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Combined Interdisciplinary Rehabilitation for Persisting Symptoms following a Mild Traumatic Brain Injury

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Abstract

Mild traumatic brain injuries (mTBI's) are the most frequently experienced form of traumatic brain injury. Certain demographic characteristics, including older age, female sex, and pre-existing mental health conditions, increase the risk of experiencing persisting symptoms beyond the acute injury phase. Care for individuals with an mTBI is limited by geography, non-standardized trajectories of care, and gaps in healthcare provider knowledge. An interdisciplinary outpatient intervention has been created to address these issues, but has not been evaluated. Accordingly, the overall purpose of this thesis was to investigate treatment outcomes of individuals with persisting symptoms following an mTBI after completing a combined outpatient physiotherapy and occupational therapy rehabilitation intervention. This question was investigated through three studies evaluating changes in subjective outcomes and how they are influenced by different demographics. The results demonstrated individuals improved in performance and satisfaction of self-identified goals after completing this intervention in-person, and most frequently chose productivity-based goals (Study 1). Additionally, age, baseline symptom and anxiety scores, sex, days since injury, education, and mechanism of injury did not influence change in satisfaction with self-identified goals (Study 2). Lastly, there may be no differences in subjective outcomes after completing a virtual version of this intervention, especially for females (Study 3). In conclusion, this study demonstrates the in-person version of this intervention improves performance and satisfaction of participant-identified goals for adults with persisting symptoms following an mTBI that require physiotherapy and occupational therapy services. Additionally, there may be no difference in subjective changes following participation between in-person or virtual mTBI rehabilitation, particularly in female participants. However, future work is necessary to expand on this work and evaluate whether these preliminary results are supported with a fully powered study.

Keywords

Mild traumatic brain injury, mTBI, interdisciplinary, rehabilitation, patient-centered care, goal setting

Summary for Lay Audience

Mild traumatic brain injuries (mTBI's), or concussions, are the most common form of traumatic brain injury. People that are older, have pre-existing anxiety or depression, and females are more likely to continue experiencing symptoms a year after their injury. However, care for individuals with an mTBI is limited by geography, limited healthcare provider knowledge, and non-standardized care. This is problematic as individuals respond best to prompt care that targets their individual needs. Accordingly, the overall purpose of this thesis was to investigate treatment outcomes of individuals with persisting symptoms following an mTBI after completing a combined outpatient physiotherapy and occupational therapy rehabilitation intervention. This question was investigated through three studies. The results showed participants improved in performance and satisfaction of self-identified goals after completing this intervention in-person, and most frequently chose productivity-based goals, like returning to work, grocery shopping, and cleaning (Study 1). Additionally, age, initial mTBI symptom and anxiety scores, sex, days since injury, education, and mechanism of injury did not influence change in satisfaction with self-identified goals (Study 2). Lastly, there may be no differences in participant-rated anxiety, mTBI symptoms, vision, or performance or satisfaction of goals between the virtual and in-person versions of this intervention, especially for females (Study 3). In conclusion, this study demonstrates the in-person version of this intervention improves performance and satisfaction ratings of goals chosen by adults with persisting symptoms following an mTBI that require physiotherapy and occupational therapy services. Additionally, there may no difference in participant-reported symptoms, anxiety, vision difficulties, or performance or satisfaction with participant-identified goals after completing the in-person or virtual mTBI rehabilitation intervention, particularly in female participants. However, more research is necessary to further understand how participants respond to this intervention, which should include more participants and investigating other outcomes, to support our initial results.

Co-Authorship Statement (where applicable)

This thesis contains material from one published manuscript (Chapter 2) and two manuscripts that are being prepared for submission (Chapters 3 and 4) that encompass the collaborative work of researchers and co-authors. Marquise Morrissey (Bonn) is the primary author of all of the chapters contained in this thesis. Dr. Jim Dickey (Professor in the School of Kinesiology, Faculty of Health Science, Western University), Dr. Laura Graham (Assistant Professor, School of Physical Therapy, Faculty of Health Sciences), Shannon McGuire (Physiotherapist, Acquired Brain Injury Outpatient Program, Parkwood Institute), and Becky Moran (Occupational Therapist, Acquired Brain Injury Outpatient Program, Parkwood Institute) co-authored Chapters 2-4. Dr. Jim Dickey and Dr. Laura Graham contributed to data analysis and manuscript preparation. Shannon McGuire and Becky Moran contributed to data collection and manuscript preparation, and created the BrainEx90 and virtual BrainEx90 interventions.

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Chapter 1

1 Introduction

1.1 Mild Traumatic Brain Injury

Traumatic brain injuries (TBI's) occur from external forces transferring mechanical energy to the brain.[1] These forces can be from an object striking one's head, hitting a surface or object with one's head, acceleration of the brain without the head directly contacting an object or surface, or forces from a blast. Mild traumatic brain injuries (mTBI's) are the most common form of TBI's.[2] There has been debate regarding the terms "concussion" and "mild traumatic brain injury",[3] however recent consensus identifies the terms are interchangeable when neuroimaging is normal or not clinically indicated.[1] An mTBI is characterized as a potential injury to the brain due to the mechanism of injury, along with a grade 13-15 on the Glasgow Coma Scale within 30 minutes of the injury, and at least one of: <30 minutes loss of consciousness, <24 hours post-traumatic amnesia, impaired mental state immediately following the injury, and/or transient neurological deficit.[4] There are no objective measures to diagnose an mTBI.[1]

Contrary to previous literature stating symptoms following an mTBI are resolved by three months,[4] recent literature states approximately 40% of individuals with an mTBI continue to report symptoms a year following their injury.[5] Individuals with persisting symptoms following an mTBI may struggle in various facets of life, including work,[6] sport, or school.[7] The definition of persisting symptoms following an mTBI has been debated, however a recent expert consensus defines persisting symptoms according to three criteria: the presence of symptoms not attributed to a preexisting condition that appeared within hours of the injury, experiencing these symptoms every day for three months following the injury, and these symptoms impact the individual's life.[8]

Symptoms following an mTBI can fall within four categories: altered mental state (e.g., confusion, disorientation, etc.), physical symptoms (e.g., headache, nausea, sensitivity to light or noise, etc.), cognitive symptoms (e.g., memory problems, "mental fog", etc.), or emotional symptoms (e.g., emotional lability or irritability).[1] The cognitive symptoms of memory problems and taking longer to think are the most frequently reported persisting symptoms, each persisting in approximately 70% of individuals that have symptoms six months following their injury.[5] Poor concentration, fatigue, headache, sleep disturbance, and irritability are also reported in between 50 and 60% of individuals that have symptoms at three months.[5] These symptoms have been attributed to a multitude of biological changes following an

mTBI, including autonomic dysfunction,[9] inflammation, cellular injury, neurotransmitter dysregulation and increased cellular metabolic demand,[10] etc.

1.2 mTBI Epidemiology

Anyone can experience an mTBI since slips, trips, falls and head impacts are relatively frequent. However, data from emergency departments states that children, younger adult males and older adult females are at an increased risk.[11] Similarly, concussion rates reported by family physicians in Ontario indicate that males and younger individuals have an increased risk.[12] The authors hypothesize that these groups of individuals may be more likely to experience an mTBI because they participate in riskier daily activities and contact sports. Individuals from rural areas are also more likely to experience an mTBI compared to urban counterparts for these reasons, along with an increased risk of motor vehicle collisions and potentially higher risk employment, for example mining, agriculture or forestry.[13, 14] However, individuals from rural areas are less likely to receive appropriate treatment because of their limited access to specialized services (including clinicians and imaging), limited mTBI education in schools, reduced funding for appropriately trained personnel in high school sporting events, and lower average economic status, compared to individuals in urban areas.[13]

Individuals with pre-existing anxiety or depression are nearly three times more likely to have persisting symptoms three months following an mTBI,[15, 16] perhaps due to psychological proneness.[17] Additionally, women are more than two times more likely to experience persisting symptoms three months following their injury,[15, 16] however the reasoning is unclear. Cultural and gender norms, accuracy of symptom reporting, hormones, and/or neural architecture differences between sexes have all been hypothesized.[18] Lastly, increased age is also a risk factor for persisting symptoms, as each year increases the risk of experiencing persisting symptoms by 5%.[15, 19] This risk may be because of the impact of aging, which may make the older brain more vulnerable to injuries.[20]

1.3 Rehabilitation Following an mTBI

Outcomes, including symptom reduction and time to return to work, are improved when individuals with an mTBI have prompt access to individualized rehabilitation.[21, 22] However, access to specialized care in Ontario is limited, with time from injury to assessment for specialized care reportedly six months in Ontario.[23] Long wait times for government or private care may be the result of non-standardized trajectories of care, gaps in healthcare provider knowledge on recent recommendations for mTBI

rehabilitation,[24] and increases in mTBI diagnoses.[25] Accordingly, innovative ways of providing rehabilitation are necessary to improve access to care, which may improve outcomes.

Timely, individualized rehabilitation is recommended for individuals with persisting symptoms following an mTBI.[22, 26, 27] However, stronger evidence is necessary to support rehabilitation on it's own.[28] Previous literature[28] states that one of the difficulties in providing evidence to support rehabilitation independently as a form of treatment is the variation between studies, eliminating the possibility of performing meta-analyses. However, the variation between studies may be a natural consequence of the variability of patients' symptoms following an mTBI, and an indicator of the importance of clinical judgement and therapies based on patients' individual needs.

Virtual rehabilitation may be an appropriate option for improving access to care. Virtual rehabilitation, or telerehabilitation, refers to using applications based on, or enhanced by, technology to improve human health and function.[29] Benefits of virtual rehabilitation may include improved attendance, decreased wait times for care,[30] and improved access to care.[13] Virtual rehabilitation has resulted in similar outcomes to in-person care in a variety of rehabilitation contexts, such as stroke,[31] COVID-19,[32] and knee osteoarthritis.[33] Furthermore, preliminary data indicates virtual rehabilitation may be beneficial for brain injury populations,[34, 35] but evidence is mixed.[36, 37] Additionally, virtual rehabilitation may improve timely access to care for those in rural areas, without incurring the usual travel cost associated with seeing a healthcare provider with expertise in mTBI.[13]

1.4 Interdisciplinary mTBI Services

Interdisciplinary care is recommended for people living with persisting symptoms for more than one month following an mTBI,[22, 27] which may include a multitude of care providers (e.g., physiotherapists, occupational therapists, speech and language pathologists, athletic therapists, social workers and physiatrists).[27] However, rehabilitation for an mTBI from multiple healthcare providers simultaneously is infrequently explored. The limited evidence available typically evaluates individuals receiving treatment from several different providers individually over the same period of time, with some evidence of effectiveness.[38, 39] But this approach using concurrent but independent rehabilitation is burdensome. For example, the coordination of multiple appointments per week, travel, and independent work outside of rehabilitation time may result in increased cognitive load and accordingly increased symptoms.[40] Therefore, rehabilitation needs must be prioritized for these individuals. Another option is combined rehabilitation, in which rehabilitation providers from different fields work together to deliver combined

therapy. These healthcare providers can then work together to prioritize patients' tasks and provide exercises that enable improvements in multiple areas, such as headaches, sleep disorders, anxiety, or depression.[22, 27]

Physiotherapists are the most commonly accessed rehabilitation providers by individuals with persisting symptoms following an mTBI.[41, 42] They have the expertise to assess and create individualized rehabilitation programs, and specialize in identifying and treating neuromuscular, cardiopulmonary-vascular and musculoskeletal impairments,[43] which are commonly experienced by individuals with an mTBI.[27, 44, 45] Physiotherapists are experts in prescribing exercise for rehabilitation, which is more beneficial than usual care for individuals with an mTBI.[46, 47] Additionally, physiotherapists provide vestibular rehabilitation,[48] and vestibular symptoms are often a complaint following an mTBI.[5]

Physiotherapists and occupational therapists have many overlapping scopes of practice,[49] which may facilitate interdisciplinary communication. Occupational therapists assess, treat and work to prevent disorders that impact function or adaptive behaviour.[50] Occupational therapy may be an appropriate component of mTBI rehabilitation,[22] as daily occupations provide meaning and help individuals understand their new identity following their injury.[51] Additionally, occupational therapists can roster for the controlled act of Psychotherapy,[50] which may be beneficial for individuals with persisting symptoms following an mTBI.[52] Physiotherapy and occupational therapy are both recommended components of mTBI rehabilitation.[27] Accordingly, co-treatment sessions following a brain injury may be appropriate as it may promote cooperation and timely feedback among practitioners.[53]

All practitioners need to provide individualized, patient-centered care for everyone.[22, 26] Physiotherapists and occupational therapists are expected to practice patient-centered care as it is a core competency among both professions.[43, 50] Patient-centered care should include patient individuality, empowerment, respect, empathy, biopsychosocial care, communication, and shared decision-making.[54] When implemented, patient-centered care improves patient's knowledge and skills for treating their health condition, enhances satisfaction and quality of life, and reduces admissions and re-admissions.[55]

1.5 Patient-Centered Goal Setting

Patient-centered care facilitates collective goal setting,[56] which is an essential component of rehabilitation for any health condition.[57] However, goal setting practices in rehabilitation vary.[58] This can result in inconsistent patient involvement and therefore clinician-dominated approaches.[59] This is

especially problematic with the mTBI population, when symptoms and needs can vary greatly from one individual to the next. Patient-centered goal setting is a recommended outcome measure following a brain injury[60] as attaining patient-identified goals is associated with increased well-being.[61] Motivational interviewing may be an appropriate strategy for clinicians to determine patient-centered goals.[62] Motivational interviewing may also be an appropriate goal setting method for individuals with persisting symptoms following an mTBI,[63] but further study in this population is needed. We are unaware of any goal-setting protocols that are specifically created for the mTBI population and implemented by occupational therapists or physiotherapists.

The Canadian Occupational Performance Measure (COPM) was created by a group of Occupational Therapists to detect change in self-reported occupational performance over time.[64] It helps clinicians identify problem areas in occupational performance, evaluates performance and satisfaction relative to the patient's problem areas, provides a basis for goal setting, and measures change in the patient's performance and satisfaction over time. When completing the COPM, patients rate their perceived performance and satisfaction of each self-identified goal on a 10-point scale. The COPM has adequate clinical utility,[65] reliability, and content and construct validity.[66, 67] Although the minimal clinically important difference of the COPM has generally been accepted as 2 points, this is not empirically supported.[68] The COPM has been used to identify and evaluate goals in acquired brain injury populations,[69] but it should be used in combination with other outcome measures to correctly interpret the results.[66] For instance, anxiety can influence self-satisfaction ratings, and therefore should be considered when evaluating the results.

1.6 Assessing Persisting Symptoms Following an mTBI

A patient's rehabilitation can be evaluated with standardized subjective and objective outcomes. Objective outcomes are based on observable and quantifiable information from someone other than the patient, and do not consider the patient's experience.[70, 71] As mTBI diagnoses are clinical, objective assessments should be used to supplement symptom reporting and assist with assessing clinical recovery.[26] These assessments can include tests for vital signs, mental status, neurological exams (including cranial nerve assessments, manual muscle testing/reflexes), head and cervicothoracic exams, postural control and motor coordination, vestibular-ocular exams, and ocular/ophthalmic exams.[72] A number of specific exams have been recommended for assessing different aspects of mTBI rehabilitation, including the Buffalo Concussion Treadmill Test for cardiovascular performance,[27] Balance Error

Scoring System for balance,[73] and the Vestibular/Ocular Motor Screening assessment for vestibular and ocular functioning.[26]

Subjective outcomes (patient-reported outcome measures) support patient-centered care, and are the gold standard for evaluating patient's thoughts, feelings, and complaints about their health condition.[74, 75] Although there are many definitions of subjective outcomes,[71] they are defined in this thesis as a measurement of the patient's own health and are only known to the patient.[74] These outcome measures are typically survey instruments that can be implemented electronically or on paper, and can be administered with the help of the clinician.[74] The survey is typically in a rating scale format, and the patient's responses result in a quantitative assessment of the topic. All outcome measures need to be assessed for reliability and validity.

Many different subjective measures have been recommended for assessing mTBI rehabilitation. The Rivermead Post-Concussion Symptom Questionnaire (RPQ)[76] and Post-Concussion Symptom Scale[77] are recommended to evaluate and monitor symptoms following a concussion.[27] The RPQ demonstrates good test-retest reliability and validity three months post injury,[78] but the total Post-Concussion Symptom Scale score demonstrates low reliability four weeks following an injury.[79] The Patient Health Questionnaire 9-Item Scale (PHQ-9)[80] is recommended to screen for depression, and the Generalized Anxiety Disorder 7-Item Scale (GAD-7)[80] is recommended to screen for anxiety following an mTBI. Both the PHQ-9 and GAD-7 are validated screening instruments.[81, 82] Fatigue is difficult to assess as there are many different aspects of fatigue that can be evaluated (e.g., trait, state, physical, cognitive). Although current concussion guidelines recommend using the using the Barrow Neurological Institute Fatigue Scale or the RPQ[22, 84] to assess fatigue, the guidelines do not provide recommendations for assessing different aspects of fatigue. Accordingly, other standardized fatigue assessments may also be appropriate (e.g., the Fatigue Severity Scale and the Modified Fatigue Impact Scale).[85] The Barrow Neurological Institute Fatigue Scale and Modified Fatigue Impact Scale have been validated in the brain injury population,[86, 87] but to our knowledge, the Fatigue Severity Scale has not.

1.7 Thesis Rationale and Purpose

Rehabilitation for persisting symptoms following an mTBI requires timely individualized services that can appropriately treat the broad scope of symptoms that mTBI patients present with. However, long wait times for care, combined with increasing rates of mTBI, present a challenge for timely access to care. Innovative rehabilitation practices may be a solution to this challenge. One way to provide timely,

innovative rehabilitation is providing combined interdisciplinary care, which could reduce the number of treatment sessions a patient needs to attend per week, potentially reducing symptom exacerbation caused by increased cognitive demand.[40] As physiotherapy and occupational therapy demonstrate many overlapping practices,[49] it may be beneficial for individuals with persisting symptoms following an mTBI to receive treatment from both disciplines simultaneously.

Identifying individuals that have increased/decreased odds of improving from a particular treatment is another way to promote timely access to care. As individuals with persisting symptoms following an mTBI should receive evidence-informed care,[22, 27] it is important for them to understand their odds of benefiting from a particular treatment. In having all the information necessary to make an informed decision, individuals with an mTBI can select treatment that is right for them early in their recovery. Accordingly, wait times for treatment may decrease as patients attend fewer treatment sessions and different types of rehabilitation in a desperate effort for recovery.

Virtual rehabilitation may also promote timely, innovative access to care. Although virtual rehabilitation for many health conditions has increased following the COVID-19 pandemic, there has been limited investigation into the mTBI population receiving virtual rehabilitation. Furthermore, it is unclear whether these individuals demonstrate differences in outcomes following virtual treatment compared to completing in-person rehabilitation. If there are no differences in outcomes between virtual and in-person rehabilitation, then virtual rehabilitation may be an appropriate rehabilitation option for individuals with an mTBI.

Therefore, the overall purpose of this thesis was to investigate treatment outcomes of individuals with persisting symptoms following an mTBI after completing BrainEx90, a combined outpatient physiotherapy and occupational therapy rehabilitation program. Specifically, we were interested in the following three aims:

Aim 1: Investigating whether completing the interdisciplinary outpatient rehabilitation intervention, or the choice of specific goal types, influenced performance and satisfaction ratings of these goals. Additionally, we were interested in determining the number and types of rehabilitation goals chosen by participants.

Aim 2: Evaluating whether prognostic factors associated with persisting symptoms following an mTBI influence participants' responses to a combined physiotherapy and occupational therapy rehabilitation program.

Aim 3: Comparing patient outcomes between participants that completed the rehabilitation program virtually and in-person. Additionally, we wanted to investigate differences in outcomes between virtual and in-person rehabilitation participants based on sex.

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Chapter 2

2 Completing an interdisciplinary outpatient intervention improves patient rehabilitation goals for individuals with persisting symptoms following a mild traumatic brain injury

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2.1 Introduction

Traumatic brain injury (TBI) is one of the leading causes of death and disability in North America,[1] with mild traumatic brain injury (mTBI) accounting for 70-90% of all TBIs.[2] Furthermore, one in every 200 Canadians reported that a brain injury was their most disabling injury in 2014.[3] In Ontario (population of 13.5 million people[4]), the high incidence of brain injuries contributes to approximately $110 million dollars spent annually on tertiary mTBI care.[5] Considering the large number of individuals with mTBIs, combined with the large economic cost on a publicly funded healthcare system, new and innovative rehabilitation interventions are needed.

Group rehabilitation interventions may help reduce the economic cost associated with mTBIs and increase the number of patients a clinician can treat in a day. Group-based interventions are recommended to promote psychosocial rehabilitation following a moderate to severe TBI,[6] but we are not aware of any recommendations for individuals with an mTBI. It is also recommended that individuals with any level of TBI have access to individualized care.[7, 8] Therefore, group rehabilitation interventions with customizable activities can provide individualized care that may benefit individuals with an mTBI.

Rehabilitation following a brain injury also improves with expertise from a variety of healthcare practitioners, meaning interdisciplinary teams are appropriate[6, 9] and are becoming more common.[10] Interdisciplinary clinics may improve functional gains and reduce hospital stay following acute brain injuries,[11, 12] and may reduce persisting symptoms.[13] Furthermore, interdisciplinary collaboration, in this case physiotherapy and occupational therapy, may benefit individuals with an mTBI. Combined physiotherapy and occupational therapy may be beneficial because of the intersections of their scope of practice.[14] Additionally, these different allied healthcare practitioners can work together to overcome

common mTBI symptom and rehabilitation challenges, including creating innovative interventions and promoting patient-specific rehabilitation.[15]

The Canadian Occupational Performance Measure (COPM) is a client-centered measure that detects change in a client's occupational performance.[16, 17] The COPM is administered through a semi-structured one-on-one interview to identify patient's occupational goals and self-rated goal performance and satisfaction.[16] The occupation-related goals identified on the COPM, (e.g., activities of daily living, social activities, employment-related tasks, and studying) are categorized into three types: leisure, productivity, and self-care.[18] The COPM has adequate reliability, construct[19] and content validity,[20] and clinical utility.[21] It has successfully demonstrated change in goal performance and satisfaction ratings following intervention for people living with stroke,[22] cerebral palsy,[23] and brain injury.[19, 24, 25]

The purpose of this study was to evaluate change in patient-reported goal performance and satisfaction in adults with persisting symptoms following an mTBI after completing an interdisciplinary group rehabilitation intervention. The first objective was to determine the number and types of rehabilitation goals chosen by participants. The second objective was to investigate whether completing the interdisciplinary outpatient rehabilitation intervention, or choosing specific types of goals, influenced performance and satisfaction ratings of these goals.

2.2 Methods

2.2.1 Participants

Adults who successfully completed the BrainEx90 interdisciplinary outpatient intervention at Parkwood Institute in London, Ontario, Canada between November 2013 and September 2019 were included in this study. Inclusion criteria included individuals that were referred to BrainEx90, were diagnosed with an mTBI, were 18 years of age or older, were not seeking third party service funding, could tolerate group settings, and could attend at least twelve of the sixteen 90-minute sessions at Parkwood Institute. This study was approved by the Health Science Research Ethics Board at the University of Western Ontario and Lawson Health Research Institute.

2.2.2 Procedure

The physiotherapist and occupational therapist who performed initial and discharge assessments were the same clinicians who performed the intervention and obtained consent for researchers to collect

participant assessment data. An occupational therapist administered the COPM as part of their initial and discharge assessment. Participants were asked to identify up to six goals and rate their perceived performance and satisfaction for each goal on a 10-point scale. Assessments were performed approximately one week before participants' first BrainEx90 session and approximately 4-6 weeks following their final BrainEx90 session. Each 90-minute BrainEx90 session comprised 70-minutes of circuit training, including 5- or 10-minute stations that addressed common impairments in cognition, balance, endurance, vision, vestibular function, and self-management. The physiotherapist or occupational therapist tailored station activities to each participant's needs/abilities during each session. Each session also included a 20-minute education section on recovery-related topics, such as anxiety, nutrition, and mindfulness. The physiotherapist and occupational therapist provided weekly homework to participants, and progressed activities for each station, as appropriate for each session. A full description of the BrainEx90 protocol is provided elsewhere.[26]

Independent assessors performed a chart review of BrainEx90 assessments to collate de-identified demographic, goal, performance and satisfaction rating information for each participant. Assessors independently categorized goals as productivity, self-care, or leisure using defined descriptions.[16] A trained registered occupational therapist, who assessed BrainEx90 participants, reviewed goal categorizations when assessors did not reach agreement.

2.2.3 Data Analysis

Descriptive statistics were performed to characterize gender, age, time from injury to referral, and time from injury to starting the intervention. The interrater reliability of the initial categorization for each goal type (productivity, self-care, and leisure) between the two researchers was assessed using Cohen's kappa. Agreement was interpreted as slight (0.01-0.20), fair (0.21-0.40), moderate (0.41-0.60), substantial (0.61-0.80), and almost perfect/perfect (0.81-1.00).[27]

A linear mixed effects model was used to predict patient-reported performance and satisfaction based on time (pre and post BrainEx90) and goal type (productivity, self-care, and leisure). This model investigated whether time, specific rehabilitation goals, or a combination of time and goal type, best predicted participants' goal performance and satisfaction ratings after completing BrainEx90. Time and goal type were entered as fixed effects. Participant was the random effect as it was expected that each participant would respond variably to the intervention. Main effect and interaction terms were described using Type III Wald F tests with Kenward-Roger estimation of degrees of freedom, and the Tukey

method for controlling multiple comparison bias was applied within post-hoc testing. All statistical analyses were completed using R (R Core Team 2019), with mixed effects models evaluated using the lme4[28] and car[29] packages. Post-hoc analyses were conducted using the emmeans[30] package, and comparisons were assessed using an experiment-wise alpha of 0.05.

2.3 Results

A total of 217 participants were included in this study. Most participants were female (71%), and the average age was 44.4 (± 13.5 years). The average length of time from injury to referral was 137.2 days (range of 1 to 4800 days), and the average length of time from injury to starting the intervention was 766.5 days (range of 162 to 5066 days). Most injuries occurred from a fall (35%), followed by hitting their head (24%), playing sports (20%), motor vehicle collision (16%), assault (4%), and one non-traumatic brain injury (<1%). The mechanism of injury for one participant was unspecified.

There were 1008 goals identified; 457 (45%) were categorized as productivity, 371 (37%) were leisure and 180 (18%) were self-care. Interrater reliability estimates for leisure, productivity, and self-care were almost perfect (κ= 0.87), substantial (κ= 0.62) and moderate (κ= 0.52), respectively. Participants generally rated pre- and post-BrainEx90 goal performance higher than goal satisfaction (3.2 ± 1.8 versus 1.9 ± 1.6, and 5.5 ± 2.2 versus 5.0 ± 2.8, respectively). Individual satisfaction and performance ratings for each goal type are presented in Table 1.

Table 1. Mean pre- and post-BrainEx90 goal ratings, using the Canadian Occupational Performance Measure ten-point scale. One represents not able to do at all/not at all satisfied, and ten represents able to do extremely well/extremely satisfied.

	Performance		Satisfaction	
Goal Type	**Pre-BrainEx90 Mean Rating (Standard Deviation)**	**Post-BrainEx90 Mean Rating (Standard Deviation)**	**Pre-BrainEx90 Mean Rating (Standard Deviation)**	**Post-BrainEx90 Mean Rating (Standard Deviation)**
Leisure	3.0 (2.1)	4.7 (2.2)	2.2 (1.6)	3.8 (2.0)
Productivity	2.7 (1.9)	4.6 (2.9)	2.4 (2.0)	4.2 (2.9)
Self-Care	4.3 (1.9)	6.6 (2.3)	2.2 (1.7)	5.9 (3.4)

Goal performance was better predicted by the significant main effects of goal type ([leisure, productivity, and self-care; [$F(2,152) = 14.18$, $p < .01$]) and time (pre and post BrainEx90; [$F(1,141) = 37.73$, $p < .01$]). The interaction between goal type and time was not statistically significant ([$F(2,141) = 0.46$, $p = .63$]; Table 2). Post-hoc testing of the main effect of goal type revealed that self-care ratings [5.5, 95% CI (4.9, 6.0)] were significantly higher than leisure [3.9, 95% CI (3.2, 4.6), $t(158) = 3.86$, $p < .01$], and productivity ratings [3.6, 95% CI (3.0, 4.2), $t(146) = 4.98$, $p < .01$], with no statistically significant difference demonstrated between leisure and productivity ratings. Ratings of all goal types improved beyond the optimal cut-off value of 0.9.[31]

Goal satisfaction was best predicted by the significant interaction of goal type (leisure, productivity and self-care) and time (pre and post BrainEx90; [$F(2,141) = 3.63$, $p = .03$]), illustrated in Table 2. Before BrainEx90, there were no statistically significant differences between satisfaction ratings of leisure [2.2, 95% CI (1.2, 3.2)], productivity [2.4, 95% CI (1.5, 3.2), $t(149) = 0.34$, $p = .94$], or self-care goals [2.2, 95% CI (1.4, 3.0), $t(151) = 0.08$, $p = .99$], nor was there a difference between productivity and self-care goals [$t(144) = 0.29$, $p = .95$]. After BrainEx90, however, satisfaction with self-care goals [5.9, 95% CI (5.1, 6.7)] was rated significantly higher than satisfaction with leisure goals [3.8, 95% CI (2.8, 4.8),

t(151) = 3.24, $p < .01$] and productivity goals [4.2, 95% CI (3.3, 5.0), t(144) = 2.97, $p < .01$]. No significant rating difference was demonstrated between leisure and productivity goals [t(149) = 0.54, p = .85]. Goal satisfaction for all three goal types demonstrated a statistically significant improvement over time. Ratings of all goal types improved beyond the optimal cut-off value of 1.45.[31]

Table 2. Linear-mixed effects model results evaluating the effects of time (pre- and post-BrainEx90) and goal type (leisure, productivity, and self-care) on change in Canadian Occupational Performance Measure ratings.

Performance			
	F Statistic	**Degrees of Freedom**	***p* Value**
Goal Type	14.18	2	<0.01*
Time	37.73	1	<0.03*
Goal Type by Time	0.46	2	0.63
Satisfaction			
Goal Type	3.19	2	0.04*
Time	43.75	1	<0.01*

2.4 Discussion

Participants in the BrainEx90 intervention selected productivity goals more often than leisure or self-care goals. Mean performance and satisfaction ratings were low before and after the intervention, but improved following BrainEx90. Participant's productivity, leisure, and self-care satisfaction ratings, and performance ratings, demonstrated statistically significant improvements after completing the intervention. Performance and satisfaction ratings of all goal types demonstrated clinically meaningful improvement following the intervention, however, satisfaction ratings of self-care goals were significantly greater than leisure or productivity satisfaction ratings. These results support implementing

interdisciplinary group interventions with customizable activities for adults with persisting symptoms following an mTBI to address patient-identified goals.

Self-care goals were the least frequently selected goals, which may reflect certain characteristics of our participant population. For example, BrainEx90 is an outpatient rehabilitation intervention, so participants were likely higher functioning and had fewer self-care activity limitations compared to individuals in an inpatient intervention. Participants in this study mainly identified productivity goals, which is consistent with previous mTBI research in participants with persisting symptoms.[32] The average participant age in this study (44 years) falls within the highest Canadian employment age range (15-64 years[33]), so our participants may have been focused on productivity goals related to employment. Furthermore, our participants' emphasis on productivity goals may be related to the importance of productivity or returning to work after a brain injury due to feelings of loss, lack of socialization or normalcy, or a change in personal identity.[34]

Although productivity goals were the most frequently chosen goals, the largest improvements were reported for self-care goals. Similar to the results of a pain management study,[35] self-care goals may have improved more than productivity goals because BrainEx90 may be better suited to improve self-care goals. Alternatively, self-care goals may be considered more rudimentary than productivity goals, as they are often performed at home or in a quiet environment. As productivity goals may be more complex and provoke more symptoms than self-care goals, participants may have successfully completed self-care goals earlier in their rehabilitation than productivity goals, resulting in higher satisfaction ratings. Accordingly, participants with productivity goals may benefit from an increased focus on productivity-related skills in the BrainEx90 intervention, may require more time in the intervention, or may benefit from additional specialized rehabilitation targeting any underlying symptoms that may be inhibiting participants from achieving their goals. Further research is necessary to explore these hypotheses before intervention modifications are made.

Participants reported clinically meaningful improvements in performance and satisfaction ratings on all goals. Goal satisfaction, but not goal performance, significantly differed between goal types. Improvements in satisfaction may reflect a change in participants' expectations for recovery and rehabilitation,[32] possibly indicating a response shift.[36] Response shift refers to a change in someone's self-evaluation of a construct, and can be the result of someone recalibrating their internal scale, changing their values, or changing the target construct.[37] Participants in the current study identified goals

before the BrainEx90 intervention and reassessed the same goals following the intervention, which eliminated the possibility of altering the target construct. However, the education provided in our intervention may have promoted realistic recovery expectations and increased self-awareness,[38] possibly recalibrating participants' goal satisfaction scale. Further research is necessary to evaluate whether a response shift may contribute to changes in goal performance or satisfaction ratings, and if said response shift is influenced by goal type.

Participants in this study were over two years post-injury on average, although their time from injury to referral was less than six months. The average wait time for specialized tertiary care following an mTBI in Ontario is seven[39] to ten[5] months post-injury. However, these wait times are based on services provided by private practices or fee-for-service providers. Parkwood Institute's Acquired Brain Injury Outpatient Program is one of only a few publicly funded interdisciplinary brain injury rehabilitation programs in Ontario. Additionally, the incidence of mTBI's has steadily increased since 2005, with one in every 200 Canadians experiencing one.[3] Increased incidence without increased funding or number of specialized services may have contributed to long wait times. Importantly, our participants were more than two years post injury (i.e., chronic), and therefore our findings may not be generalizable to individuals with acute injuries.

This study builds on the evidence supporting the implementation of interdisciplinary group rehabilitation interventions for adults with persistent symptoms post-mTBI by providing evidence of improved goal performance and satisfaction. However, this study is not without limitations. Without a control group, maturation effects caused purely by the passage of time may have occurred.[40] Accordingly, we cannot be certain that our intervention caused the observed changes in goal satisfaction and performance. However, spontaneous recovery was unlikely given the average time from injury to starting the BrainEx90 intervention was more than two years, and most individuals with an mTBI recover within the first year of injury.[41] Desirability bias may have also been a factor, where the occupational therapist administering the COPM was one of two occupational therapists who provided the intervention. Lastly, 71% of the participant population was female. Although males have a higher incidence of mTBI,[42] females have a worse prognosis following their injury,[7] and are more likely to seek outpatient therapy following a TBI.[43] Therefore, our sex ratio is relatively consistent with clinical presentation. Future studies should explicitly attempt to recruit male participants to balance the sample demographics, and rigorously investigate the impact of sex on these results.

2.5 Conclusion

Productivity rehabilitation goals were the most commonly selected goal type. Goal performance and satisfaction significantly improved over time, but change in self-care satisfaction ratings improved more than satisfaction ratings with leisure and productivity goals. While we cannot rule out maturation and response shift biases, our participants were in the chronic phase of recovery following an mTBI, so we would not expect marked spontaneous improvement to explain these pre-post BrainEx90 changes. Other organizations may benefit from implementing interventions similar to BrainEx90 for individuals with persisting symptoms following an mTBI as it significantly improves performance and satisfaction ratings of participant-identified rehabilitation goals.

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Chapter 3

3 Baseline scores do not identify individuals that experience clinically important improvements in goal satisfaction after completing an interdisciplinary mTBI rehabilitation program

A version of this manuscript has been submitted to the Journal of Concussion for publication.

3.1 Introduction

Every year, approximately 56 million people worldwide experience a mild traumatic brain injury (mTBI), of which 80% fully recover within eight weeks of their injury.[1] The remaining 20% of individuals experience persisting symptoms and often have difficulties or an inability to return to pre-injury daily activities, including leisure, home, and work/school-related activities.[2] For instance, only half of individuals that sustain an mTBI return to work within one month following their injury, and 80% return by six months.[3] Financial burden of an mTBI may be described by the wage loss due to time off work or through estimated health care provider costs, where adults with persistent symptoms are often referred for medical and allied health services in outpatient hospital departments or community care settings.[4] A Canadian study of a sample of adults with an mTBI referred to an outpatient head injury clinic estimated 30-37 health care visits per person over a year, or $3000 per person.[5] A New Zealand study of a sample of adults with TBI estimated a cost of $983 USD per person with an mTBI more than matched controls over a 6 month period.[6] Authors in both studies highlighted the difficulty of estimating true burden given variation of tracking methods across centers, and variation in access to private versus publicly-funded services. Yet another study suggested that a person's symptoms might impact health care provider costs: Cogan et al.[7] concluded that health care provider costs (including physician, physiotherapy, occupational therapy and others) for people with an mTBI presenting with chronic vestibular impairment were 51% higher when compared to individuals with an mTBI without vestibular symptoms. Considering the economic burden of mTBI's, effective and evidence-informed rehabilitation is imperative, particularly for those with persisting symptoms.

Several studies have evaluated factors that predict individuals who will develop persisting symptoms following an mTBI.[8-11] Female sex,[8, 11] older age,[9, 11] less education,[9] increased number/severity of symptoms, increased days since injury,[12] and the presence of baseline or post-injury anxiety/mental illness[8, 11] are associated with an increased risk of persisting symptoms following an mTBI. However,

there is mixed evidence to support mechanism of injury as a predicting factor. For example, Silverberg et al.[8] and Theadom et al.[11] did not support mechanism of injury as a predicting factor, but injury from an assault was deemed significant by Lingsma et al.[9] Although all the preceding factors have been evaluated for their influence on developing persisting symptoms, they have not been evaluated regarding their impact on rehabilitation outcomes. Ability to predict who is likely to improve with rehabilitation could support care prioritization and care coordination, which may in turn improve cost- effectiveness. For example, a Canadian study evaluated healthcare economics of a sample of 335 adults with an mTBI referred to an outpatient head injury clinic between 2014 and 2015. These authors studied healthcare visit types (including family physicians, physiotherapy, occupational therapy, social work, and others), intensity, and cost, and estimated an excess of $500,000 Canadian dollars were spent over the year the sample was studied.[5]

Current management guidelines for persistent symptoms following an mTBI recommend timely, evidence-based interdisciplinary care,[13] however there are no recommendations on how to implement this care. Furthermore, it can be difficult to provide all necessary services as patient's appointments need to be scheduled in a way that balances convenience, yet considers symptom-moderated gradual activity resumption.[13, 14] Interdisciplinary group therapy is an alternative treatment option, where patients receive rehabilitation from more than one allied healthcare provider simultaneously, potentially reducing health care visits. A scoping review found that group rehabilitation may be widely used in TBI outpatient care settings, and that group treatment may provide emotional support, socialization, and peer learning opportunities.[15] The review highlighted that existing studies primarily assessed impairments, did not compare group treatment to control or one-to-one services, and did not assess "real-world" activities or participation goals, and analyses did not support notions of who may be best suited for group programming.[15]

Understanding change in participant-centered goals is important because successful goal attainment is associated with improved feelings of well-being following a brain injury,[16] and using participant-centered goals is a recommended rehabilitation outcome measure following a brain injury.[17] Preliminary data from the combined occupational therapy and physiotherapy group program sampled in this study demonstrated participants significantly improved their perceived performance and satisfaction with self-identified goals after completing the intervention.[18] The purpose of this study was to evaluate whether prognostic factors associated with persisting symptoms following an mTBI influenced participant's goal satisfaction following participation in a combined physiotherapy and occupational therapy group intervention.

3.2 Methods

3.2.1 Participants

The study sample was recruited from an outpatient brain injury program in southwestern Ontario, Canada. BrainEx90 is a combined physiotherapy and occupational therapy group intervention available to patients accepted to the Outpatient Acquired Brain Injury (ABI) Program at Parkwood Institute in London, Ontario, Canada. The Outpatient ABI Program offers physiatry, physiotherapy, occupational therapy, speech-language pathology, and social work. The ABI Program accepts referrals from physicians, nurse practitioners, physiatry, neurosurgery, and neuropsychology; if a patient is over the age of 18, has experienced a brain injury within 2 years of the referral date, does not have access to third party funding for health care services, and has a diagnosis of a brain injury. ABI Program patients are offered to participate in BrainEx90 if they have a mild brain injury, and can tolerate or would be appropriate in a group treatment environment. Patients with moderate-severe ABI who would not tolerate or be inappropriate to treat in a group setting, are offered one-to-one care within the ABI Program; and those with access to third party funding are referred onto the interdisciplinary outpatient intervention that focuses solely on patients whose care is funded through a third-party. All patients who participate in BrainEx90 were offered to participate in this study. Patients who provided written informed consent, and completed a minimum of 12 of 16 BrainEx90 sessions were considered eligible for this study. All study participants completed BrainEx90 between November 2013 and September 2019. This study was approved by the Health Science Research Ethics Board at the University of Western Ontario and Lawson Health Research Institute.

3.2.2 Procedure

Approximately one week prior to a participant's first BrainEx90 session, participants complete an in-person physiotherapy assessment, and an in-person occupational therapy assessment to assess baseline functional abilities, patient-reported symptom severity, and confirm demographic details. Multiple BrainEx90 groups with 7-8 participants each ran throughout the week. Two consistent pairs of clinicians (one physiotherapist and one occupational therapist) led each group. The physiotherapist in one pair (SM), and the occupational therapist in the other pair (BM) are authors on this study and developed BrainEx90. All four clinicians have many years of experience treating adults with persisting symptoms post-mTBI, layered on top of years of experience treating mild and moderate-severe brain injury and stroke. Participants were assigned to the group led by the therapist who completed their assessment. Each

BrainEx90 group was one 90-minute session per week for 16 weeks. Each 90-minute session consisted of 40 minutes of circuit training, 20 minutes of group education, and then 30 minutes of circuit training. Circuit training required participants to rotate through stations that focused on self-management, rest, cognition, balance, exercise tolerance, vision, or vestibular function. The therapists leading the session would tailor the activity to the participant's needs or abilities (e.g., if the balance station activity that day was single leg stance, the physiotherapist might decide to increase challenge by adding eye/head movement, foam surface, or closed eyes; the self-management station was led by the occupational therapist who would tailor the discussion to a topic of strategy applicable to the participant); and/or therapists would decide whether a participant would circulate through 1 or 2 rest stations, and 1 or 2 dynamic balance/exercise tolerance stations during the circuit training portions of the session. Circuit stations are within close proximity, allowing interaction between participants. All participants participated in the group education session at the same time. Each week covered a different topic, e.g., mindfulness meditation, strategies for attending special events, planning and pacing activity for symptom management, and were led by the physiotherapist, occupational therapist, or another team member as appropriate (e.g., social worker on coping). Each participant was invited to share their views or comments with the group during these sessions.

3.2.3 Measures

Demographic information, including age, sex, days since injury, level of education, and mechanism of injury were collected upon admission to the interdisciplinary outpatient acquired brain injury rehabilitation intervention. Education was categorized as less than high school, high school diploma or high school diploma equivalency certificate, college or general and vocational college (CEGEP) or non-university certificate or diploma, bachelor's degree, graduate or professional degree, or unknown. Mechanism of injury was categorized as motor vehicle accident, fall, sports-related, hit head, assault, and non-TBI (e.g., stroke).

During the baseline assessment, the occupational therapist administered the Canadian Occupational Performance Measure (COPM)[19] with each participant. In completing the COPM, participants identified a maximum of six goals and rated their perceived performance satisfaction (COPM-S), and perceived performance (COPM-P) of each goal on a scale of 1 (not satisfied) to 10 (extremely satisfied). Participants' baseline mTBI symptom severity was assessed using the Rivermead Post-Concussion Symptoms Questionnaire (RPQ).[20] The RPQ is a 16-item questionnaire assessing perceived severity of

common brain injury symptoms (e.g., headache, depression, fatigue, etc.) on a five-point Likert scale, where higher scores indicate greater symptom severity. RPQ modified scoring system was used, where the RPQ score was divided into two sub-scores for analysis: headache, nausea, and dizziness made up RPQ3 and remaining symptoms made up RPQ13[21]. This modified scoring system has demonstrated improved psychometric properties over using a single summary score[18]. Participants' baseline anxiety was assessed using the 7-Item Generalized Anxiety Disorder Scale (GAD-7).[22] Scores can range from 0-21, where higher scores indicate increased anxiety.[22] Four to six weeks following their last group session, participants re-rated their perceived satisfaction with each previously identified goal (COPM-S).

3.2.4 Analysis

Binomial logistic regression was performed to identify which participants were more likely to clinically improve after completing the combined physiotherapy and occupational therapy group program. Clinical improvement was defined as a two or more point increase in their COPM scores;[19] those that did not improve demonstrated less than a two-point increase. Change in COPM-S score was the binomial dependent outcome selected a-priori instead of both COPM-S and COPM-P, because change in both was found to have significantly improved in this sample.[18]

Independent variables in the regression analysis included age, sex, days since injury, baseline COPM score, education, number of sessions, mechanism of injury, RPQ3 score, RPQ13 score, and GAD7 score. Sample-based multicollinearity was assessed by evaluating the univariate correlations between predictor variables. If the initial full model determined an independent variable was not statistically significant, the variable was omitted from the regression model, and the parsed model was rerun. Bootstrapping was used to assess the generalizability of the final model[23] using the area under the receiver operator curve (ROC).[24] Linearity was assessed using a Box-Tidwell procedure with a Bonferroni correction, where $p = 0.005$, as there were ten independent variables.[25] All analyses were performed using R (R Core Team, 2019), with binomial logistic regression performed using lme4.[26]

3.3 Results

A total of 198 adults (44.7 ± 13.6 years old) were included in this study, and 73% (144 participants) were female. The average time since injury to starting the group intervention was 782 (± 598.6 days), and on average participants attended 16.2 sessions (± 4.3 sessions, range of 12-32 sessions). This variance was

attributed to some participants missed sessions, for example, due to illness or holiday, while some participants attended additional sessions. Additional information characterizing the sample is described in Table 3.

Table 3. Sample demographics (n=198).

Variable	Mean (Std Dev)	N(%)
Age	44.7 (13.6)	
Female	44.1 (14.1)	
Male	46.2 (12.4)	
Sex		
Female		144 (73)
Male		54 (27)
Days since injury	782 (598.6)	
Education		
Less than high school		11 (5.6)
High school diploma or equivalent		36 (18.2)
College or equivalent		74 (37.4)
Bachelor's degree		62 (31.3)
Graduate or professional degree		14 (7.1)
Unknown		1 (0.5)
Mechanism of Injury		
Motor vehicle collision		31 (15.7)
Fall		72 (36.4)
Sport-related injury		42 (21.2)

Hit their head		44 (22.2)
Assault		8 (4.0)
Other		1 (0.5)
Number of completed sessions	16.2 (4.3)	
RPQ-3	6.6 (2.3)	
RPQ-13	30.7 (10.3)	
GAD-7	10.2 (7)	
Baseline COPM-S	8.8 (4.8)	

3.3.1 Logistic Regression

One hundred and eighty-three individuals (92%) clinically improved their COPM-S score after completing the group intervention. The univariate correlations between predictor variables were all less than .32 except for between RPQ3 and RPQ13 (r = .57) and between GAD7 and RPQ13 (r = .51). Initial logistic regression, including age, sex, days since injury, baseline COPM score, education, mechanism of injury, number of sessions, RPQ3 score, RPQ13 score, and GAD7 score indicated that baseline COPM-S score was the only significant factor (p = .02; Table 4). Re- evaluation using the COPM-S baseline score as the only independent variable in the logistic regression determined that the COPM-S baseline score was still significant (p = .03), suggesting the association is unlikely due to chance. Specifically, COPM-S baseline score had an odds ratio (OR) of .90 (p = .03, 95% CI .81 to .99), indicating that one-unit increase in the COPM-S baseline scores was associated with .90 times lower odds of change in COPM-S score. This suggests that for each unit increase in the COPM-S baseline score, the odds of the change in COPM-S score decreased by approximately 10%. The odds ratio being less than 1 implies Inverse or negative association between the COPM-S baseline scores and the likelihood of the change in COPM-S score, after adjusting the model. The R-squared value for our logistic regression adjusted model was 11%. This indicates that approximately 11% of the variation in the change in COPM-S score can be explained by the baseline COPM-S score.

The generalizability of the logistic regression model was assessed using bootstrapping with 25 bootstrap samples. The mean area under the ROC across the samples was .57 (95% CI .43-.71), indicating poor discrimination ability.[24] Accordingly, the model using the COPM-S baseline score predicted that every individual would clinically improve their satisfaction with self- identified goals after completing the group intervention. The model was unable to predict individuals who would not clinically improve their satisfaction with self-identified goals after completing the group intervention.

Table 4. Initial logistic regression analysis evaluating possible predictive factors for clinically important improvement on self-identified goals following completion of group intervention.

	Odds ratio	**Standard error**	**Z-score**	***p*-value**	**95% confidence interval**	
Age	1.02	.02	.77	.44	.97	1.06
Sex	2.04	1.28	1.14	.26	.60	6.98
Days since injury	1.00	.00	-1.72	.09	.999	1.00
Education	1.00	.18	-.00	1.0	.70	1.43
Mechanism of injury	.93	.24	-.30	.77	.56	1.54
Number of completed sessions	.93	.05	-1.29	.20	.83	1.04
RPQ-3	1.10	.17	.61	.54	.81	1.50
RPQ-13	.99	.04	-.17	.87	.92	1.07
GAD-7	1.05	.05	1.08	.28	.96	1.16
Baseline COPM-S	.90	.05	-2.35	.02	.80	.98
Constant	17.25	39.91	1.23	.22	.19	1607.85

3.4 Discussion

There is some evidence that pre-injury psychosocial factors, age, gender, education, mechanism of injury, and baseline concussion symptoms may influence the risk of developing persisting symptoms following an mTBI.[8, 9, 12] However, there is limited evidence investigating whether these factors can distinguish between responders and non-responders in mTBI rehabilitation interventions. Accordingly, the purpose of this study was to evaluate whether prognostic factors associated with persisting symptoms following an mTBI are associated with change in participant's goal satisfaction following participation in a combined physiotherapy and occupational therapy group intervention. Age, sex, education, number of days since injury, mechanism of injury, level of education, number of sessions, or baseline RPQ3, RPQ13, or GAD7 scores did not predict individuals who were less likely to improve following participation in the combined physiotherapy and occupational therapy intervention. Although baseline COPM-S scores were statistically significant in the logistic regression, the AUC value indicates baseline COPM-S scores do not predict which individuals will not experience a clinically important increase in satisfaction with self-identified goals. Therefore, these findings do not inform clinical expectations of who is unlikely to benefit from this combined group intervention.

Ninety-two percent of individuals in the combined physiotherapy and occupational therapy program self-reported clinically significant improvements in their COPM-S scores after participating in the intervention. Physiotherapy and occupational therapy are recommended following an mTBI,[13] and are some of the most frequently sought healthcare providers following an mTBI.[4, 5] However, current recommendations do not include co-treatment between physiotherapists and occupational therapists, or between any two healthcare practitioners.[15] This may because it has only recently been adopted, therefore there is little literature evaluating it's efficacy, and it is difficult to quantify.[27] Co-treatment encourages efficient inter-disciplinary communication, improves efficiency, and reduces service duplication.[28] Patient satisfaction with the group intervention is assessed by the ABI Program as part of usual care and quality assurance. Study on patient and practitioner opinions on co-treatment would therefore be a reasonable and valuable topic to explore in the future, and support an existing gap in literature on TBI group rehabilitation.[15]

The results of our study indicate that age, education level, sex, time since injury, mechanism of injury, number of sessions attended, or baseline symptoms, did not predict whether participants would clinically improve their satisfaction with self-identified goals. The results of our study support a previous study that

states baseline RPQ scores did not predict long-term physical or mental health in older adults with an mTBI.[29] However, the results of our study do not seem to align to a similar study that assessed influence of premorbid and baseline characteristics on changes in patient-reported ratings of perceived rehabilitation outcomes (using the Mayo-Portland Adaptability Inventory – Fourth Edition, MPAI-4), in a sample of adults with an mTBI.[30] That study demonstrated that higher Beck Depression Inventory-second edition scores and presence of a psychiatric history predicted poorer MPAI-4 scores at three-month follow up. The difference in results between the previous study and ours may be attributed to the difference in outcome measures, study design, and injury acuity. For example, both the COPM and MPAI-4 are patient- reported measures of perceived rehabilitation outcomes; however, the MPAI assesses a set list of 35 items representing a broad scope of activities, while the COPM assesses goal performance and performance satisfaction with up to six self-selected, meaningful and appropriate activities.[31,19] Secondly, the rehabilitation intervention in that study used a baseline screening process to identify which individual rehabilitation programs would be suitable for the participant, including physiotherapy, occupational therapy, speech therapy, and/or psychological treatment. In contrast, all participants in our study participated in the same combined physiotherapy and occupational therapy intervention, which ensured all participants received both services. Lastly, that study evaluated participants in the acute and post-acute mTBI phase, whereas participants in our study were in the chronic mTBI phase with persisting symptoms (over two years post-injury).

Our model's low R-squared value (11%) indicates that other unknown factors may be missing from the model.[32] Accordingly, these unknown factors may improve predictions of who will not experience change in goal satisfaction. This is an important topic for further exploration, as identifying these factors may help detect individuals who require different care, or areas to improve the current combined physiotherapy and occupational therapy group intervention. Other variables associated with persisting symptoms following an mTBI, including history of mental health conditions,[8] coping strategies,[33] psychological flexibility,[34] and somatization of symptoms[35] should be investigated. Additionally, factors associated with change in chronic pain conditions, including readiness to change[36] and baseline disability[37] should also be evaluated.

Evaluating improvement with different outcome measures may help distinguish between who will or will not improve following participation in the group intervention. Although the COPM has adequate reliability, construct[38] and content validity,[39] and clinical utility,[40] other outcome measures may also be appropriate depending on how one assesses improvement. For instance, the Quality of Life After Brain

Injury scale (QOLIBRI) assesses health-related quality of life according to abilities, emotions, function in daily life, social relationships, and how feelings and physical limitations bother the respondent. The QOLIBRI demonstrates adequate reliability in English and excellent internal consistency.[41] This measure may be appropriate in garnering a holistic assessment of participant response to treatment. Additionally, outcome measures assessing impairments or limitations in cognition, balance, vision, vestibular function or exercise tolerance, may be appropriate to identify treatment responders and non-responders, given the circuit station activities focus on cognition, balance, vision, vestibular function, and exercise tolerance. This would be an appropriate area for future analysis, given these domains are assessed as part of usual clinical practice in this setting.

This study was not performed without limitations. First, this study did not include a control group, and therefore spontaneous recovery cannot be ruled out. However, spontaneous recovery more than one year following an mTBI is unlikely,[42] and 92.6% of the participants entered the group program more than one year following their mTBI. In fact, the average time from injury to starting the group intervention was more than two years. Furthermore, it is unknown how these findings would compare to a sample of adults who completed one-to-one physiotherapy and occupational therapy. There may also be a risk of social desirability bias, where participants were assessed by the same occupational therapist who led their group intervention. Lastly, the participant population was mainly female (73%), therefore limiting the application of these results to males. However, females are more likely to seek treatment following a brain injury,[43] therefore our study population is consistent with clinical presentation patterns. Future studies should include a control group, attain COPM scores from a therapist that is not providing treatment, and include additional factors (e.g., pre-existing mental health, coping style, etc.) in their analyses. Future research should also investigate the relationship between change in satisfaction with self-rated goals and objective improvements in the functions required for these goal activities (e.g., cognition, vision, and balance).

3.5 Conclusion

Following an mTBI, approximately 40% of individuals will experience persisting symptoms. Certain factors, including age, sex, days since injury, education, mechanism of injury, mental health, and initial symptoms experienced, may influence the likelihood of developing persisting symptoms. However, the results of this study indicated none of these factors predicted which individuals did not experience a clinically important improvement in satisfaction with self-identified goals. 92% of participants reported

clinically important improvement in goal satisfaction. These findings do not inform clinical expectations of who is unlikely to benefit from group interventions nor who should not be considered eligible to participate in combined physiotherapy and occupational therapy group interventions.

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Chapter 4

4 Outcomes from virtual and in-person interdisciplinary mTBI rehabilitation: A pilot study

4.1 Introduction

Approximately 1.6% of Canadians 12 years and older experienced a concussion/mild traumatic brain injury (mTBI) in 2019.[1] Since 40% of individuals experience persisting symptoms[2] and require treatment, then roughly 245,000 Canadians will require treatment for their symptoms each year. However, there are a limited number of rehabilitation centers, and their interventions have waitlists. One study reported that individuals with persistent concussion symptoms waited an average of nearly 10 months for a specialized assessment in Toronto, Ontario.[3] The geographic location of specialty rehabilitation centers is also a barrier to care for individuals that live in rural areas.[4, 5] For instance, rural mTBI healthcare providers note barriers to care can include travel, paying for care, finding specialty clinics, and getting time off work for treatment.[4] Accordingly, individuals with an mTBI that live in rural regions have reduced access to mTBI care and are less likely to seek care compared to their urban counterparts.[5] Therefore, alternatives to in-person interventions are necessary to provide equitable and accessible care to all individuals with an mTBI.

Personal factors, such as sex and age, influence mTBI incidence and rehabilitation.[6, 7] For example, females (aged 35-49) are more likely to experience persisting cognitive and somatic symptoms following an mTBI,[6] which may be attributed to increased psychological[8] and/or hormonal changes[9] in that time of life. Additionally, women demonstrate an increased risk of suicide following an mTBI.[10] Women with other health conditions also have different rehabilitation preferences (e.g., individualized rehabilitation, appointment flexibility),[11] but it is unclear whether these results apply to brain injury rehabilitation.

Although there are some reports of telerehabilitation (virtual) treatment for mTBI rehabilitation pre-pandemic,[12, 13] telerehabilitation has become more prevalent in Canada and the United States following the COVID-19 pandemic[14, 15] when many outpatient services were closed. Telerehabilitation may be feasible for subacute mTBI[14] and moderate to severe brain injury rehabilitation,[16] and users report it is easy to use and are satisfied with their care.[14, 16] Benefits of transitioning to telerehabilitation include increased patient accountability, better access to group therapy, and decreased travel time to appointments.[17] However, much of the research on telerehabilitation for mTBI rehabilitation is limited to

small studies.[18, 19] Additionally, some preliminary data suggests virtual rehabilitation may result in inferior outcomes.[14, 20] Therefore, more research is necessary to investigate these initial claims, and further investigate whether telerehabilitation serves as equitable care compared to in-person rehabilitation.

In accordance with COVID-19 protocols, many in-person outpatient mTBI services were disrupted.[14, 15] However, these patients continued to require treatment. Therefore, in London, Ontario, Canada, clinicians that run the BrainEx90 rehabilitation intervention at Parkwood Institute pivoted the in-person combined physical therapy and occupational therapy intervention[21] to a virtual platform. Although 93% of healthcare providers indicated that they would consider using telemedicine to provide care to their concussion patients once the pandemic is over,[15] it is unclear whether there are differences in patient outcomes in the virtual compared to the in-person rehabilitation intervention. Therefore, the primary purpose of this pilot study was to compare patient outcomes after completing the rehabilitation intervention virtually to in-person. The secondary purpose of this study was to investigate differences in outcomes between groups based on sex.

4.2 Methods

4.2.1 Participants

Individuals who successfully completed the in-person rehabilitation intervention and consented to participation between August 2015 and August 2019, or successfully completed the virtual rehabilitation intervention and consented to participation between March 2020 and January 2023, were included in this study. A sample size calculation was not performed a-priori as the virtual rehabilitation intervention was created to continue providing care to individuals with persisting symptoms following an mTBI during the COVID-19 government-mandated lockdown. Therefore, we recruited as many participants as possible while the in-person rehabilitation intervention could not operate. All participants who completed either format of the rehabilitation intervention needed to be 18 years of age or older, diagnosed with an mTBI and referred to Parkwood Institute for rehabilitation, and could tolerate group settings. This study was approved by the Health Science Research Ethics Board at Western University and Lawson Health Research Institute.

4.2.2 Procedure

Eligible individuals interested in participating were contacted electronically by a research coordinator, and all study participants provided electronic consent to participate in this study. Participants who completed the in-person rehabilitation intervention completed all assessments in person. Individuals in the virtual intervention completed all subjective assessments electronically on Microsoft Forms, except they completed the Canadian Occupational Performance Measure (COPM)[22] in-person with an occupational therapist. All participants completed the Rivermead Post-Concussion Symptoms Questionnaire (RPQ),[23] the Generalized-Anxiety Seven-Item Questionnaire (GAD-7),[24] Fatigue Severity Scale (FSS),[25] Brain Injury Vision Symptom Survey (BIVSS),[26] and the COPM. Assessments were completed approximately one week prior to starting the intervention, and within six weeks of their last session.

The in-person and virtual rehabilitation interventions were organized and led by the same occupational therapists and physiotherapists; therefore, all components were consistent between interventions. Each intervention included stations that focused on vision, cognition, vestibular function, endurance, self-management, and balance. All participants also completed the same education sessions, such as nutrition, attending special events, returning to exercise, daily activity pacing and planning, etc. All participants completed one 90-minute session per week over 16 weeks. However, in-person rehabilitation followed a circuit-training format, where all stations were set-up and one participant completed each station for a set period of time, and then rotated to the next station. Each station was tailored for the individual's needs, such as the balance station involving balancing on flat ground or on foam. In comparison, participants in the virtual rehabilitation intervention used an online video conferencing platform (Microsoft Teams), and they completed each station together. Stations were still tailored to each participant's needs. Participants in the virtual intervention also received weekly email reminders, and a manual to follow along with at home. In-person sessions included 7-8 participants per group, whereas virtual sessions included 6 participants per group.

4.2.3 Analysis

Descriptive statistics were performed to characterize age and sex of group participants. Changes in outcomes between groups, including GAD-7, FSS, RPQ, BIVSS, and COPM (divided into

performance (COPM-P) and satisfaction (COPM-S)) were compared using t-tests, Welch's t-tests, or Mann Whitney U tests as appropriate. Prior to evaluating change between groups, assumptions were assessed. Normality was assessed using Shapiro-Wilks tests, homogeneity was assessed using F tests, and outliers were assessed using boxplots. Comparisons were assessed using an experiment-wise alpha of 0.05. Data that met all assumptions were analyzed using t-tests, whereas data that did not meet assumptions was analyzed using either Welch's t-tests or Mann Whitney U tests, as appropriate. The magnitude of the changes were compared to minimum clinically important difference thresholds, when possible. Effect sizes and their 95% confidence intervals were assessed using Cohen's d or Glass rank biserial correlation, as appropriate. Effect sizes calculated using Cohen's d were evaluated as small (0.2), medium (0.5), or large (0.8),[27, 28] whereas effect sizes calculated using Glass rank biserial correlation were evaluated as small (0.56), medium (0.64), or large (0.71).[29] All statistical analyses were completed using tidyverse[30] and effectsize[31] packages in R (R Core Team 2019). These analyses were re-run for each sex separately.

4.3 Results

Eight individuals in the virtual rehabilitation intervention (all female, 51.8 ± 8.7 years) and 35 individuals in the in-person intervention (45 ± 11.7 years, including eight males) participated in this study. FSS pre- and post-assessment data was not available for 33 individuals, therefore FSS was not analyzed. It is likely that the timing of their participation predated when the FSS was added to the clinical assessment battery. Many of the parameters had outlying data points (RPQ 2, GAD-7 5, BIVSS 2, COPM-S 1); however, all outliers were included due to the small sample size and the recommendation that circumstances for outlying data points should be evaluated rather than simply omitting them.[32] GAD-7, RPQ, and COPM-P were assessed using t-tests as all assumptions were met. COPM-S did not demonstrate homogeneity of variances ($p < 0.05$), therefore it was assessed using Welch's t-test. BIVSS was not normally distributed, therefore it was analyzed using a Mann Whitney U test. No statistically significant differences were detected between groups in any outcome, and all outcomes had small effect sizes (Table 5).

Secondary sex analyses compared females in the virtual and in-person rehabilitation interventions, as the virtual rehabilitation group did not include any consenting males. Eight female virtual rehabilitation participants (51.8 ± 8.7 years), and 27 female in-person

rehabilitation participants (44 ± 11.5 years) were included in the secondary sex analyses. Many of the parameters had outlying data points (RPQ 3, GAD-7 4, BIVSS 2, COPM-S 2); however, all data was included. Analyses were similar to the primary analyses, where COPM-S was assessed using Welch's t-test due to non-homogeneity of variances, and BIVSS was assessed using a Mann Whitney U test due to a non-normal distribution. GAD-7, RPQ, and COPM-P were assessed using t-tests.

No statistically significant differences were detected between groups among female participants in any outcome, and all outcomes had small effect sizes (Table 6). Additionally, COPM-P and COPM-S clinically improved for both groups in both analyses.[22]

Table 5. Assumption and group comparison outcomes between virtual and in-person rehabilitation groups.

Outcome		Change in Outcome (Standard Deviation)	Shapiro-Wilks W value (p value)	F Test F value (p value)	t-test T value (p value)	Mann Whitney U W value (p value)	Welch's t test (p value)	Effect Size (95% Confidence Interval)
RPQ	**In-Person**	-6.0 (10.5)	0.96 (0.10)	0.72 (0.49)	-0.03 (0.97)			0.01 (-0.78, 0.76)
	Virtual	-5.9 (12.3)						
GAD-7	**In-Person**	-2.6 (5.0)	0.95 (0.07)	0.49 (0.16)	-0.15 (0.88)			0.06 (-0.83, 0.71)
	Virtual	-2.3 (7.1)						
BIVSS	**In-Person**	-9.6 (20.3)	0.81 (<0.05)*	1.79 (0.43)		104.5 (0.27)		0.25 (-0.61, 0.19)
	Virtual	0 (15.2)						
COPM-P	**In-Person**	2.8 (1.6)	0.98 (0.53)	0.60 (0.30)	-1.06 (0.30)			0.42 (-1.19, 0.36)
	Virtual	3.5 (2.1)						
COPM-S	**In-Person**	3.6 (2.1)	0.99 (0.95)	0.30 (0.02)*			-0.36 (0.72)	0.21 (-0.97, 0.56)
	Virtual	4.0 (3.8)						

*Statistically significant, where $p < 0.05$.

Table 6. Assumption and group comparison outcomes between female virtual and in-person rehabilitation groups.

Outcome		Change in Outcome (Standard Deviation)	Shapiro-Wilks W value (p value)	F Test F value (p value)	t-test T value (p value)	Mann Whitney U W value (p value)	Welch's t test (p value)	Effect Size (95% Confidence Interval)
RPQ	**In-Person**	-6.4 (11.6)	0.97 (0.41)	0.88 (0.75)	-0.11 (0.91)			0.04 (-0.83, 0.75)
	Virtual	-5.9 (12.3)						
GAD-7	**In-Person**	-1.7 (4.7)	0.96 (0.13)	0.44 (0.12)	0.27 (0.79)			0.11 (-0.68, 0.90)
	Virtual	-2.3 (7.1)						
BIVSS	**In-Person**	-10.4 (22.3)	0.82 (<0.05)*	2.16 (0.30)		81 (0.30)		0.25 (-0.62, 0.20)
	Virtual	0 (15.2)						
COPM-P	**In-Person**	2.7 (1.7)	0.97 (0.48)	0.69 (0.45)	-1.10 (0.28)			0.44 (-1.24, 0.35)
	Virtual	3.5 (2.1)						
COPM-S	**In-Person**	3.5 (2.2)	0.98 (0.82)	0.32 (0.03)*			-0.39 (0.71)	0.21 (-1.00, 0.58)
	Virtual	4.1 (3.8)						

*Statistically significant, where $p < 0.05$

4.4 Discussion

There is conflicting evidence on the efficacy of virtual mTBI rehabilitation compared to in-person interventions.[14, 18-20, 33] The purpose of this study was to compare patient outcomes after completing a 16-session combined physiotherapy and occupational therapy rehabilitation intervention virtually to in-person. Additionally, this study evaluated patient outcomes for female participants between virtual and in-person rehabilitation participants. This pilot study demonstrated no statistically significant differences in change in RPQ, GAD-7, BIVSS, COPM-P or COPM-S outcomes between in-person and virtual rehabilitation groups. COPM-P and COPM-S outcomes clinically improved for both rehabilitation groups. These findings also applied to our secondary sex analyses of the female participants in each group. Accordingly, our preliminary data suggests there may be no difference in subjective changes following participation in in-person or virtual mTBI rehabilitation, particularly in female participants.

There were no significant differences between the virtual and in-person rehabilitation groups in any outcome measured. These results contradict previous preliminary studies,[14, 20] perhaps due to differences in outcomes measured, variation in treatment provided, age or sex of participants. Individuals in the study by Langevin et al. (2023) needed to have at least dizziness, neck pain and/or headache attributed to their injury, and demonstrate cervical injury on assessment. Individuals in this study did not need to experience these specific symptoms to be included. Furthermore, the average age of our study participants was older than those in Langevin et al.'s study. Our outcomes focused on many different facets of rehabilitation, including vision, cognition, vestibular function, endurance, self-management, balance, and education. In contrast, the other studies focused on cervical spine, cardiovascular, static and dynamic balance,[14] or general advice, aerobic, vestibular, and cervical rehabilitation.[20] Lastly, our study combined rehabilitation from a physiotherapist and occupational therapist, whereas the other studies included treatment from kinesiologists, neuropsychologists, and physiotherapists. The differences in symptoms and outcomes highlight the variation in mTBI presentation and reinforce that mTBI treatment needs to be individualized.[34, 35]

The majority of participants in this study were female, and they demonstrated no significant differences in improvement between virtual and in-person rehabilitation. Accordingly, virtual rehabilitation may lead to similar outcomes for in-person rehabilitation for females. The improvement in RPQ scores[36] in both the virtual and in-person intervention may demonstrate this intervention's ability to clinically improve persisting symptoms in women. However, the lack of clinical improvement in GAD-7 outcomes[37] indicates both versions of the intervention may not improve anxiety in participants. Accordingly, this may highlight an area for improvement for both versions of the intervention. Although anxiety is not the only mental health condition that some individuals with an mTBI experience (therefore should not be the only indicator of mental health status), it is one of the most common mental health conditions following an mTBI[38] and therefore needs to be assessed. Considering women with a brain injury report a lack of care for their needs, including mental health,[39] this is an important area for further research, specifically for women in this interdisciplinary intervention.

This study was not completed without limitations. Primarily, this study was completed with small and unequal sample sizes, therefore reducing the power of our analyses and increasing the risk of Type II errors.[40] However, effect sizes were provided to strengthen the interpretation of these findings. Additionally, this study did not use a statistical approach that was specific for equivalence or noninferiority analysis. A lack of male participants was also a limitation in this study, and further analyses are required with more male participants to evaluate men's performance in the virtual and in-person rehabilitation interventions. Furthermore, study participants were not asked their pronouns or gender identity, which did not allow for this study to consider how our interventions impact different genders, or gender minority individuals.[41] Accordingly, future studies are needed to evaluate the influence of participants' gender identity. Lastly, although subjective outcomes are an important component of evaluating change in the rehabilitation process,[42] objective outcomes would strengthen the findings from this study to either support or refute virtual rehabilitation. Future analyses of these cohorts could include comparing participant performance on standardized measures of cognition, vision, balance, and vestibular function.

4.5 Conclusion

Access to mTBI care can be difficult for a myriad of reasons, including geography, long wait times, and funding. Telerehabilitation may be an appropriate way to increase access to mTBI care. The results of this study suggest there may be no difference in subjective outcomes following virtual or in-person rehabilitation for individuals with an mTBI. Accordingly, virtual rehabilitation may be appropriate for individuals requiring physiotherapy and occupational therapy following an mTBI. We are most confident in these findings for female participants due to the limited number of male participants in this study. Further research is necessary to expand upon these preliminary results.

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5 Discussion

The purpose of this thesis was to investigate treatment outcomes of individuals with persisting symptoms following an mTBI after completing a combined physiotherapy and occupational therapy rehabilitation intervention. This final chapter expands on how the results apply across the studies, along with the strengths and limitations of this thesis, and future directions for related research.

5.1 Summary

This thesis investigated an interdisciplinary combined physiotherapy and occupational therapy outpatient rehabilitation intervention for individuals with persisting symptoms following an mTBI. It was created and is run by occupational therapists and physiotherapists with experience treating individuals with persisting symptoms following an mTBI, and is comprised of sixteen 90-minute weekly sessions. Each session includes cognition, balance, endurance, vision, vestibular function, and self-management exercises, tailored to individual needs. Each session also includes a group education component, where a different topic is addressed at each session (e.g., nutrition, pacing and planning, anxiety, attending social events). The group intervention is offered virtually and in- person. Group sizes range from 6-8 participants.

Participants in this intervention wait months to attend, consistent with wait times for specialized mTBI care in Ontario.[1, 2] Protracted wait times are problematic as access to timely care improves outcomes in this patient population.[3] Accordingly, this study had three main objectives: 1) Investigate whether completing the interdisciplinary outpatient rehabilitation intervention, or choosing specific types of goals, influenced performance and satisfaction ratings of these goals. Additionally, determine the number and types of rehabilitation goals chosen by participants, 2) Evaluate whether prognostic factors associated with developing persisting symptoms following an mTBI influenced change in goal satisfaction following participation in the interdisciplinary outpatient rehabilitation intervention, and 3) Compare patient outcomes after completing the interdisciplinary outpatient rehabilitation intervention virtually to in-person. Additionally, we wanted to

investigate differences in outcomes between virtual and in-person versions of the interdisciplinary outpatient rehabilitation intervention based on sex.

5.2 Thesis Overview

The first study evaluated the change in performance and satisfaction of patient-identified goals after completing the interdisciplinary outpatient rehabilitation intervention. Furthermore, we evaluated which types of rehabilitation goals were more frequently chosen by participants using the COPM. This study included 217 participants (44.4 ± 13.5 years old, 154 females) that completed the rehabilitation intervention. A linear mixed-effect model was used to predict patient-reported performance and satisfaction based on time (pre- and post-rehabilitation intervention) and goal type (productivity, self-care, and leisure). The majority of rehabilitation goals were productivity-related (45%), followed by leisure (37%), and self-care (18%). Performance and satisfaction ratings of all goal types statistically and clinically significantly improved after completing the rehabilitation intervention. Furthermore, satisfaction with self-care goals improved significantly more than satisfaction with leisure or productivity goals.

After demonstrating improvement in patient-identified rehabilitation goals (**Study 1**), we sought to evaluate whether prognostic factors associated with persisting symptoms following an mTBI influenced participant's change in goal satisfaction after completing the rehabilitation intervention (**Study 2**). The second study included 198 participants (44.7 ± 13.6 years old, 144 females), and used a binominal logistic regression to identify which participants were more likely to clinically improve, via the satisfaction score of the COPM. Prognostic factors evaluated included age, sex, days since injury, baseline satisfaction COPM score, education, number of sessions, mechanism of injury, RPQ3 score, RPQ13 score, and GAD-7 score. The vast majority of participants (92%) clinically improved after completing the rehabilitation intervention. None of the prognostic factors were associated with change in goal satisfaction. Furthermore, the model demonstrated low specificity (0%), indicating that the model could not identify individuals who would not respond to the intervention.

Study 1 and **Study 2** demonstrated improved COPM outcomes after completing the interdisciplinary intervention in-person. Therefore, **Study 3** compared patient outcomes after completing the interdisciplinary outpatient rehabilitation intervention virtually to in-person. Forty-three individuals (eight female virtual rehabilitation participants, 51.8 ± 8.7 years; 35 in-person participants, 27 females, 45 ± 11.7 years) completed patient-reported outcome measures as part of their initial and follow-up assessments, including COPM, RPQ, GAD-7, and BIVSS. Changes in outcomes were assessed using t-tests, Welch's t-tests, or Mann Whitney U tests, as appropriate. Additionally, all analyses were re-run comparing females between the virtual and in-person groups. No statistically significant differences were detected between groups in any outcome in either analysis. The results of this study suggest there may be no difference in subjective outcomes following virtual or in-person rehabilitation for individuals with an mTBI, particularly in female participants.

5.3 Combined Interdisciplinary Physiotherapy and Occupational Therapy for Persisting Symptoms Following an mTBI

In summary, this combined physiotherapy and occupational therapy rehabilitation intervention improves patient-identified goals for individuals with persisting symptoms following an mTBI. Furthermore, responses do not vary depending on format (i.e., virtual or in-person) and we have identified that age, sex, days since injury, education, mechanism of injury, baseline COPM-S, GAD-7, and RPQ scores do not influence someone's likelihood of benefitting from the in-person intervention. Our work builds on existing literature demonstrating the effectiveness of interdisciplinary care for individuals with persisting symptoms following an mTBI.[4-6] However, participants in previous studies attended treatment sessions with different healthcare providers over the same timeframe (e.g., physiotherapy Monday, psychotherapy Tuesday, occupational therapy Wednesday). Our study utilized a combined treatment, where participants attended sessions that included both physiotherapy and occupational therapy, simultaneously. Regardless of the format (i.e., virtual or in-person), satisfaction and performance of patient-identified goals clinically improved. These findings are important for future work,

as wait times for specialized mTBI care in Ontario are long,[1, 2] and innovative ways of improving access to care is necessary. Furthermore, a virtual combined intervention removes the geography barrier and allows individuals to receive therapy even if they are located too far to drive to attend in-person treatment. This includes individuals in rural areas, who are less likely to receive treatment.[7]

Participant-centered goals are a recommended rehabilitation outcome measure for individuals with a brain injury,[8] and individuals in the in-person and virtual interdisciplinary rehabilitation intervention demonstrated clinical improvements with both satisfaction and performance of self-identified goals. These changes may have been a result of a response shift,[9] where participant's improvements represent a change in their expectations for recovery and rehabilitation. However, successfully achieving goals is associated with feelings of well-being following a brain injury.[10] Accordingly, it is important that participants are satisfied with their goal achievement, as achieving patient-identified goals is associated with higher quality of life.[11] Productivity goals were the most frequently chosen goal type by participants in the in-person rehabilitation intervention (as identified in **Study 1**). As this was an outpatient population, participants may have preferred productivity goals because they may have been more higher functioning compared to participants in an inpatient intervention. Furthermore, the motivation to return to productivity-related goals like work may have been related to feelings of lack of normalcy or socialization, loss, and/or change in identity.[12]

Symptoms that individuals experience following an mTBI vary,[3] and although the majority of participants in this study improved, it remains unclear if anyone is less likely to benefit from this intervention. The results of **Study 2** indicated that baseline COPM, baseline symptom score (using the RPQ), baseline anxiety, sex, age, days since injury, education, and mechanism of injury did not influence goal satisfaction. However, our model demonstrated low specificity. Although the factors investigated are associated with persisting symptoms,[13-16] other factors, such as history of mental health conditions[14] and coping strategies[17] should be investigated. Furthermore, symptom profiles should be investigated. For instance, individuals with cervicovestibular impairments with virtual rehabilitation.[18] Although our intervention encompasses rehabilitation for many different

symptoms (i.e., cognition, balance, endurance, vision, vestibular function, and self-management), investigating different symptoms as a risk factor for improvement for both virtual and in-person rehabilitation is warranted. In understanding who is more/less likely to respond, individuals can be informed of their likelihood to improve, and therefore may receive appropriate treatment sooner.

The majority of participants in all studies in this thesis were female, which may be related to women having a worse prognosis following an mTBI,[14] possibly contributing to a greater likelihood of engaging in rehabilitation for persistent mTBI symptoms. Other studies also have majority female participants,[18, 19] though one study reported a fairly even number of males and females.[1] Our results indicate that women report improvements in persisting mTBI symptoms, and satisfaction and performance with self-identified goals after completing either version of the rehabilitation intervention. Although there were few males included in all studies, the results of **Study 2** indicate that sex does not influence goal satisfaction after completing this interdisciplinary intervention in-person. Accordingly, the in-person format of this rehabilitation intervention was equally appropriate for males and females. It remains unclear if men have different outcomes after completing the virtual version of this intervention as we did not have enough male participants to perform this analysis.

5.4 Limitations

These studies were not performed without limitations. While patient-identified goals are an important outcome as they promote patient-centered care,[20] using additional outcome measures would have bolstered our results evaluating participant changes after completing the interdisciplinary intervention. For instance, objective outcomes should be included as they are recommended to help determine clinical recovery.[21] Furthermore, using objective outcomes may highlight strengths or weaknesses within the intervention (e.g., balance, cognition, or vision changes, etc.). Lastly, although the COPM is reliable, demonstrates construct[22] and content validity,[23] and clinical utility,[24] and has been used in the brain injury population previously,[22, 25, 26] the minimal clinically important difference of 2 points requires further evaluation.[27] Using outcome measures with validated minimal

clinically important differences will further support the clinical application of these study results.

This thesis was limited by a small male sample, so a secondary sex analysis between males could not be completed in **Study 3**. Previous literature indicates males may not consent or refuse to participate for a multitude of reasons, including time constraints, inability to understand the study's purpose, and apprehension over medical testing.[28] Males consent more to research participation than females,[29] but females with an mTBI have a worse prognosis[30] and are more likely to seek outpatient therapy following a brain injury,[31] which may explain why our study population was primarily female. Accordingly, this study would be improved with a larger male sample, and a secondary sex analysis of males in **Study 3**. Another limitation of these studies was a lack of control group. It is unlikely that participants in this intervention spontaneously recovered as most were beyond a year from injury,[32] however, recovery due to passing time alone cannot be ruled out.[33] It is also unclear how these participants would have responded to individual physiotherapy and/or occupational therapy services. Lastly, all outcome measures in this thesis (aside from virtual outcomes collected in **Study 3**) were collected by the treating occupational therapist and/or physiotherapist. Therefore, desirability bias amongst participants cannot be ruled out.

5.5 Future Directions

The results of this thesis provide the foundation for evaluating combined interdisciplinary rehabilitation, with many opportunities for future work. First, future work should compare outcomes to individuals in a control group to ensure that the changes were not due to spontaneous recovery from time alone.[33] Additionally, future work should compare outcomes from the interdisciplinary intervention to individuals participating in one-to-one physiotherapy and/or occupational therapy interventions. If this research supports combined interdisciplinary rehabilitation, it will support implementing the intervention in more mTBI rehabilitation centers. Accordingly, more individuals may participate, which could help reduce the number of appointments patients have per week with individual therapists and may help reduce waitlists for care. Furthermore, combined occupational therapy and physiotherapy interventions should also be compared to other

combined rehabilitation interventions. Although there is a large overlap in the scopes of practice between physiotherapy and occupational therapy,[34] future work evaluating the effectiveness of combined interventions with speech and language pathologists, social workers, psychotherapists, and other healthcare providers, may also be beneficial.

Further investigation of participant symptoms and intervention outcomes would improve the evaluation of this intervention, and improve its validity. Future studies should investigate how symptom presentation correlates to intervention outcomes, which would highlight the strengths and areas for improvement within the intervention. Since this intervention is targeted for all adults with persisting symptoms following an mTBI who require physiotherapy and occupational therapy services, it is currently indicated for adults with an array of persistent or prolonged symptoms post-mTBI. Accordingly, it's important to ensure the intervention can be tailored to target any symptom to provide the best care possible.

Although patient-reported subjective outcomes are important for evaluating rehabilitation effects,[35] objective outcomes should be included in future work. Including these outcomes may reduce the risk of desirability bias, and support recommendations for evaluating mTBI rehabilitation.[3, 21] Objective outcomes may include tests such as the Balance Error Scoring System and the Vestibular/Ocular Motor Screening assessment, as practice guidelines recommend[21]. Additionally, future studies should include a subjective fatigue outcome, as it is a commonly reported persistent symptom.[36] Fatigue outcome scales may include the Barrow Neurological Institute Fatigue Scale[37] or the Modified Fatigue Impact Scale.[38] Although we attempted to evaluate Fatigue Severity Scale outcomes in **Study 3**, unfortunately a large amount of the data was incomplete and analysis was not possible. Future studies should also include a larger male sample to evaluate these findings amongst the male sex. This is important, as males report more mTBI's than females,[39] even though women report more persisting symptoms.[14] It is unclear why females report more persisting symptoms, but hypotheses have included hormonal and anatomical differences, along with gender and cultural norms.[40] Future analyses should also explore whether sex and gender influence responses to the intervention,[41] as well as social, political, economic, or cultural considerations that might

highlight how to better meet needs for under-serviced groups. Lastly, future studies evaluating the efficacy of virtual rehabilitation should include more participants. The sample size of our pilot study in **Study 3** was small, therefore our results were preliminary.

5.6 Conclusions

Individuals with persisting symptoms following an mTBI require specialized, timely access to care.[3] However, wait times for such services in Ontario are long,[1] and there are geographic barriers to access care,[7] therefore innovative rehabilitation interventions are necessary. The purpose of this thesis was to investigate treatment outcomes of individuals with persisting symptoms following an mTBI after completing a combined outpatient physiotherapy and occupational therapy rehabilitation intervention. The results of this thesis demonstrate individuals improved in performance and satisfaction of self-identified goals after completing this intervention in-person. Additionally, there may be no differences in subjective outcomes after completing a virtual version of this intervention, especially for females. Furthermore, factors associated with having persisting symptoms following an mTBI (including age, baseline symptom and anxiety scores, sex, days since injury, education, number of sessions, and mechanism of injury) were not associated with a reduced risk of improving satisfaction with self-identified goals. However, future work is necessary to expand on this work and evaluate whether these preliminary results are supported with a fully powered study.

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Curriculum Vitae

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Related Work Experience	Teaching Assistant The University of Western Ontario 2016-2023
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Publications:

1. Bonn, M. M., Graham, L. J., Marrocco, S., Jeske, S., Moran, B., & Wolfe, D. L. (2023). Usability evaluation of a self-management mobile application for individuals with a mild traumatic brain injury. Digital Health, 9: 20552076231183555. DOI: 10.1177/20552076231183555.
2. Bonn, M.M., Dickey, J.P. Moran, B., McGuire, S., Graham, L. (2023). Completing an interdisciplinary outpatient rehabilitation intervention improves patient rehabilitation goals following a mild traumatic brain injury. Physiotherapy Theory and Practice, 39(2): 310-316. DOI: 10.1080/09593985.2021.2022046.
3. Bonn, M.M., Harriss, A., Dickey, J.P. (2021). Performing more than 20 purposeful headers in a soccer season may alter autonomic function in female youth soccer players. Research in Sports Medicine, 29(5): 440-448. DOI: 10.1080/15438627.2021.1888098.
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Refereed Conference Proceedings:

1. Bonn, M.M., Bloom, S., Wolfe, D., Graham, L. (2022). MyBrainPacer app use may improve symptoms following an mTBI. Journal of Head Trauma Rehabilitation. 37(6): E597-E598.
2. Bonn M.M., Marrocco S., Moran B., Wolfe D., Gilvesy J., Graham L. (2020). Evaluating the usability of a mobile pacing and planning points program for individuals with persistent symptoms post-concussion/mild traumatic brain injury. Journal of Head Trauma. 35(2): E242.
3. Bonn M.M., Dickey J.P., Moran M., McGuire S., Graham L. (2020). BrainEx90 Improves goal performance and satisfaction in adults with persistent symptoms post-concussion/mild traumatic brain injury. Journal of Head Trauma. 35(2): E241-E242.

Conference Contributions (Other Than Refereed Conference Proceedings):

1. Podium Presentation. Virtual rehabilitation may improve persisting post-concussive symptoms: A pilot study. 14th World Congress on Brain Injury, Dublin, Ireland, March 2023.

2. Poster Presentation. MyBrainPacer app use may improve symptoms following an mTBI. 2022 IPBIS and NABIS Joint Conference on Brain Injury, New York, New York, September 2022.
3. Poster Presentation. Individuals with persistent post-concussive symptoms display individual trajectories when using a symptom management mobile application. Canadian Concussion Network Second Annual Research and Community Engagement Meeting, Montreal, Quebec, June 2022.
4. Poster Presentation. Interdisciplinary outpatient rehabilitation improves satisfaction with self-identified goals for all adults with an mTBI. Parkwood Institute Research Day, London, Ontario, April 2021.
5. Poster Presentation. Validating the MyBrainPacer™ mobile application for individuals with an mTBI. Parkwood Institute Research Day, London, Ontario, April 2021.
6. Invited Speaker. Mental illness, mTBI, and the role of the physiotherapist. Canadian Concussion Network First Annual Research and Community Engagement Meeting, Calgary, Alberta, January 2021.
7. Poster Presentation. Identifying and supporting individuals with mental health conditions following a mild traumatic brain injury: Recommendations for physiotherapists. Mental Health Research and Innovation Day, London, Ontario, November 2020.
8. Poster Presentation. Evaluating the usability of a mobile pacing and planning points program for individuals with persistent symptoms post-concussion/mild traumatic brain injury. ABI2020: 15th Annual Conference on Brain Injury: Best Practices in Brain Injury Medicine and Neurorehab - Improving Outcomes through Interdisciplinary Collaboration, New Orleans, Louisiana, February 2020.
9. Poster Presentation. BrainEx90 Improves goal performance and satisfaction in adults with persistent symptoms post-concussion/mild traumatic brain injury. ABI2020: 15th Annual Conference on Brain Injury: Best Practices in Brain Injury Medicine and Neurorehab - Improving Outcomes through Interdisciplinary Collaboration, New Orleans, Louisiana, February 2020.
10. Poster Presentation. Biofeedback can improve driving performance in individuals with persistent post-concussive symptoms: Preliminary findings from an eight-week intervention. London Health Research Day, London, Ontario, April 2019.
11. Poster Presentation. Using biofeedback to improve driving performance in individuals with persistent post-concussion symptoms: Preliminary findings. Parkwood Institute Research Day, London, Ontario, April 2019.
12. Poster Presentation. Biofeedback can improve driving performance in individuals with persistent post-concussive symptoms: Preliminary findings from an eight-week intervention. World Congress on Brain Injury, Toronto, Ontario, March 2019.
13. Poster Presentation. Driving performance and persistent post-concussive symptoms: Preliminary impact of a neurofeedback and heart rate variability intervention. Health and Rehabilitation Sciences Graduate Research Conference, London, Ontario, February 2019.
14. Poster Presentation. The effects of subconcussive impacts on heart rate variability in female youth soccer players. Experimental Biology, San Diego, California, April 2018.

15. Podium Presentation. Proposed study evaluating the effectiveness of neurofeedback and heart rate variability biofeedback for individuals with long-term post-concussive symptoms. Bodies of Knowledge, Toronto, Ontario May 2017.