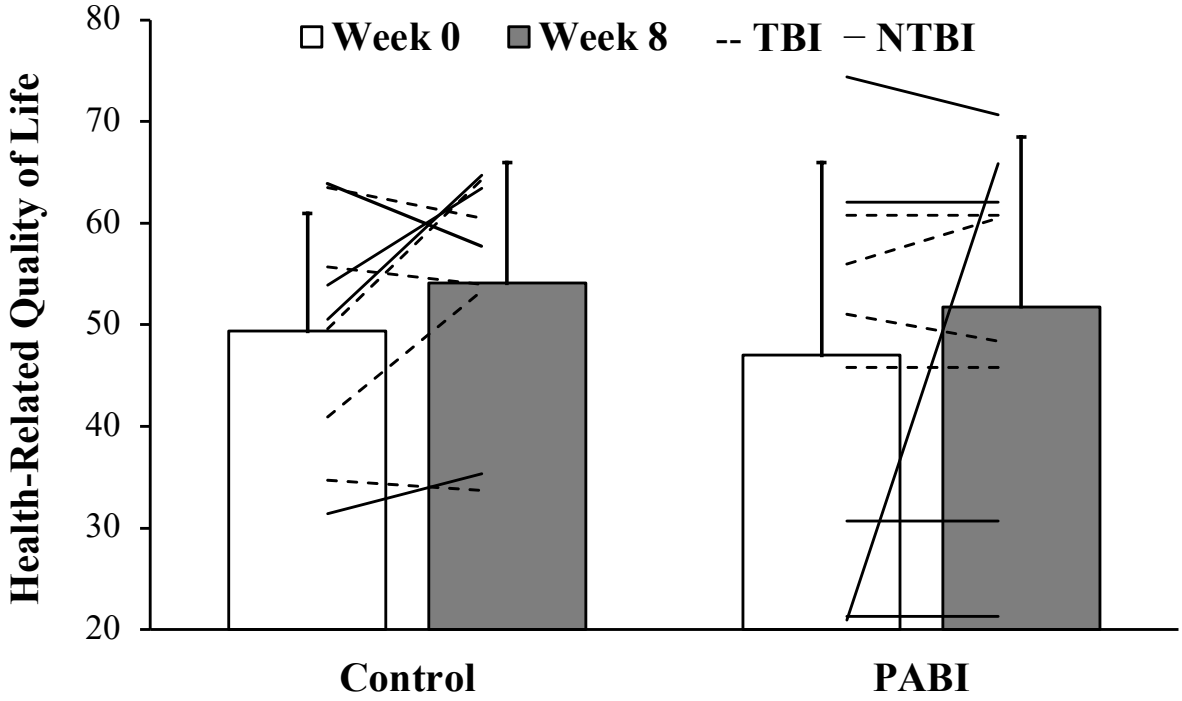

Figure 4.5. Self-reported health-related quality of life across groups and timepoints. Note: individual data points for people with traumatic brain injury (TBI) are dashed and for people with non-traumatic brain injury (NTBI) are solid.

4.6 PABI Program Participant Feedback

Appendix E provides an aggregated summary of voluntary participant feedback after completing the PABI program. Participants described the PiezoRx as an “excellent resource”, thought the program was helpful for “organizing their day” and “holding them accountable”, and liked the program’s emphasis on the benefits of long-term physical activity. They also enjoyed the exercise portion of the sessions, citing that the exercise circuits and partner activities were enjoyable, and the sample exercises were convenient to do at home without equipment. Some aspects they did not like were the complexity of some of the educational material and the group size felt too large for the meeting room. One person also stated, “there was limited individual attention” and “more follow-ups would be helpful”. When asked what could have been done differently, participants recommended extending the length of the exercise portion of the sessions, access to the educational presentations after the session, and having more long-term check-ins.

Chapter 5: DISCUSSION

The purpose of this study was to evaluate the effectiveness of Nova Scotia Health's PABI Program, an eight-week intervention designed to improve physical and sedentary activity levels in people with ABI. It was hypothesized that the PABI program would increase free-living step count levels, increase free-living standing time, decrease free-living sedentary levels, and increase HRQoL levels of the intervention group. The findings indicate that all hypotheses should be rejected, as step counts, standing time, sedentary time, and HRQoL did not change from week 0 to week 8 (all, $p \geq 0.34$). This evaluation of the impact of the PABI program on the habitual movement behaviours of people with ABI has provided Nova Scotia Health with important feedback on how to adapt future iterations of the program.

5.1 Changes in Physical Activity

After completing the PABI program, the intervention group did not increase their step counts (week 8–week 0=-378 steps/day, p=0.34, d=-0.08) or MVPA levels (+4 minutes/week, p=0.85, d=0.09). The minor step count fluctuations observed for all participants in Figure 4.2 indicated the program did not stimulate temporary increases in physical activity levels either. These results were unexpected because a major part of the intervention was using the step counts provided by the PiezoRx to set progressive step goals to prompt increases throughout the intervention. The lack of change could have been due to relatively high step count levels of our sample, with five of nine intervention participants averaging at least ~5000 steps/day throughout the program. Although we did not see improvements in the participants with low step counts (i.e., <4000 steps/day), the program may be more effective for inactive people with ABI. A previous study evaluating

a 12-week at-home educational module program on physical activity levels in 23 people with ABI observed a 61 counts/minute increase (p=0.02, d=0.75) and 70 minutes/week increase in MVPA levels (p=0.03, d=0.69) (13). Though these increases were only temporary (i.e., return to baseline values after 12 weeks), two programs with similar content delivery (i.e., educational sessions with health care professionals) and volume (i.e., the PABI program had 11 group sessions vs. 10 private online sessions) exhibited conflicting results (13).

The previous intervention did not use wearable devices to set step goals but participants were provided with written exercise prescriptions to motivate them to increase their physical activity levels (13). The biggest difference between the previous intervention and the PABI program was group-based versus individual educational sessions, suggesting the increased attention of these private one-on-one sessions may have led to these temporary increases in physical activity levels (13). Another likely reason that the PABI program did not see physical activity increases is that an eight-week intervention (with 1-2 sessions/week) was not enough volume to largely impact habitual physical activity levels. Some of the feedback received indicates that participants felt the groups may have been too large and that there were not enough follow-up sessions. Future iterations of the PABI program may look to reduce the size of the groups and increase the length of the program to elicit long-term lifestyle adaptations and better prepare them for independent activity (e.g., going for a walk alone).

Another interesting finding from the physical activity outcomes was the discrepancies between self-reported MVPA and activPAL-derived MVPA. At week 0, the intervention and control groups overestimated (p=0.01) their MVPA levels by 91 minutes/week and 253 minutes/week, respectively. Intriguingly, the intervention group

and control groups no longer overestimated (p=0.14) their MVPA levels during week 8. The PABI program could have falsely concluded to reduce MVPA levels from week 0 to week 8 (d=-0.45) in the intervention group if the PASB-Q was the primary MVPA measure. The overestimation error observed was the opposite of the previous PASB-Q validation attempts which demonstrated that active older (51) and younger adults (52) tended to underestimate their MVPA levels. These conflicting findings are likely because physically active people often underestimate the intensity of physical activity while inactive people overestimate it (91). This means that active adults typically misclassify MVPA activities (e.g., jogging) as LPA while inactive adults perceive LPA (e.g., leisurely walking) as MVPA due to their low aerobic fitness (91). This demonstrates the need for more physical activity interventions to objectively evaluate changes in habitual physical activity to avoid the recall biases associated with self-report.

5.2 Changes in Postural Time

This was the first study to objectively assess changes in postural time before and after an intervention for people with ABI. The intervention group did not reduce their sedentary time (week 8–week 0=-0.1 hours/day, p=0.85, d=0.05) or increase their standing time (week 8–week 0=-0.2 hours/day, p=0.72, d=-0.08). This indicates that the program did not adapt the postural behaviours of intervention participants. In contrast, the previously mentioned 18-week sports-based PASABI program observed a 3.1 hours/day *increase* in self-reported sedentary time for their intervention group (14). However, if the present study relied on self-reported sedentary time via the PASB-Q as a primary outcome, the intervention group would have decreased their sedentary time by 2.9 hours/day (d=0.84). It is important to note that the General Physical Activity Questionnaire (15) and the PASB-Q (51) have been shown to grossly underestimate

sedentary time in healthy populations. The increased prevalence of cognitive impairment common amongst the ABI population makes relying on self-report questionnaires to assess people with ABI less reliable (16). Thus, future interventions should ensure they are objectively monitoring changes in postural behaviours and avoiding self-report whenever possible.

When looking at the current design of the PABI program and previous interventions (13,14), the educational content has primarily focused on the importance of integrating physical activities (e.g., aerobic training, resistance training, sports) into the lives of people with ABI. Participants indicated that some of the content presented may have been too complex for people unfamiliar with physical activity terminology. They also requested permanent access to the information presented in slideshows to review the content. Nonetheless, the physical activity-centred approach did not impact the movement behaviours of people with ABI. Upon visual inspection of Figure 4.1 and Figure 4.4, two of nine intervention participants improved step counts from week 0 to week 8 but five of nine intervention participants reduced sedentary time. While this could be due to random variability, it could indicate that for inactive and sedentary people, reducing sedentary time may be a more feasible first step than increasing physical activity levels.

To elicit more long-term changes in inactive, sedentary populations like people with ABI, building interventions with a step-wise approach may be necessary (88). For instance, educating participants on the risks of prolonged sedentary time, asking participants to be mindful of their sedentary time, and giving them sedentary-based goals (e.g., standing after 30 minutes of sitting) at the beginning of the intervention may elicit more behavioural change. Over time, the intervention can slowly progress into more complex step count-based goals for LPA (e.g., go for a 5-minute walk) and MVPA (e.g.,

climb two flights of stairs) if appropriate (88). Adapting the educational content to better incorporate this step-wise approach, extending the length of the PABI program, and providing greater access to the information presented may create more sustained, positive lifestyle changes for people with ABI.

5.3 Changes in Health-Related Quality of Life

It was also important to consider how the intervention impacted the participants' perceptions of their HRQoL. The intervention group maintained a similar HRQoL according to the QOLIBRI scale (p=0.21, d=0.28). This indicates that the intervention did not change HRQoL for the intervention group, which mirrors the findings of a previous HRQoL intervention for people with ABI (20). The previous intervention included twelve sessions using workbooks and in-person educational classes focused on nutrition, relaxation, and goal-setting techniques with less emphasis on physical activity (20). It seems that education-based interventions designed to provide resources and tools to improve various aspects of HRQoL are not enough to impact people with ABI. This conflicts with the results of a systematic review of physical activity interventions for improving the HRQoL for people with ABI, demonstrating that any mode of physical activity (e.g., aerobic training, resistance training, sports) is enough to improve HRQoL (12). The 38 interventions summarized in the review were almost exclusively training interventions (e.g., aquatic training, cycle training) and were less focused on delivering educational content (12). A common suggestion by program participants was to increase the length of the warm-up (e.g., increase the five-minute walk to be longer) and exercise portions of the sessions. Thus, future iterations of the PABI program may see enhanced HRQoL improvements if the program was altered to include more structured exercise opportunities in combination with its educational resources.

Interestingly, there was overwhelmingly positive feedback from all intervention participants despite the lack of self-reported HRQoL improvements. Several people stated that they felt the program had a positive impact on their lifestyles, including feeling more energetic and in better physical shape. An important consideration when designing behavioural change interventions is the commitment level of the participants (92). For instance, the transtheoretical model of behaviour change indicates that people can be in five phases of behaviour change: precontemplation, contemplation, preparation, action, or maintenance (92). The intervention participants in our sample may not have been in the phase of behaviour change (e.g., participants were still in the contemplation phase) that would elicit physical activity adaptations. It it worth noting that the intervention group averaged ~6000 steps/day at baseline, suggesting many of them were already engaging in some physical activity and were likely in the later phases of the transtheoretical model. Also, these participants demonstrated motivation to change by signing up for the program, placing them in the preparation, action, or maintenance phases of behaviour change. Going forward, it may be helpful to include more behaviour change education into the PABI program and/or evaluate the commitment level of participants to change their behaviour.

One of the most common statements was the challenge of staying motivated to be physically active during the winter months. Both cohorts of the intervention took place from September to October 2022 and January to February 2023. Evidence shows that people are less physically active and more sedentary during the fall and winter months, which may have made it more challenging to improve activity levels (93). For example, if the movement behaviours of the intervention group did not change but the control group became less active and/or more sedentary, then the intervention could be perceived as

protective from the proposed seasonal challenges. However, the control and intervention groups were measured during the same time window (September 2022-February 2023) and the movement behaviours and HRQoL of the control group did not change. This downplays the possibility of a protective effect but does not disprove that the intervention may be more effective in the summer months. Future iterations of the PABI program may be completed during the spring and summer months to explore this theory.

5.4 Strengths & Limitations

This study was designed to evaluate an existing Nova Scotia Health outpatient program and improve the standard of care for Nova Scotians living with ABI. The study was strengthened by including objective measures of physical activity, standing time, and sedentary time and including an ABI-specific HRQoL scale instead of relying on a general scale. Including thigh-worn activity monitoring ensured that observed recall bias from self-report activity questionnaires was avoided and implementing an ABI-specific measure of HRQoL provided additional consideration of how ABI impacts several aspects of daily life. Implementing a time-matched control group of people with ABI ensured that an observed change (or lack of change) in the intervention group could be attributed to the program. Effect sizes for within-group and between-group differences were reported throughout as a guide for potential habitual movement behaviour changes in a more statistically powered sample. The study design also provided participants with the opportunity to share their program experience and what could be done differently for future program iterations.

This study is not without its limitations. Though the study included people with NTBI and TBI, 38% of the sample were diagnosed with stroke and 44% of the sample were diagnosed with concussion. We did not have access to detailed information

regarding the period of time since their injury, severity of injury, or pre-injury habitual activity levels. Future studies should look to include a variety of ABI diagnoses (e.g., hematoma, meningitis, brain tumour) and ABI severities to determine if the type of injury influences movement behaviours and HRQoL. This study was limited to functionally-independent people with ABI (e.g., were not in a wheelchair, no severe cognitive impairments), excluding a large portion of the ABI population. If more staff and resources (e.g., accessible exercise equipment, harnesses, walking aids) were dedicated to facilities like the NeuroCommons, programming could be expanded to include ABI populations dealing with severe impairments. Due to the variability of ABI types, impairments, and symptoms, designing a single intervention for everyone may not be the appropriate strategy. Creating individualized programming which adapts to the unique circumstances of each person may be the most effective way to elicit lifestyle adaptations.

The implementation of an ABI-specific measure of HRQoL provided additional insight into the burden of an ABI, but the validity and generalizability of the QOLIBRI is limited (18). As mentioned, the QOLBRI and generic scales like the SF-36 have been shown to be significantly correlated (r=0.23-0.64) for all aspects of HRQoL but the QOLIBRI has an enhanced ability to detect subtle changes in HRQoL (18). However, a benefit to using generic HRQoL scales is the scores produced can be compared across healthy populations. Future program iterations may benefit from including several HRQoL scales (e.g., the QOLIBRI and SF-36) and measuring it more frequently (e.g., several times per week) to gather a more comprehensive outlook on changes in HRQoL. The eight-week PABI program was also considerably shorter than previous interventions ranging from 12-18 weeks (13,14,20). This may have played a role in why the PABI participants did not improve their habitual movement behaviours. This study did not

investigate the impact of the program on other clinical outcomes (e.g., cardiovascular fitness, cognitive function, etc.). For instance, if the PABI program was unable to impact habitual movement behaviours but improved the cognitive function and aerobic fitness of participants, that would support the efficacy of the existing program. Nova Scotia Health should look to further investigate the impact of the PABI program on these outcomes, including a cost-effectiveness analysis to determine if more funding should be allotted for physical activity rehabilitation programming.

5.5 Implications & Future Directions

Eight weeks of education was not enough to improve the movement behaviours and HRQoL of people with ABI. However, the ineffectiveness of the PABI program and participant feedback has provided valuable information for future program iterations. Adjusting the PABI program (e.g., increasing the program length, incorporating more sedentary behaviour content, including more structured physical activity) is just one way to improve the standard of ABI care in Nova Scotia. The PABI program was limited to a small subpopulation of functionally independent people living with long-term ABI. All people with ABI, regardless of physical and cognitive ability, should have access to ongoing rehabilitation programming. For example, Peter's Place is a private community clinic located in Halifax, Nova Scotia which provides continued education-based programs like the ABI Day Program. The Brain Injury Association of Nova Scotia also hosts community programs such as the weekly Walk and Talk for brain injury survivors and family members in Halifax. The hope is to see these ABI programs expand to a level analogous to cardiac rehabilitation programming with a variety of inpatient and long-term outpatient options. Increasing the accessibility to services like the ABI Day Program, Peter's Place, and the Brain Injury Association of Nova Scotia will inevitably improve the

standard of care for people with ABI.

5.6 Conclusion

The PABI program was unable to increase free-living step count levels, increase free-living standing time, decrease free-living sedentary levels, and increase HRQoL levels of people with ABI. Though it was shown to be ineffective at altering these outcomes, the findings from this study will help Nova Scotia Health elevate the standard of care for Nova Scotians with ABI and develop future rehabilitation programs for ABI populations. This includes focusing more educational content on sedentary activity, increasing the length of the intervention, and providing more opportunities to engage in structured physical activity (e.g., ABI-specific exercise training).

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Appendix A: Curriculum Vitae

Liam P. Pellerine

MSc Candidate

Division of Kinesiology, Department of Health & Human Performance

Dalhousie University

Halifax, Nova Scotia, Canada, B3H 4R2

Phone: +1 (902) 476-2321

Email: liam.pellerine@dal.ca

EDUCATION HISTORY

Bachelor of Science in Kinesiology (Honours)
2017-2021
Dalhousie University, Halifax, Nova Scotia, Canada
Supervisor: Dr. Derek Kimmerly & Dr. Myles O'Brien
Thesis Title: "*Criterion-Validity of the Physical Activity Vital Sign for Estimating Moderate-to-Vigorous Intensity Physical Activity Levels in Younger and Older Adults*"

- GPA: 4.1/4.3

Master of Science in Kinesiology 2021-Present
Dalhousie University, Halifax, Nova Scotia, Canada
Supervisor: Dr. Ryan Frayne & Dr. Myles O'Brien
Thesis Committee: Dr. Gail Dechman, Dr. David McArthur
Thesis Title: "*Evaluating the Effectiveness of an 8-week Intervention for Reducing Sedentary Time and Increasing Physical Activity Levels for People with Acquired Brain Injury*"

- GPA: 4.2/4.3

ACADEMIC INTERESTS

- Building and Maintaining Community Exercise Programs for Clinical Populations.
- Mobility and Movement Interventions in Hospital Care.
- Integration of Physical Activity and Exercise in Healthcare by Primary Care Providers and Qualified Exercise Professionals.
- Development and Validity of Physical Activity Monitors and Metrics.

BRIEF SUMMARY OF DOCUMENT

- 7 Published Articles (*n*=4 first-author) since 2022
- 3 Published Conference Abstracts (attended 2 other professional meetings)
- Served as a Teaching Assistant and Research Assistant in Dalhousie University's Kinesiology and Medicine Departments
- MSc Kinesiology funded through Canadian Institute for Health Research.

PEER-REVIEWED JOURNAL ARTICLES

Published Articles (Total: *n*=9; *n*=4 first-author)

1) O'Brien MW, **Pellerine LP**, Howitt SD, deGraauw C, Fowles JR. Characterization of Physical Activity Counselling and Exercise Prescription Practices of Chiropractors in Canada and Internationally. *Journal of the Canadian Chiropractic Association*. In Press.

2) Schwartz BD, **Pellerine LP**, Bray NW, Fowles JR, Furlano JA, Morava A, Nagpal TS, O'Brien MW. Binge Drinking and Smoking are Associated with Worse Academic Performance in Canadian Undergraduate Students. *Journal of American College Health*. In Press.

3) **Pellerine LP**, Petterson JL, Shivgulam ME, Johansson PJ, Hettiarachchi P, Kimmerly DS, Frayne RJ, O'Brien MW. Step Length, But Not Stepping Cadence Strongly Predicts Activity Intensity During Jogging and Running. *Measurement of Physical Education and Exercise Science.* In Press.

4) O'Brien MW, Petterson JL, **Pellerine LP**, Shivgulam ME, Kimmerly DS, Frayne RJ, Hettiarachchi P, Johansson PJ. Moving Beyond the Characterization of Activity Intensity Bouts as Square-Waves Signals. *Journal for the Measurement of Physical Behaviour.* In Press.

5) O'Brien MW, **Pellerine LP**, Shivgulam ME, Kimmerly DS. Disagreements in Physical Activity Monitor Validation Study Guidelines Create Challenges in Conducting Validity Studies. *Frontiers in Digital Health.* 4:1063324

6) Shivgulam ME, Petterson JL, **Pellerine LP**, Kimmerly DS, O'Brien MW. (2023). The Stryd Foot Pod is a Valid Measure of Stepping Cadence During Treadmill Walking and Running. *Journal for Measurement of Physical Behaviour.* 6(1): 73-78.

7) **Pellerine LP**, Bray NW, Fowles JR, Furlano JA, Morava A, Nagpal TS, O'Brien MW. (2022). The Influence of Motivators and Barriers to Exercise on Attaining Physical Activity and Sedentary Time Guidelines Among Canadian Undergraduate Students. *International Journal of Environmental Research & Public Health.* 19(19): 12225.

8) **Pellerine LP**, O'Brien MW, Shields CA, Crowell SJ, Strang R, Fowles JR. (2022). Health Care Providers' Perspectives on Promoting Physical Activity and Exercise in Health Care. *International Journal of Environmental Research & Public Health.* 19(15): 9466.

9) **Pellerine LP**, Kimmerly DS, Fowles JR, O'Brien MW. (2022). Calibrating the Physical Activity Vital Sign to Estimate Habitual Moderate-to-Vigorous Physical Activity More Accurately in Active Young Adults: A Cautionary Tale. *Journal for the Measurement of Physical Behaviour.* 5(2): 103-110.

MANUSCRIPTS WITH REVISIONS REQUESTED UNDER PEER REVIEW

Pellerine LP, Bray NW, Fowles JR, Furlano JA, Morava A, Nagpal TS, O'Brien MW**.** Increased Screen Time During Leisure and Time to Fall Asleep are Associated with Worse Academic Performance in Canadian Undergraduate Students. Submitted to *International Journal of Health Promotion and Practice*

ACADEMIC CONFERENCE PRESENTATIONS

Published Conference Presentations

1) **Pellerine LP**, Miller K, Frayne RJ, O'Brien MW. Characterizing Habitual Physical Activity and Sedentary Time in Outpatients with an Acquired Brain Injury. (2023). *American College of Sports Medicine.*

2) **Pellerine LP**, Bray NW, Fowles JR, Furlano JA, Morava A, Nagpal TS, O'Brien MW. (2022). Impact of motivators and barriers to exercise on attaining to physical activity and sedentary time guidelines among Canadian undergraduate students. *Applied Physiology, Nutrition and Metabolism.* 47(10): S90

3) **Pellerine LP**, Kimmerly DS, Fowles JR, O'Brien MW. (2021). Criterion-validity of the Physical Activity Vital Sign for estimating habitual moderate-to-vigorous physical activity in active younger and older adults. *Applied Physiology, Nutrition and Metabolism.* 46(10): S70.

Professional Meetings and Other Academic Conferences

1) **Pellerine LP**, Miller K, Frayne RJ, O'Brien MW. Evaluating the Effectiveness of an 8-week Physical Activity Intervention for People with Acquired Brain Injury. Atlantic Provinces Exercise Science Conference. Université de Moncton, Moncton, New Brunswick, Canada.

2) **Pellerine LP**, Kimmerly DS, Fowles JR, O'Brien MW. (2021). Criterion Validation of the Physical Activity Vital Sign Questionnaire Estimation of Habitual Moderate-Vigorous Physical Activity in Younger and Older Adults. Atlantic Provinces Exercise Science Conference. University of New Brunswick, Fredericton, New Brunswick, Canada.

RESEARCH EMPLOYMENT & TEACHING EXPERIENCE

Research Assistant
Geriatric Medicine Research Unit, Halifax, NS — Dec 2021-Present
"The Breaking "Bad Rest" Study: Interrupting Sedentary Time to Reverse Frailty Levels in Acute Care"
ClinicalTrials.gov Identifier: NCT03682523
Dr. Olga Theou

Research Assistant
Dalhousie University, Halifax, NS — Nov 2021-Apr 2022
"Validity of the ActivPAL and Stryd Activity Monitors Across Walking and Jogging Stepping Speeds"
Dr. Myles O'Brien

Teaching Assistant
Dalhousie University, Halifax, NS — Nov 2021-Apr 2022
Honours in Kinesiology (KINE 4901)

FUNDING, DISTINCTIONS, & AWARDS

Dalhousie University MSc-Kinesiology 2023
Atlantic Provinces Exercise Science Conference
Graduate Presentations – 2nd Place
$100

Canadian Institutes of Health Research Master's Funding
$17,500 2022

Dalhousie University BSc-Kinesiology
Atlantic Provinces Exercise Science Conference 2021
Undergraduate Presentations – 1st Place
$100

Margorie Ball Memorial Scholarship 2020
$1000

Dean's List 2018-2021
3.7 GPA or higher

Dalhousie In-Course Scholarship 2018-2019
$1000 per year (2 years)

Hector McInnes Memorial Scholarship 2017
$750

NSSAF Academic Excellence & Leadership Award 2017
In recognition of demonstrating excellence in high-school academics and sport
$250

PROFESSIONAL AFFILIATIONS & SERVICE

Journal Reviewer (n=1 manuscript)

JMIR Rehabilitation and Assistive Technologies	2023; n=1

Certifications

Montreal Cognitive Assessment – Certified Patient Screener	2022-Present
Interprofessional Health Education – Certificate	2021

Memberships

Canadian Society for Exercise Physiology (CSEP)	2021-Present
American College of Sports Medicine (ACSM)	2023-Present

Committees & Volunteering

World Delirium Awareness Day – Hospital Patient Screener	2022-2023
Autonomic Cardiovascular Control & Exercise Lab – Study Participant	2019-2023
Empire Hockey Goaltending Academy – On-Ice Instructor	2013-2021
Mussels LGBTQ+ Adult Alliance Hockey Group – On-Ice Instructor	2017-2020

Appendix B: QOLIBRI Questionnaire

QOLIBRI – QUALITY OF LIFE AFTER BRAIN INJURY
by Von Steinbuchel et al.

In the first part of this questionnaire, we would like to know **how satisfied** you are with different aspects of your life since your brain injury. For each question, please circle the answer which is closest to how you feel now (including the past week). If you have problems filling out the questionnaire, please ask for help.

PART A – These questions are about your thinking abilities now (including the past week):

1. How satisfied are you with your ability to concentrate, for example when reading or keeping track of a conversation?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

2. How satisfied are you with your ability to express yourself and understand others in a conversation?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

3. How satisfied are you with your ability to remember everyday things, for example where you have put things?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

4. How satisfied are you with your ability to plan and work out solutions to everyday practical problems, for example what to do when you lose your keys?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

5. How satisfied are you with your ability to make decisions?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

6. How satisfied are you with your ability to find your way around?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

7. How satisfied are you with your speed of thinking?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

For scoring purposes only: _____ out of 35 (NOT AT ALL = 1, VERY = 5)

PART B – These questions are about your emotions and view of yourself now (including the past week):

1. How satisfied are you with your level of energy?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

2. How satisfied are you with your level of motivation to do things?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

3. How satisfied are you with your self-esteem, how valuable you feel?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

4. How satisfied are you with the way you look?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

5. How satisfied are you with what you have achieved since your brain injury?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

6. How satisfied are you with the way you perceive yourself?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

7. How satisfied are you with your future?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

For scoring purposes only: _____ out of 35 (NOT AT ALL = 1, VERY = 5)

PART C– These questions are about your independence and how you function in daily life now (including the past week):

1. How satisfied are you the extent of your independence from others?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

2. How satisfied are you with your ability to get out and about?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

3. How satisfied are you with your ability to carry out domestic activities, for example cooking or repairing things?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

4. How satisfied are you with your ability to run your personal finances?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

5. How satisfied are you with your participation in work or education?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

6. How satisfied are you with your participation in social and leisure activities, for example sports, hobbies, parties?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

7. How satisfied are you with the extent to which you are in charge of your own life?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

For scoring purposes only: _____ out of 35 (NOT AT ALL = 1, VERY = 5)

PART D – These questions are about your social relationships now (including the past week):

1. How satisfied are you with your ability to feel affection towards others, for example your partner, family, friends?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

2. How satisfied are you with your relationships with members of your family?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

3. How satisfied are you with your relationships with your friends?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

4. How satisfied are you with your relationship with a partner or with not having a partner?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

5. How satisfied are you with your sex life?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

6. How satisfied are you with the attitudes of other people towards you?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

For scoring purposes only: _____ out of 30 (NOT AT ALL = 1, VERY = 5)
In the second part, we would like to know **how bothered** you feel by different problems. For each question, please circle the answer which is closest to how you feel now (including the past week). If you have problems filling out the questionnaire, please ask for help.

PART E – These questions are about how bothered you are by your feelings now (including the past week):

1. How bothered are you by feeling lonely, even when you are with other people?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

2. How bothered are you by feeling bored?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

3. How bothered are you by feeling anxious?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

4. How bothered are you by feeling sad or depressed?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

5. How bothered are you by feeling angry or aggressive?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

For scoring purposes only: _____ out of 25 (NOT AT ALL = 5, VERY = 1)

PART F – These questions are about how bothered you are by physical problems now (including the past week):

1. How bothered are you by slowness and/or clumsiness of movement?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

2. How bothered are you by effects of any other injuries you sustained at the same time as your brain injury?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

3. How bothered are you by pain, including headaches?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

4. How bothered are you by problems with seeing or hearing?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

5. Overall, how bothered are you by the effects of your brain injury?

NOT AT ALL SLIGHTLY MODERATELY QUITE VERY

For scoring purposes only: _____ out of 25 (NOT AT ALL = 5, VERY = 1)

Appendix C: Nova Scotia Health ABI Day Program Referral Form

nova scotia health

ACQUIRED BRAIN INJURY

Outreach, Day Program, and Coordinator – ABI Ambulatory Care Teams Referral Form

SECTION B

Requesting services of:

❑ ABI Outreach	❑ ABI Day Program	❑ Coordinator – ABI Ambulatory Care Teams
Provides support, education and consultation to service providers, families / caregivers and individuals living with ABI in the community setting within NS Health Central Zone. ❑ ABI education ❑ Cognitive needs ❑ Perceptual needs ❑ Community living skills i.e. transportation / banking ❑ Caregiver support / education ❑ Counselling / emotional support ❑ Self-care skills ❑ Functional mobility i.e. transfer, fall prevention ❑ Facilitate connection to community support ❑ Behaviour management ❑ Leisure education ❑ ABI consultation for staff	Group based program located at the Bedford Neuro Commons that provides education and intervention to manage ABI symptoms and associated difficulties. ❑ ABI education ❑ Fatigue management ❑ Memory strategies ❑ Leisure exploration and sampling ❑ Relaxation ❑ Emotional regulation ❑ Additional considerations impacting ability to attend daily treatment? (i.e. endurance; transportation; work schedules; other.) _____ _____	Through an intake process, identifies client needs, develops recommendations and evaluates the most appropriate ABI service to meet the client's and the family's goals. ❑ Determine appropriate referrals and coordinate ABI ambulatory care services. ❑ Provide consultation to assit with complex discharge planning. ❑ Provide assistance locating exisiting community based services within NS Health Central Zone.

Considerations / Contraindications (i.e. harmful involvement with substances, primary psychiatric diagnosis, seizures, behavioural patterns, dietary restrictions, etc.): _____

_____

Form completed by (please print): _____ Phone: _____

Signature: _____

Please fax form to 902-425-6574. **Coordinator – ABI Ambulatory Care Teams Tel: 902-473-1186**

ACQUIRED BRAIN INJURY

Outreach, Day Program, and Coordinator − ABI Ambulatory Care Teams Referral Form

Fax to: 902−425−6574

SECTION A

Client Name: _____ Referral Date (YYYY/MON/DD): _____

Primary Diagnosis: _____

Date & Cause of ABI (YYYY/MON/DD): _____

_____

Relevent Past Medical History: _____

Is client aware of this referral? ❑ Yes ❑ No

Person to contact for appointment? Name: _____ Phone: _____

CURRENT LIVING STATUS

❑ Living in community: ❑ Alone ❑ With supports (specify): _____

❑ In hospital: Hospital name & unit: _____

Anticipated D/C date and destination (YYYY/MON/DD): _____

Specify supports recommended for D/C: _____

_____

_____

PROFESSIONALS / AGENCIES CURRENTLY INVOLVED WITH CLIENT (if known):

❑ Dietary
❑ Neurology
❑ NS Dept. of Health
❑ Continuing Care
❑ Physiatry
❑ Psychology
❑ Social Work
❑ Vocational Counselling
❑ Neurosurgery
❑ NS Dept. of Community Services
❑ Occupational Therapy
❑ Physiotherapy
❑ Specialty Nurse Practitioner
❑ Speech Language Pathology
❑ Recreation Therapy
❑ Other (specify): _____

What do you hope to achieve with this referral? _____

_____

_____

Appendix D: Activity Monitor Sleep/Nap and Activity Log

Date	**Time you woke up**	**Time you fell asleep**	**Other Exercise Activities (Start/End Times)**
Ex. July 20th, 2021	**8:00 am**	**10:00 pm**	**Swimming (10am-11am)**

Appendix E: Participant Feedback Responses

Note: Responses have been aggregated for all program participants

What did you like or find helpful about this series?

- The PiezoRx was an excellent resource
- The goal setting, risk, and rewards chart
- Protocols to know when and how much to progress
- Helpful for organizing the day
- Setting personal goals and having to be accountable for them
- The emphasis on the benefits of long-term PA brought awareness and motivation (i.e., video on PA)
- Recognizing a small success as SUCCESS, helps to motivate for more successes
- The coloured handouts, booklet, exercises diagrams
- Check-in phone calls and the ability to share personal experiences
- All ladies in the group made it a safe and comfortable to perform exercises/talk about issues
- Individual adaptability of the exercises
- Real world solutions and modifications for home
- Exercises look differently, with same result
- The pedometers were helpful for feedback
- Material was fun and interactive

What didn't you like, or found unhelpful about this series?

- Need better music
- Some of the material presented was too complicated
- Class size, limited individual attention (6 might be too much)
- The room was crowded and warm (might need to move stuff out of the room)

What would you like done differently?

- Spend less time on safety protocols
- Make the exercise portion of the classes longer (especially the 5-minute warm-ups)
- Provide access to the content slides after the session is over
- Discuss short term and long-term goals again mid-series (keep this an individual discussion)
- Would be good to have more long-term check-in options
- This would have been nice to have earlier in the day, when you have more energy
- A water cooler would be helpful
- Longer breaks before and after exercise

What are your thoughts about the exercises presented?

- Fun and interactive
- Enjoyable and allowed to find out what one can actually do
- Partner exercises were fun
- Liked the sessions with exercise stations
- Leisure activities were fun (e.g., bocce ball)
- Great variety, appropriately difficult and adaptable
- Easy to do at home, no need to buy anything

Appendix F: Supplemental Tables

Supplemental Table S1. List of self-reported co-morbidities provided at baseline for the pooled sample, control group, and intervention group.

Co-Morbidity	*n* (%) Pooled Sample (*n*=18)	*n* (%) Control Group (*n*=9)	*n* (%) Intervention Group (*n*=9)
Anxiety	3 (16)	1 (11)	2 (2)
Asthma	3 (16)	1 (11)	2 (2)
ADHD	3 (16)	1 (11)	2 (2)
Bell's Palsy	1 (6)	1 (11)	0 (0)
Bipolar Disorder	3 (16)	2 (22)	1 (11)
Carpal Tunnel Syndrome	1 (6)	1 (11)	0 (0)
Coronary Artery Disease	2 (11)	1 (11)	1 (11)
Crohn's Disease	1 (6)	0 (0)	1 (11)
Depression	3 (16)	0 (0)	3 (33)
Diabetes Mellitus	1 (6)	1 (11)	0 (0)
Fibromyalgia	3 (16)	1 (11)	2 (2)
Hernia	1 (6)	0 (0)	1 (11)
Hypertension	1 (6)	1 (11)	0 (0)
Hypotension	1 (6)	1 (11)	0 (0)
Hypothyroidism	1 (6)	1 (11)	0 (0)
Interstitial Cystitis	2 (11)	1 (11)	1 (11)
Irritable Bowel Syndrome	3 (16)	2 (2)	1 (11)
Osteoarthritis	2 (11)	1 (11)	1 (11)
Presbycusis	1 (6)	0 (0)	1 (11)
Spinal Stenosis	2 (11)	1 (11)	1 (11)
≥2 Co-morbidities	**11 (61)**	**5 (56)**	**6 (67)**
≥3 Co-morbidities	**8 (44)**	**4 (44)**	**4 (44)**
≥4 Co-morbidities	**4 (22)**	**2 (22)**	**2 (22)**

Note: ADHD, Attention-Deficit/Hyperactivity Disorder.

Supplemental Table S2. List of self-reported medications provided at baseline for the pooled sample, control group, and intervention group.

Medication	*n* (%) Pooled Sample (*n*=18)	*n* (%) Control Group (*n*=9)	*n* (%) Intervention Group (*n*=9)
Allergy Medications			
Intranasal corticosteroids	1 (6)	0 (0)	1 (11)
Anti-infective Medications			
Antifungals	1 (6)	0 (0)	1 (11)
Bladder Medications			
Alpha-blockers	1 (6)	1 (11)	0 (0)
Beta-3 adrenergic agonists	1 (6)	0 (0)	1 (11)
Muscarinic antagonists	1 (6)	0 (0)	1 (11)
Cardiovascular Medications			
ACE/ARB inhibitors	4 (22)	1 (11)	3 (33)
Anticoagulants	1 (6)	0 (0)	1 (11)
Antiplatelets	2 (11)	1 (11)	1 (11)
Beta-blockers	4 (22)	1 (11)	3 (33)
Calcium channel blockers	2 (11)	1 (11)	1 (11)
Diuretics	1 (6)	0 (0)	1 (11)
Nitrates	2 (11)	1 (11)	1 (11)
Cholesterol Medications			
HMG-CoA reductase inhibitors	4 (22)	2 (22)	2 (22)
Digestive Medications			
H2 receptor antagonists	1 (6)	0 (0)	1 (11)
Proton pump inhibitors	5 (26)	2 (22)	3 (33)
Antispasmodics	2 (11)	1 (11)	1 (11)
Calcium antagonists	2 (11)	1 (11)	1 (11)
Immunosuppressive Medications			
Azathioprine	1 (6)	0 (0)	1 (11)
Monoclonal antibodies	3 (16)	1 (11)	2 (22)
Oral corticosteroids	1 (6)	0 (0)	1 (11)
Pain Medications			
Gabapentinoids	1 (6)	0 (0)	1 (11)
Non-steroid anti-inflammatories	1 (6)	0 (0)	1 (11)
Psychiatric Medications			
ADHD stimulants	3 (16)	1 (11)	2 (22)
Anti-psychotics	1 (6)	0 (0)	1 (11)

Anxiolytics	2 (11)	1 (11)	1 (11)
Selective serotonin/norepinephrine reuptake inhibitors	10 (55)	3 (33)	7 (78)
Tricyclic antidepressants	2 (11)	1 (11)	1 (11)
Respiratory Medications			
Inhaled beta-agonists	3 (16)	1 (11)	2 (22)
Inhaled corticosteroids	2 (11)	1 (11)	1 (11)
Multi-Medication Use			
3 or more medications	12 (67)	6 (67)	6 (67)
5 or more medications	9 (50)	3 (33)	6 (67)

Note: ACE, angiotensin-converting enzyme; ARB, angiotensin receptor blockers; HMG-CoA, 3-hydroxy-3-methylglutaryl coenzyme A; H2, dihydrogen; ADHD, Attention-Deficit/Hyperactivity Disorder.