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The Impact of Outpatient Exercise on Cognitive Function:

An Intervention for Moderate to Severe Traumatic Brain Injury Populations

A dissertation submitted in partial satisfaction of the

requirements for the degree

Doctor of Nursing Practice

by

Suwen Pan

2026

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ABSTRACT OF THE DISSERTATION

The Impact of Outpatient Exercise on Cognitive Function:
An Intervention for Moderate to Severe Traumatic Brain Injury Populations

by

Suwen Pan

Doctor of Nursing Practice

University of California, Los Angeles, 2026

Professor Wendie Robbins, Chair

Background: Moderate to severe traumatic brain injury (msTBI) is a risk factor for ongoing cognitive decline, and cognitive impairment may progressively worsen into advanced dementia.

Objectives: The Doctor of Nursing Practice (DNP) Scholarly Project aims to assess whether an 8-week moderate-intensity cycling exercise program can enhance neuropsychological and cognitive quality of life (QOL) scores in patients with TBI. **Methods:** A quasi-experimental pre- and post-intervention design was used. Seven msTBI participants with cognitive impairment, aged 22-65 and at least 6 months post-injury, completed eight weeks of supervised cycling exercise, twice weekly for 40 minutes per session, at a hospital wellness center. Three cognitive

function tests [Modified Mini-Mental Status Exam (3MS), Trail Making Test Part A (TMT-A), Trail Making Test Part B (TMT-B)] and two Quality of Life measures [Traumatic Brain Injury Quality of Life (TBI-QOL) Cognition-General Concerns, and Executive Function] were administered before and after the exercise program. Pre- and post-intervention Wilcoxon signed-rank tests were performed to evaluate the effects of the exercise on the participants. **Results:** The mean scores on the 3MS and TMT-B tests showed significant improvement (α level = 0.05) compared to pre-intervention scores ($\Delta = 5.14, \rho = 0.027$; $\Delta = -57.71, \rho = 0.046$), while mean score changes for TMT-A, TBI General Concern, and TBI Executive Function were not statistically significantly different ($\Delta = 4.57, \rho = 1.000$; $\Delta = 0.26, \rho = 0.753$; and $\Delta = 2.56, \rho = 0.499$, respectively). Hedges' correction for 3MS and TMT-B pre- and post-intervention changes indicates a large effect size ($g = -1.25$ and 1.07 , respectively). **Conclusion:** The designed cycling exercise program may improve cognitive functions in patients with msTBI, as evidenced by significantly higher scores on the 3MS and TMT-B. Both tools are effective for evaluating cognitive function in msTBI participants. The project provides insights into designing standardized long-term aerobic exercise for future initiatives to promote cognitive health and prevent dementia among patients with TBI.

The dissertation of Suwen Pan is approved.

Gerardo Flores

Christine Samuel-Nakamura

Wendie Robbins, Committee Chair

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2026

This dissertation is dedicated to my traumatic brain injury patients and their families or caregivers. When I care for them and talk with them, I always recognize that they have faced challenges that others cannot imagine. They endure with strength, not only physically but also mentally and cognitively. Many feel sad, anxious, and uncertain at the beginning of their injury, then become positive thinkers, support others, and engage with the communities they belong to. Some may have to pause their studies or work but eventually return to school and work to continue pursuing their dreams. No matter where they have been or will end up, they inspire me to care for them and maintain their health as much as I can as a primary care provider. In light of this, I decided to seek sustainable, non-pharmacologic methods to help people with traumatic brain injuries.

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Lastly, I would like to thank the eight traumatic brain injury patients who participated in my scholarly project. Their engagement and belief in me have helped me keep my faith and motivation throughout this unforgettable expedition.

VITA

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CHAPTER ONE: INTRODUCTION

Traumatic brain injury (TBI) is a significant risk factor for persistent cognitive decline, and cognitive impairment may gradually deteriorate into advanced dementia (Bryant et al., 2023). In 2020, approximately 214,000 Americans were hospitalized due to TBIs (Centers for Disease Control and Prevention [CDC], 2024a). About 50% of TBI patients were readmitted to hospitals at least once within the first five years following injury (Kaplan et al., 2023). The financial burden on the United States (U.S.) healthcare system for treating TBIs is substantial. The healthcare system spends approximately \$40 billion annually on the treatment of nonfatal TBIs (CDC, 2024b). Each emergency visit for a TBI patient may cost between \$2,600 and \$60,000, depending on the level of care required, such as transfer or admission (Marin et al., 2016). The average cost of readmission is nearly \$16,000 per patient (Ghabowen et al., 2024). If TBI patients develop cognitive impairment, the cost is even higher. Patients with cognitive impairment spent \$6,883 (females) to \$7,276 (males) more on healthcare services annually than patients without cognitive impairment (Sheets, 2025). Traumatic brain injuries often impose significant financial strain on individuals and families, as patients frequently lose their ability to work due to residual physical and cognitive disabilities for either short or long durations. Patients suffering from moderate to severe TBIs (msTBIs) are at a higher risk of lifelong disability compared to the mild TBI population. Approximately 44% of patients with msTBI are unable to return to work (Luca et al., 2019). One of the critical criteria for diagnosing msTBI is a Glasgow Coma Scale (GCS) score of ≤ 12 within 24 hours post-injury; scores of 9-12 indicate moderate TBIs, while scores of 3-8 indicate severe TBIs (Alashram, 2024).

Cognitive recovery is a treatment focus for msTBI patients during rehabilitation. A study by Bryant et al. (2023) found that during the acute phase of TBIs, 32% to 51% of patients exhibit

varying levels of cognitive impairment, typically correlated with the injury's severity. Six months post-injury, 21% to 36% of these patients do not recover cognitive function to pre-injury levels (Bryant et al., 2023). The most prominent cognitive deficits observed after TBIs are decreased attention, memory, and executive function (Ahmed et al., 2017; Chan et al., 2024). Cognitive deficits ultimately affect the quality of life (QOL) for TBI patients.

Problem Statement

TBIs result from external mechanical forces affecting the brain, leading to long-lasting cognitive dysfunction. Research indicates that TBI patients often suffer from diffuse axonal damage caused by the acceleration or deceleration of the head following acute injuries. Severe persistent changes can lead to unconsciousness, significant disability, and even death (Ahmed et al., 2017). In the chronic phase, diffuse axonal injury can lead to cerebral atrophy, characterized by dilated ventricles and a thinning of the corpus callosum. These pathological changes in the brain following injuries are linked to Alzheimer's disease and dementia pugilistica (Ahmed et al., 2017).

Over the past two decades, no pharmacological regimens have yielded promising outcomes for cognitive impairment treatment (Gomez-Pinilla & Mercado, 2022). Research on non-pharmacological interventions, such as exercise, to enhance cognitive function in TBI patients has been conducted and shows that physical exercise, including high- or moderate-intensity exercise, correlates with improved cognitive function following TBIs. The exercise regimens studied have varied, including treadmill training, stair climbing, and stationary cycling, typically performed three times a week for 30-60 minutes over 4-12 weeks (López et al., 2024; Plawecki et al., 2023; Wender et al., 2021). With these findings, however, a long-term exercise regimen after TBIs has not been standardized in treatment plans due to clinical constraints.

Additionally, many TBI patients have difficulty accessing, or face delays in receiving high-quality subacute and long-term rehabilitation services either in the U.S. or worldwide (Matney et al., 2022). This proposed Doctor of Nursing Practice (DNP) Scholarly Project aims to evaluate whether incorporating a standardized moderate-intensity level of a stationary cycling exercise program into the treatment plan for msTBI patients at a physical rehabilitation center outpatient clinic would improve the scores on three neuropsychological tests, the Modified Mini-Mental Status (3MS) test, the Trail Making Test Part A (TMT-A), and the Trail Making Test Part B (TMT-B), within 12 weeks. The project also aimed to assess whether participants' subjective cognitive QOL scores, as demonstrated via two Traumatic Brain Injury Quality of Life questionnaires (TBI-QOL), Cognition-General Concerns and Executive Function, would be ameliorated after the exercise program.

Moderate-intensity exercise is defined as maintaining heart rate at 50% to 70% of the patient's heart rate capacity during the exercise, which is calculated by the formula $220 - \text{age}$ at the beginning of the program (American Heart Association [AHA], 2024). Hence, the targeted minimum heart rate ($HR_{\min}$) and the maximum heart rate ($HR_{\max}$) of the project participants during moderate-intensity exercise are $50\% \times (220 - \text{age})$ and $70\% \times (220 - \text{age})$. Another indicator of exercise intensity for the DNP project is the Borg Rating of Perceived Exertion (RPE) (6-20), a psychophysical tool for assessing subjective effort during exercise (Scherr et al., 2013). The scale is recommended by the American College of Sports Medicine (Liguori et al., 2022), particularly for predicting exercise intensity in patients with disabilities, such as those with TBI. The Borg scale is positively correlated with heart rates ranging from 60 beats per minute (bpm) (Borg Level 6) to 200 bpm (Borg Level 20). One RPE point is approximately equivalent to 10 bpm (Scherr et al., 2013). An RPE of 12-14 is considered

moderate intensity (Grummt et al., 2024).

Clinical Question

To initiate the literature review, the Patient Population, Intervention, Comparison, Outcome, and Time question was defined: In msTBI patients with cognitive impairments (P), does an 8-week (T) evidence-based moderate-intensity stationary cycling exercise program incorporated into the treatment plan (I), compared to no intervention (C), affect patients' cognitive function and QOL (O)?

Nursing Essentials

The American Association of Colleges of Nursing (AACN) 2021 Essentials Domain 2: Patient-Centered Care highlights that nursing practice should offer holistic and evidence-based approaches to address patients' individual needs and promote health (AACN, 2021). This DNP project implemented a carefully designed exercise intervention for TBI program participants based on the literature review and synthesis to ensure feasibility and patient safety. The project aimed to improve cognitive function for patients with msTBI, enhance QOL, and potentially reduce the financial burdens associated with injuries later in life. Providing patient-centered care that considers disabilities, and socioeconomic factors will foster the adoption of interventions among participants.

The process of exploring and synthesizing evidence-based practice (EBP) through literature review, followed by project planning, implementation, evaluation, and dissemination, also aligns with AACN Essentials Domain 4: Scholarship for the Nursing Discipline (AACN, 2021). Guided by this domain, the DNP project assessed whether the exercise program yielded positive outcomes for patients, explained the rationale behind the intervention and its results, and potentially provided standardized recommendations for future advanced clinical practice in this

specialized field. Additionally, the DNP project protected the rights and interests of program participants and adhered to Institutional Review Board (IRB) ethical requirements before, during, and after implementation. A theoretical framework guided the EBP research and application process in the practice setting.

CHAPTER TWO: THEORETICAL FRAMEWORK

A theoretical framework or model is essential for DNP projects because it provides the tools to design, apply, and evaluate the Quality Improvement or Program Improvement more effectively, and in turn, improve patient outcomes and reduce the cost of disease complications (Marshall et al., 2014). The theoretical framework used for this DNP Scholarly Project was the IOWA Model Revised of Evidence-Based Practice to Promote Quality Care (Buckwalter et al., 2017) (Appendix A). The IOWA Model was designed and initiated by nurses at the University of Iowa Hospitals and Clinics in the 1990s (Buckwalter et al., 2017). The model aims to help nurses and nursing leaders evaluate and apply research findings to bedside or clinical practice and improve patient outcomes. The original IOWA Model, derived from the Diffusion of Innovations theory by E.H. Rogers, was revised in 2015 to meet the growth and changes of science in health care (Buckwalter et al., 2017). The revised model is the widely used theoretical framework to guide nurses through the process of EBP in different countries (Melnik & Fineout-Overholt, 2023). Similarly, in several other EBP models, the IOWA Model Revised outlines steps for nursing clinicians and researchers to identify the problem, search and synthesize research findings, and implement and evaluate practice. Furthermore, it contains implementation strategies to improve intervention adoption (Buckwalter et al., 2017). Nurses can follow the comprehensive steps through the model and translate theories or research evidence into their practice and studies (Melnik & Fineout-Overholt, 2023). There are seven steps listed in the

IOWA Model Revised.

Step 1: identify the trigger or problem. Step 2: specify the reason or question. Step 3: form a team and connect with stakeholders. Step 4: search, appraise, synthesize the literature review, and decide whether the evidence is robust enough to apply. Step 5: design and initiate the change or intervention in a pilot group or area first, then evaluate outcomes through data collection and analysis. Step 6: integrate and sustain the intervention. Step 7: Disseminate the result (Buckwalter et al., 2017).

The IOWA Model is a structural and comprehensive process guide for EBP. It is helpful for healthcare professionals from novices to experts and can be used in various bedside or teaching settings (Buckwalter et al., 2017). In addition, the 2015 revised model explicitly includes patient and family values and preferences during the application and emphasizes the tenable changes during EBP processes to achieve the best patient outcomes (Buckwalter et al., 2017). A study revealed that staff nurses, nursing faculty, leaders, and specialists believed that the IOWA Model benefits nursing-directed patient care and assists nurse-led practice change. The model provides nurses with a supportive EBP environment and knowledge infrastructure, encourages nursing engagement, and promotes shared governance (Duff et al., 2020).

Application of the IOWA Model Revised to the DNP Scholarly Project

The following steps of the IOWA Model Revised were applied to the DNP project. First, the triggering issue was identified. Patients with msTBIs often have cognitive impairment after brain injury, which affects their QOL and may deteriorate into severe dementia in later life. The purpose statement was defined with the PICOT question for the DNP Scholarly Project. The issue was considered a priority, as incorporating non-pharmacologic standardized treatment plans for improving cognitive function for msTBI patients is sporadic. The consequence of

dementia prevention in the msTBI population is prominent in reducing healthcare spending for society and patients.

Next, the DNP project lead formed a team to brainstorm and address the issue. The team members for the project included patients with msTBIs, their families/caregivers, physical therapists (PTs), occupational therapists (OTs), speech therapists (STs), professionals in Physical Medicine and Rehabilitation (PM&R), neuropsychiatrists, neuropsychologists, the Quality Improvement Department, and hospital administration. To find the best evidence-based practice for guiding the design of the standardized exercise program in the outpatient setting, a literature review was conducted. Databases searched included PubMed, EMBASE, and Web of Science. Keywords for the research were “traumatic brain injury” AND “aerobic exercise” OR “moderate-intensity exercise” AND “cognitive function” OR cognition. The research results were narrowed in each database by applying the filters. The publication date was up to 5 years, and only full-text articles were included. Research reviews and syntheses were conducted to weigh the risks and benefits of the intervention.

Sufficient evidence was found; therefore, the DNP project lead designed and initiated the exercise intervention for the participants based on the evidence. Before the start of the intervention, patients or their surrogates provided informed consent. Through implementation of the program, the DNP project lead utilized strategies to provide adoption of the practice, monitored patients’ responses, and collected outcome data. Strategy plans were applied, including presenting updated research evidence to stakeholders to garner attention, support, and input, creating a flyer for recruiting TBI participants (Appendix B), educating patients and clinical staff about the purposes of the exercise program, reminding patients between exercise sessions, soliciting patient input, and creating solutions for individual barriers. Statistical tests

were conducted to determine if there were improvements in patients' cognition and QOL measures before and after the standardized exercise treatment.

After data analysis, the project lead assessed whether the proposed changes for adoption in practice were feasible and safe for TBI populations and could eventually be integrated into their treatment plans. The DNP project lead monitored key indicators, such as neuropsychological scores and complications related to the exercise program. The project outcomes were presented to the stakeholders, including patients and the administrative team. Ultimately, the results will be shared at the university's Nursing Science and Innovation Conference and the facility's Research Council. The project report will be published on the university's School of Nursing research website and in the organization's Advanced Practice Provider Newsletter.

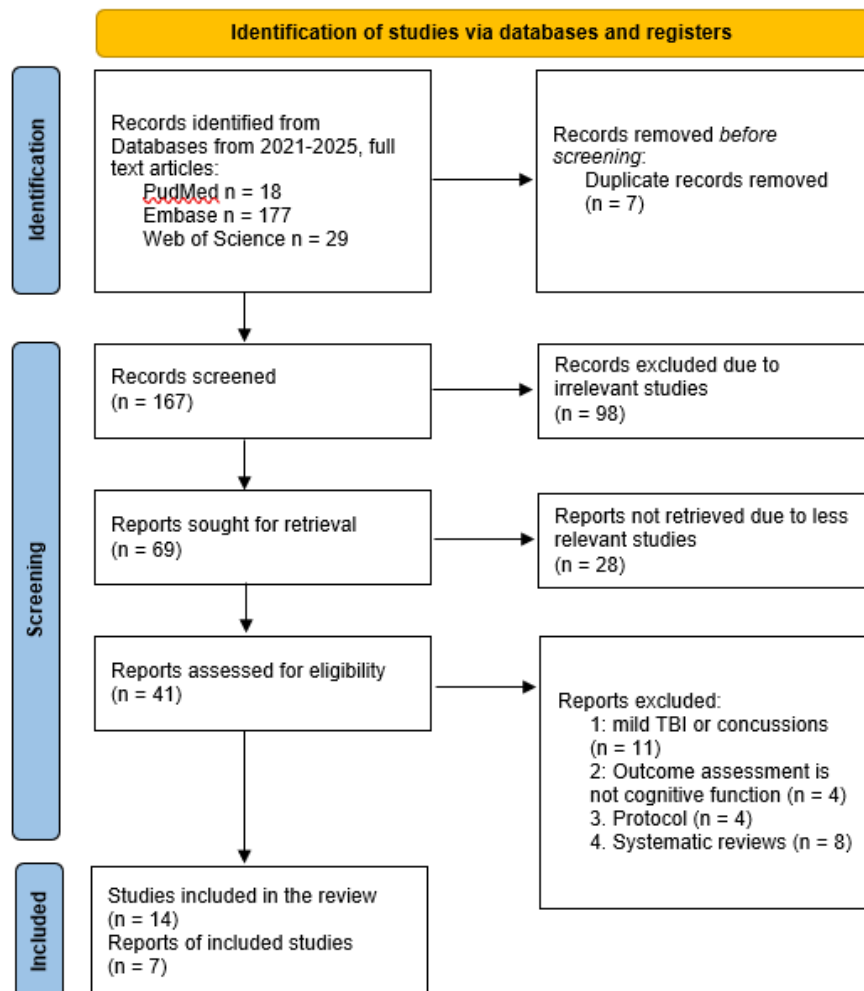
CHAPTER THREE: REVIEW OF LITERATURE

Literature Search

A systematic literature review was conducted using the databases PubMed, EMBASE, and Web of Science, covering the period from January 1, 2021, to July 9, 2025. Only full-text articles were included, and the results were summarized following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Figure 1). The search keywords used were as follows: for the population, "traumatic brain injury"; for the intervention, "aerobic exercise" or "moderate-intensity exercise"; and for the outcome, "cognitive function" or "cognition". The number of articles identified in each database was 18 from PubMed, 177 from EMBASE, and 29 from Web of Science. Seven duplicate articles were removed using EndNote 21 software. From the remaining 167 articles, 69 studies specifically related to exercise interventions and cognitive function measurements for the TBI population were selected for

scoping reviews. Twenty-eight articles were excluded from in-depth review due to their focus on less relevant topics, such as different study populations (including stroke, Alzheimer’s disease, and healthy individuals) and alternative outcome measurements (including treatment adherence, exercise tolerance, biomarkers, and cerebral artery blood velocity). Ultimately, 14 articles were included for critical evaluation, and seven of these were identified as references for the DNP project, which were used to design evidence-based interventions and outcome measures. Research protocols and systematic review studies were excluded from this analysis.

Figure 1: *The PRISMA flowchart*



Literature Review

The seven studies included in the Table of Evidence for this scholarly project focus on patients with moderate and/or severe TBI, aerobic exercise, and assessments of cognitive function or QOL. This information is particularly relevant to the clinical question of the DNP project.

López et al. (2024) designed a pre- and post-test study to examine whether aerobic exercise can improve cognitive function in individuals with chronic severe TBI. The researchers recruited six participants who met the criteria for a supervised 20-week program of moderate to high-intensity cycling, with or without treadmill exercise, following completion of a standard outpatient rehabilitation program. The TMT-B was administered before, during, and after the exercise program. The results showed that five out of six patients increased their TMT-B scores by more than 10% from their baseline measurements; three of these participants exhibited clinical improvements (+1 standard deviation above normative scores). Participants also engaged in more physical activity during the exercise program compared to the regular rehabilitation program ($5.44\% \pm 3.50$ vs. $3.54\% \pm 2.50$), with a mean adherence rate of $72.22\% \pm 18.70\%$. Although this study is not a randomized controlled trial (RCT) and has a small sample size, the supervised cycling approach following routine physical rehabilitation presents a feasible exercise protocol for the DNP project to consider.

To explore more effective exercise designs and appropriate cognitive function assessment tools for the msTBI population in the practice location, four RCTs were reviewed. Ding et al. (2021) conducted an RCT to evaluate whether a 12-week moderate to high-intensity aerobic exercise training (AET) program, in comparison to a stretching and toning program (SAT), could enhance cardiorespiratory fitness among msTBI participants in a community setting. The

researchers assessed peak oxygen uptake (VO₂peak) and several pre- and post-intervention cognitive tests, including Flanker Inhibitory Control and Attention Test, List Sorting Working Memory Test, Picture Sequence Memory Test, Dimensional Change Card Sort Test, Pattern Comparison Processing Speed Test, and Picture Vocabulary Test and Oral Reading Recognition. These tools measure attention, executive function, memory, processing speed, and language. The results indicated that various modes of moderate to high-intensity exercise were associated with increased VO₂peak compared to the SAT group (8% vs. -4%, $p = 0.059$), though there were no significant differences in cognitive function outcomes between the two groups ($p = 0.22$ – 0.82). A notable challenge in this research was the lower compliance rate; only 50% of participants completed more than 70% of the prescribed exercises. Addressing barriers to adherence and developing strategies to improve attrition are essential.

In another RCT, Plawecki et al. (2024) aimed to determine whether 15 sessions of supervised high-intensity training (HIT) over five weeks could enhance performance on the TMT-A, TMT-B, and Digit Symbol Substitution Test (DSST) in chronic TBI patients, compared to conventional training. The findings revealed that TMT-A improved with the HIT intervention, but TMT-B and DSST did not show the same level of improvement ($p = 0.03$ vs. 0.07). In addition to providing insights into cognition assessment tools, the measurement of safety for the exercise program was considered for adoption in this DNP scholarly project. Plawecki et al. categorized adverse events into serious reactions (such as falls with injury or cardiovascular events) and minor reactions (such as musculoskeletal pain, falls without injury, dizziness, excessive shortness of breath, hypertension, or chest pain during exercise). At the end of the program, no serious adverse events were reported. Minor adverse events, although not occurring frequently, included falls, dizziness, hypertension, fatigue, and muscle soreness. The DNP

project lead anticipated the above complications of exercise and generated plans to prevent or treat the complaints if they occurred during the implementation of the program.

Considering that moderate to high-intensity gait training has been studied in stroke populations, Shick et al. (2025) explored the feasibility of a similar exercise protocol for TBI patients. The researchers randomly assigned nine TBI participants to either moderate to high-intensity gait training or low-intensity physical therapy in an outpatient clinic over four weeks. Participants' cognitive function was evaluated using Montreal Cognitive Assessment (MoCA) scores before, during, and at the end of the study. The results indicated significant improvements in the test scores ($p < 0.01$), with lasting effects on cognitive attention observed in the intervention group. Furthermore, the study demonstrated that the designed moderate to high-intensity gait training protocol was safe and well-tolerated by subacute and chronic TBI patients of varying severity levels.

Wender et al. (2021) conducted a randomized 12-week supervised moderate-intensity cycling aerobic exercise training (AET) intervention for patients with severe TBI. Cognitive function was assessed using the Rey Auditory Verbal Learning Test (RAVLT) and the Symbol Digit Modalities Test (SDMT) before and after the intervention. The findings indicated that, compared to the stretching and toning control group, the AET participants showed significant improvements in auditory verbal learning (improvement of +14 to +17 for AET vs. +3 to +11 for control) and processing speed (improvement of +6 to +13 for AET vs. -2 to +2 for control). This was accompanied by notable increases in the volumes of the left hippocampus (increase of +128 to +388 for AET vs. -275 to -951 for control) and the right thalamus (increase of +1243 to +2398 for AET vs. -1456 to +421 for control), as detected through high-resolution magnetic resonance imaging (MRI). The authors suggested replication of the pilot design in future studies to better

understand the correlation between exercise and cognitive changes. The 12-week supervised moderate-intensity cycling program was tailored for the DNP project.

In a retrospective chart review, Klyce et al. (2021) employed the 3MS test to validate its effectiveness and accuracy in interpreting cognitive impairment in TBI patients. The 3MS test is primarily used for screening dementia in geriatric and stroke populations due to its higher sensitivity and consistency when compared to the Mini-Mental State Examination (MMSE). Upon reviewing 187 patients' charts with acute neurological injuries or illnesses (including 75 TBI patients of varying severity) in an inpatient setting, the authors concluded that the 3MS test could serve as a valuable measure of cognitive function when patients' neurotraumatic status is stable, aiding in predictions of preserved cognitive function and neurocognitive recovery. The authors also recommended using other validated cognitive assessment tools concurrently to enhance accuracy.

As mentioned previously, Ding et al. (2021) recommended that it is essential for clinicians to address barriers to exercise to improve adherence among TBI patients. Vargas et al. (2024) identified several barriers, including lack of motivation, time, and energy. Researchers emphasized the importance of assessing changes in self-reported QOL before and after the exercise program, as self-perceived symptoms may affect cognitive and physical outcomes. In the post-hoc analysis of a prospective pilot study, Vargas et al. (2024) found that, compared to the SAT group, the community-based 12-week AET significantly improved self-reported cognitive health among participants with msTBI (mean score change from 103.3 ± 16.2 to 95.9 ± 20.3 for AET vs. 101.4 ± 17.0 to 108.7 ± 18.2 for control; $p = 0.014$) and sleep quality ($p = 0.036$). The TBI-QOL questionnaire was employed to assess patients' physical, emotional, social, and cognitive well-being. Exercise compliance was reported at $76.3 \pm 20\%$ (median 80%, range

25–100%) for both groups, with no significant difference noted. Since the perception of cognitive health is crucial for exercise adherence and is also an essential component of patients' holistic health, the DNP project assessed participants' cognitive QOL via TBI-QOL patient self-reported scales.

Synthesis of Literature Review

Of the seven articles, four studies are RCTs. Six studies were conducted in outpatient settings, including outpatient clinics, homes, and gyms (Ding et al., 2021; López et al., 2024; Plawecki et al., 2024; Shick et al., 2025; Vargas et al., 2024). Most participants in the studies had chronic moderate or severe TBIs, except for one study that focused on patients in the acute phase of brain injuries or illnesses in an inpatient setting (Klyce et al., 2021). Thus, the study populations and settings in the selected articles align well with the DNP project population and practice setting, which focuses on chronic mild TBI in an outpatient clinic.

The exercise protocols varied across the studies. Two studies involved unsupervised community-based exercise (Ding et al., 2021; Vargas et al., 2024), while the remaining four studies featured supervised intervention or control exercises (López et al., 2024; Plawecki et al., 2024; Shick et al., 2025; Wender et al., 2021). While community-based exercise can be integrated into participants' daily routines, maintaining the prescribed exercise intensity can be challenging. To ensure adherence to the designed intensity levels, supervised exercise may be preferable.

In terms of exercise intensity, four studies focused on moderate-intensity or moderate-to-high-intensity levels, while one study used a high-intensity protocol (Plawecki et al., 2024). One article did not specify the exercise intensity (Vargas et al., 2024). The protocols involving moderate-intensity or moderate-to-high-intensity exercises included cycling (with or without

treadmill combinations) (López et al., 2024; Wender et al., 2021), gait training combined with stretching (Shick et al., 2025), or various modes of aerobic exercise (Ding et al., 2021). The high-intensity protocol designed by Plawecki et al. (2024) incorporated treadmill training, gait training, and stair climbing. Common protocols for the control groups included stretching and toning exercises (Plawecki et al., 2024; Shick et al., 2025; Wender et al., 2021). Exercise sessions lasted between 30 to 60 minutes, occurring two to three times per week over 4 to 12 weeks, and no studies reported adverse events.

For cognitive assessment, various measures have been administered in the selected studies. MoCA or 3MS tests were the two global cognitive function assessment tools examined by Shick et al. (2025) and Klyce et al. (2021). TMT-A with and without TMT-B were utilized by López et al. (2024) and Plawecki et al. (2024). All these measurement tools have been validated and have long been in use, offering free access. Consequently, the tools were applied to assess executive function, memory, and attention in participants with TBI for the present pilot project.

Gaps in Literature

One limitation of all selected studies is the small sample size, which hinders the generalizability of the results. While four studies are RCTs, not all are considered high-quality due to their sample sizes and participant noncompliance with the interventions. Increasing the sample size and implementing strategies to improve participant adherence to the exercise protocol are essential for enhancing the reliability and statistical power of the studies.

Participants' educational levels may confound the cognitive test scores (Klyce et al., 2021). Among the four selected RCTs, only one study revealed the educational status of its subjects (Wender et al., 2021). Ding et al. (2021) indicated that cognitive assessment scores were adjusted for severe confounding factors, such as education, age, and sex. Participants'

educational levels should be reported, and their effects on cognitive function should be analyzed and revealed in the statistical results.

Some of the selected studies focused more on changes in physical function rather than cognitive improvements (Ding et al., 2021; Plawecki et al., 2024; Shick et al., 2025), even though physical function can impact cognitive performance. Although the cognitive measurement tools used in the four RCTs and one quasi-experimental study were heterogeneous, cognitive outcomes improved to varying degrees in four of the studies (López et al., 2024; Plawecki et al., 2024; Shick et al., 2025; Wender et al., 2021). Assessing cognitive function is a complex process, particularly among populations with brain injuries or neurological illnesses. Therefore, more initiatives should be undertaken to identify a feasible and validated combination of cognitive measurements to assess cognitive changes in TBI patients after interventions.

The Roles of Doctor of Nursing Practice

The DNP Scholarly Project lead was responsible for designing the exercise program based on EBP and coordinated with the PT, OT, and ST teams, along with leaders, to promote patient health during the project's implementation in the organization. Multidisciplinary teams played a vital role in delivering the exercise program effectively and in accurately assessing patients' cognitive function promptly. The DNP project lead served as an educator, providing essential information to clinicians and exercise participants. The DNP project lead supported patients and explored strategies or modifications to enhance adherence to the intervention. Additional roles of the DNP project lead were related to investigator competency, such as collecting study results, analyzing statistical data, and evaluating project outcomes. Before the exercise intervention began, program participants were informed of and asked to sign consent forms that explained the exercise intervention. The multiple roles of the DNP project lead were

crucial for achieving the desired patient outcomes and ensuring the safety of program participants.

CHAPTER FOUR: METHODS

Ethical Considerations

Ethical concerns were addressed before the DNP Scholarly project began with the goal of ensuring patients' safety. The DNP Scholarly Project obtained approval following reviews by Rancho Research Institute and the UCLA Institutional Research Board (IRB). The leader of the DNP project has adhered to the IRB guidelines and has incorporated the IRB feedback. The project Informed Consent (Appendix C) and Health Insurance Portability and Accountability Act (HIPAA) Authorization Form (Appendix D) were clearly outlined for patients to review. Participants and their surrogates were given adequate time and the option to review and withdraw their consent at any point. The project leader addressed all relevant questions from participants to ensure they fully understood the information provided. Certified interpreters were utilized if participants could not speak or understand English. De-identified data were retained for data analysis and conclusion after the intervention procedures to protect participants' identities.

Project Design

The DNP Scholarly Project is an evidence-based pilot program that used a quasi-experimental pre- and post-test design to assess the feasibility of a tailored exercise program for participants with msTB. The participants received an eight-week supervised moderate-intensity stationary cycling exercise intervention during the program. Patients who met the inclusion and exclusion criteria were invited to join the DNP Scholarly Project pilot program. Three neuropsychological tests (the 3MS, TMT-A, and TMT-B) and two TBI-QOL short forms

(Cognition-General Concerns and Executive Function) were administered before and after the intervention. Pre- and post-intervention data were collected to compare the effects of the designed exercise on the cognitive function and quality of life of project participants.

The quasi-experimental design was chosen for the DNP Scholarly Project because it is practical for a busy clinical setting, less expensive, and requires less time to implement. The project design provided valuable insights into the relationship between the exercise intervention and changes in cognitive function in the outpatient setting, although it cannot provide the same level of causality as an RCT. Inferences on project outcomes from the exercise intervention are reduced. Other unobserved confounding factors may interfere with the results. The non-blinded design weakens the study's persuasiveness, as the biases of the program participants and the investigator may influence the results.

Sample and Setting

The DNP Scholarly Project was implemented at a Wellness Center in a historic rehabilitation center in Los Angeles County. The rehabilitation center has 158 inpatient beds and is a recognized leader in clinical research for rehabilitation medicine. The project lead aimed to recruit up to 15 participants from the center's outpatient clinics or outpatient physical rehabilitation program. TBI patients' demographic information, GCS scores during admission, cognitive function scores recorded in the outpatient STs' notes, medical history, medications, and mobility function were obtained from electronic medical records during the screening process. Patients aged 21-65 with diagnoses of msTBI and decreased cognition, without other neurological diseases and uncontrolled medical history, were further interviewed by the project lead in person or via phone to determine if they met study inclusion criteria.

The inclusion criteria were chronic TBIs for at least 6 months after injuries, having

graduated from high school or above, being able to cycle without standby assistance, follow instructions, and provide informed consent. Exclusion criteria included: being currently pregnant; history of other neurological diseases such as stroke, severe psychiatric disorders such as schizophrenia, bipolar, severe anxiety, or severe major depression; severe substance use disorders; unstable cardiopulmonary diseases such as unstable angina, heart failure, or COPD; terminal illness such as end stage renal failure; planning to join another exercise program, or engage in other moderate or high-intensity exercise and those who are unable to walk. The inclusion and exclusion criteria created a more homogenous sample to improve internal validity and help reduce the risk of confounding. Confounding factors may influence the activity levels, cognitive function, or adherence to the designed exercise intervention of TBI patients. Those who met the inclusion criteria and agreed to participate provided informed consent before joining the exercise program.

Measures

The project leader recorded each participant's heart rate and RPE during stationary cycling to ensure they reached the recommended moderate-intensity level. The correlation between the Borg RPE and HR is high during resistance exercise (weighted mean validity coefficient $r = 0.88$) (Lea et al., 2022). Gender, age, and training modes do not significantly affect the RPE scale. The reliability of the scale ranges from 0.58 to 0.97 (Lea et al., 2022).

Three neuropsychological tests, 3MS, TMT-A, and TMT-B, were administered to assess participants' cognitive function before and after the project. These three measurement tools have been widely employed in cognitive assessment research for decades. The 3MS has been used to examine global cognitive function. The test was developed to overcome some limitations of the MMSE, with higher sensitivity for detecting cognitive function in individuals with low

educational levels, mild cognitive impairment, and executive dysfunction (Teng & Chui, 1996; Van Patten et al., 2019). The 3MS demonstrates stronger construct validity (0.85) and retest reliability and validity, with sensitivity and specificity for diagnosing mild cognitive impairment of 0.84 and 0.71, respectively, outperforming the MMSE (Van Patten et al., 2019). TMT-A and TMT-B tests examine working memory, executive function, and visual attention (Dobbs & Shergill, 2013; Llinàs-Reglà et al., 2016). The retest reliability for Part A and Part B was 0.83 and 0.90, the alternative-form reliability for Part A and Part B was 0.79 and 0.88, and the construct validity was moderately correlated between the two tests (DesRosiers & Kavanagh, 1987). All three measurement tools are free and accessible online.

The 3MS is a 15-item questionnaire available in English and Spanish, with a score ranging from 0 to 100 (Teng & Chui, 1996). A lower score indicates worse cognitive impairment. Both TMTs are composed of 25 circles randomly distributed on a sheet of paper. In TMT-A, the circles are labeled with numbers from 1 to 25. Patients need to draw lines to connect the numbers in ascending order. The circles are labeled with letters from A to L and numbers from 1 to 13 in the TMT-B. Patients should draw lines alternately between the numbers and the letters in ascending order, such as 1-A-2-B, and so on. Patients should connect the circles as quickly as possible. Examiners time the patients until they reach the last number or letter. Examiners can point out mistakes instantly during the test, allowing patients to rectify them, but the timing should continue. The maximum time for both tests is 5 minutes, even if patients are unable to complete the tasks as directed. A sample short test is available for patients to practice before the formal TMT-A or TMT-B is administered. Examiners guide patients through the practice test until they grasp the concept of each test, after which they can proceed to the formal TMT-A or TMT-B.

The DNP Scholarly Project also assessed participants' perceptions of cognitive QOL changes after the exercise program using two TBI-QOL short forms (Cognition-General Concerns and Executive Function). TBI-QOL was developed by Tulskey et al. (2016) in 2007 to generate a comprehensive, patient-administered QOL measurement specific to TBI populations. The questionnaires contain 22 item banks, with full and short versions, that assess the physical, emotional, cognitive, and social domains of subjective QOL. TBI-QOL item banks (full versions), short forms, and corresponding raw score conversion tables are available free of charge to researchers and can be obtained by emailing tbi-qol@udel.edu. The TBI-QOL Cognition-General Concerns and Executive Function scales focus on subjective cognitive health in TBI populations, including aspects such as confusion, mental slowness, difficulty with task management, problem-solving difficulties, flexibility issues, and planning challenges (Tyner et al., 2020). The test-retest reliability for the full item banks of Cognition-General Concerns and Executive Function was 0.88 and 0.86, respectively, and their correlations with the Global QOL were 0.81 and 0.82 (Carlozzi et al., 2019; Tyner et al., 2020). The two short versions demonstrated high correlation with the full versions, 0.97 for Cognition-General Concerns and 0.96 for Executive Function (Carlozzi et al., 2019). The short forms were used in the DNP project to reduce the burden on TBI project participants answering questions. Each short form consists of ten questions.

Interventions

The project participants were scheduled to perform moderate-intensity exercise under supervision at the hospital Wellness Center twice a week for eight weeks, a total of 16 sessions. Participants used a stationary bike with adjustable resistance, based on their exertion and heart rate responses, under supervision during each exercise session for 40 minutes, with a 5-minute

warm-up and a 5-minute cool-down. Heart rate was monitored via the pulse oximeter during exercise to achieve 50% to 70% of the patient's heart rate capacity. Each participant received an explanation of the Borg RPE 6-20 scale before the exercise (Table 1). The target RPE level is 12-14 ("Somewhat hard"). Participants were instructed to maintain this intensity during exercise for as long as possible. The project leader evaluated patients' cognitive functions and QOL at the beginning and end of the intervention using a paper-based format. Participants were contacted by phone between exercise sessions to encourage adherence. The script of the telephone call is included in Appendix E.

Table 1: *Ratings of Perceived Exertion (RPE) Scale (Borg, 1962)*

Rating	Descriptor
6	No exertion at all
7	Extremely light
8	
9	
10	Very light
11	
12	
13	Somewhat hard
14	
15	
16	Hard (heavy)
17	
18	
19	Extremely hard
20	
	Maximum exertion

Data Analysis

Given the small sample size, Wilcoxon signed-rank tests were used to compare pre- and post-intervention measurements within the group. Comparisons among subgroups were not conducted. Hedges' correction (Hedges g) was calculated to estimate effect sizes. Analyses were conducted using SPSS Version 31.

CHAPTER FIVE: RESULTS

After screening, a total of nine eligible participants with msTBI provided informed consent to join the DNP Scholarly Project. Seven participants completed the program under supervision and responded to all pre-tests and post-tests by the end of the 8-week exercise program. One participant withdrew at the beginning of the program due to time-commitment issues. Another participant did not return for the post-intervention test after completing the program due to an emergency medical condition unrelated to the program. No adverse effects were reported during the project. Participants' heart rate or Borg RPE during each exercise session reached the recommended moderate-intensity level. The program's attendance rate was 84%.

Participants' Demographics and Characteristics

Participants' demographic information is summarized (Table 2). All seven participants were male, and their ages ranged from 22 to 48 years. Six were Latino/Hispanic, and one was Asian. The time since their TBI at program onset ranged from eight months to 27 years. Five had TBI for six months to 10 years, while two experienced injuries for 10 years or more. Six participants were diagnosed with severe TBI, and one had moderate TBI. All participants' cognitive functions, as documented in the most recent Speech Therapy Outpatient Note prior to the program, were mildly impaired. All participants had at least a high school education; two

completed 12th grade, four were enrolled in college, and one held a bachelor's degree. Two participants required canes and ankle braces when walking but could perform cycling exercises without issues.

Table 2: *Participants' Demographics and Baseline Injury Information*

Patient	Age	Gender	Ethnicity	Time since the TBI	Severity of TBI (GCS)	Cognitive Function Type and Score from Speech Therapy Assessment	Education Level
P1	31	Male	Latino	2 years 8 months	3	MoCA ^a 18	High School Grad
P2	45	Male	Latino	11 years 8 months	3	CLQT ^b mild	College
P3	43	Male	Asian	9 years 4 months	3	RBANS ^c 70	College
P4	22	Male	Latino	4 years 8 months	8	MoCA 24, RBANS 79	College
P5	35	Male	Latino	8 months	11	RBANS 78	High School Grad
P6	48	Male	Latino	27 years 9 months	3	RBANDS 67	College
P7	37	Male	Latino	8 years 10 months	3	RBANDS 95	Bachelor

Note. ^a Montreal Cognitive Assessment. ^b The Cognitive Linguistic Quick Test. ^c The Repeatable Battery for the Assessment of Neuropsychological Status.

Statistical Outcomes

Descriptive statistics for project participants' pre- and post-intervention data are summarized (Table 3). Two cognitive function scores, 3MS and TMT-B, showed significant improvement (α level = 0.05) following the exercise program (Figures 2 and 3). The mean 3MS score increased from 89.86 (SD: 3.72) to 95 (SD: 4.47) (Δ = 5.14; ρ = 0.027), and the mean

TMT-B score decreased from 190.43 (SD: 130.71) to 131.29 (SD: 110.31) ($\Delta = -57.71$; $\rho = 0.046$). Hedges' correction indicates large effect sizes for both changes ($g = 1.25$ and -1.07 , respectively). Meanwhile, the TMT-A, TBI General Concern, and TBI Executive Function scores did not change significantly after the program ($\Delta = 4.57$, $\rho = 1.000$; $\Delta = 0.26$, $\rho = 0.753$; and $\Delta = 2.56$, $\rho = 0.499$, respectively).

Table 3: *Descriptive Results on Cognitive Function Tests and TBI Quality of Life Questionnaire Outcomes (N=7)*

Variable		Mean	Standard Deviations	Paired Samples Effective Sizes (Hedges' correction, g)*	Wilcoxon Signed Ranks Test (Z score and Asymptotic Significance (2-tailed))
Pair 1 $\Delta = 5.14$	3MS assessment score preintervention	89.86	3.716	-1.248	-2.205 ^a $\rho = 0.027$
	3MS assessment score postintervention	95.00	4.472		
Pair 2 $\Delta = 4.57$	Trail Making Test Part A score preintervention	60.71	61.247	-0.183	.000 ^b $\rho = 1.000$
	Trail Making Test Part A score postintervention	65.29	80.785		
Pair 3 $\Delta = -57.71$	Trail Making Test Part B score preintervention	190.43	130.707	1.074	-1.992 ^c $\rho = 0.046$
	Trail Making Test Part B score postintervention	131.29	110.308		
Pair 4 $\Delta = 0.26$	TBI General Concern score preintervention	40.257	12.7117	-0.018	-.314 ^c $\rho = 0.753$
	TBI General Concern score postintervention	40.514	4.7925		
Pair 5 $\Delta = 2.56$	TBI Executive Function score preintervention	37.971	10.1523	-0.216	-.676 ^a $\rho = 0.499$

TBI Executive Function score postintervention	40.529	4.6432
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Note. Δ : Difference between post- and pre-intervention mean scores (post-intervention mean score – pre-intervention mean score). * Hedge’s correction interprets effect size: $g = 0.2$ small, 0.5 medium, and 0.8 large. ^a Based on negative ranks. ^b The sum of negative ranks equals the sum of positive ranks. ^c Based on positive ranks.

Figure 2: *Pre- and Post-Intervention Modified Mini-Mental Status Test Scores*

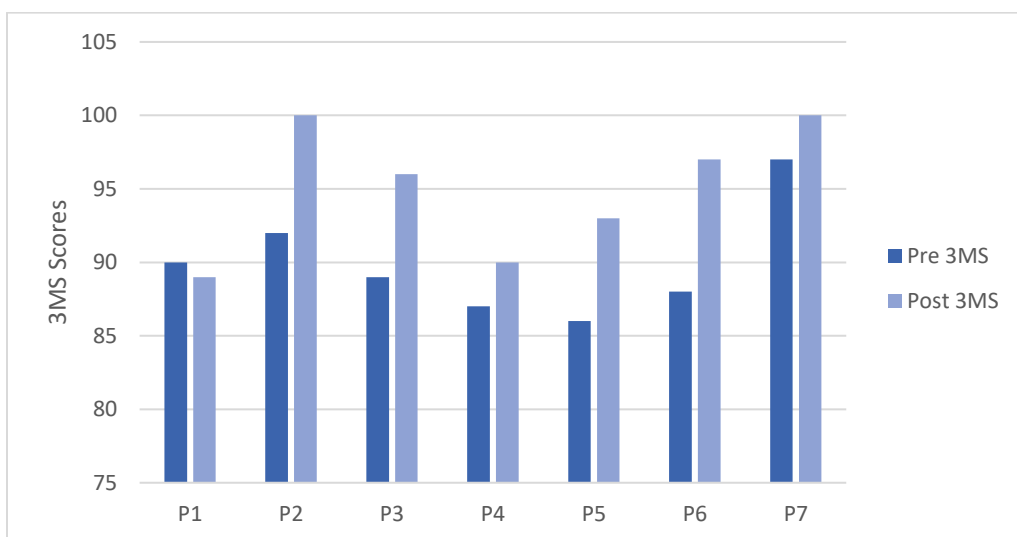
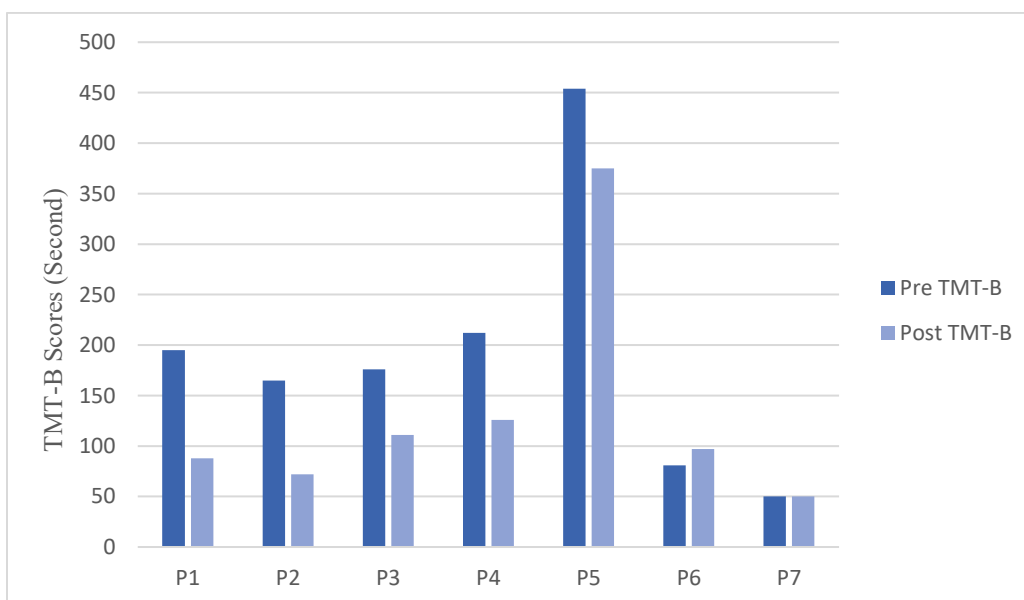


Figure 3: *Pre- and Post-Intervention Trial Making Test Part B Scores*



CHAPTER SIX: DISCUSSION

Implications

The results of the DNP Scholarly Project indicate that stationary cycling is a feasible and safe form of moderate-intensity exercise during the chronic rehabilitation phase for msTBI patients, as all participants completed the program with an adherence rate of 84%. No adverse events were reported during the project. The TBI participants' cognitive functions improved following the designed aerobic exercise intervention, as evidenced by significantly higher scores on the 3MS and TMT-B. Both tools are effective for evaluating msTBI participants' cognitive function. The DNP Scholarly Project further supported previous research suggesting that moderate-intensity exercise may be positively linked to cognitive improvements after brain injury. The lack of a statistically significant change in TMT-A scores related to the exercise might be due to most participants having normal or near-normal baseline test results. Six of the seven participants completed the test within 78 seconds. The normal score for TMT-A is 78 seconds or less, with an average of 29 seconds (Avers & Wong, 2020). The TMT-A involves fewer executive functions than TMT-B and does not adequately predict patients' working memory, inhibition control, or set-shifting abilities; however, it remains a useful test for assessing patients' visual scanning and graphomotor speed (Llinàs-Reglà et al., 2017). The participant who completed the pre- and post-test longer than the normal limit in the project has visuospatial impairments. Although both TBI QOL questionnaire results did not show significant improvement after the exercise program, four participants' Executive Function questionnaire scores increased, from an average of 31.9 to 40.9. This outcome indicates the TBI Executive Function questionnaire could still be a valuable QOL assessment tool for the msTBI population.

Prior studies indicate that physical exercise, including moderate- and high-intensity

exercise, is associated with improved cognitive function following TBIs (Alashram, 2024). Exercise influences neuroplasticity, the process by which the brain forms new neural connections to adapt to injury or stimulus, which can benefit neuronal regeneration and cognitive recovery (Gomez-Pinilla & Mercado, 2022). The DNP Scholarly Project, consistent with existing literature, provided additional insights into the design of standardized long-term aerobic exercise protocols for future initiatives to promote cognitive health and prevent dementia among patients with TBI. At a systems level, implementation of exercise intervention programs, such as the intervention in this DNP Scholarly Project, could help alleviate financial pressures on the healthcare system, patients, and their families.

For future work, the exercise program could be adapted for other populations, such as healthy older individuals or patients with mild TBIs and strokes. The program's value could be enhanced by recruiting a larger number of participants over an extended period. The supervision of outpatient moderate-intensity exercise could be transformed into a self-monitored, community-based exercise protocol to better meet patients' needs. The project results may suggest that moderate-intensity exercise can be a safe and effective long-term intervention for individuals with msTBI after completing inpatient and outpatient rehabilitation programs. Patients do not need to enroll in any formal programs if the exercise costs are unaffordable. Patients can exercise at home or in community settings if they are stable and monitor their heart rate during exercise. Devices, such as Fitbits, smartphones, and pulse oximeters, are feasible tools for monitoring heart rate at home to ensure appropriate exercise intensity.

Limitations

The lack of randomization, small sample size, convenience sampling, and single-location study design are notable limitations of the DNP Scholarly Project, which may affect the validity

and generalizability of the results and conclusions in other clinical settings. Additional limitations include recruiting a limited number of non-Latino/Hispanic and moderate TBI patients. None of the program participants were female. The results also cannot be applied to mild TBI populations. Further research should include populations with mild and moderate TBI. Other potential confounding factors, such as gender, educational levels, and pre-injury cognitive scores, should be explored in future studies. Many neuropsychological tests have been used in previous exercise programs, providing more comprehensive assessments of cognitive function. The DNP Scholarly Project used only three neuropsychological tests, which limits interpretation of results across the full spectrum of cognitive assessment. Incorporating additional cognitive assessments could help address this limitation.

CONCLUSION

Cognitive impairment is a common long-term complication for msTBI patients and affects their QOL, and often leads to financial distress. Aerobic exercise is associated with cognitive improvement in this population during the chronic phase. The tailored, eight-week, supervised cycling exercise program used in the DNP Scholarly Project aimed to identify a feasible, safe, and cost-effective method to promote cognitive health among msTBI patients in the outpatient setting. The IOWA Model Revised of Evidence-Based Practice to Promote Quality Care served as the theoretical framework for project planning, implementation, and evaluation. The program showed significant improvements in the 3MS and TMT-B cognitive function tests among msTBI participants. Patients' QOL in executive function perception also improved after the moderate-intensity exercise program. Future strategies can be implemented to promote practice sustainability and meet patients' needs. Recruiting more participants from diverse demographic backgrounds would help predict program outcomes at other practice locations. The

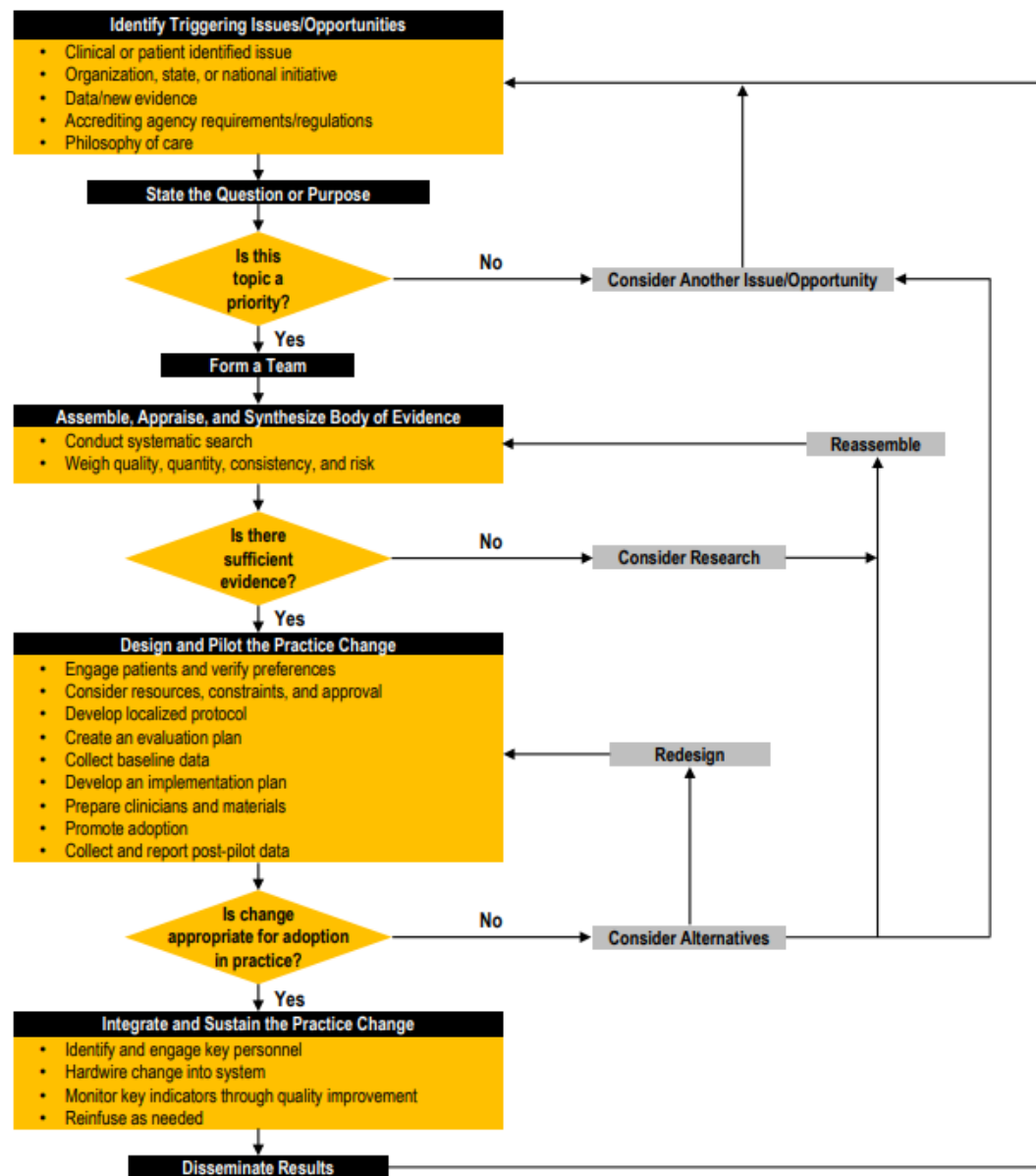
designed exercise program could be incorporated into a standardized treatment plan for msTBI populations in the outpatient setting.

APPENDICES

Appendix A

The IOWA Model Revised of Evidence-Based Practice to Promote Quality Care

The Iowa Model Revised: Evidence-Based Practice to Promote Excellence in Health Care



◆ decision point

©University of Iowa Hospitals & Clinics, Revised June 2015

Appendix B

Exercise Program Recruitment Flyer (English and Spanish Versions)

EXERCISE FOR BRAIN HEALTH

Cycling Exercise Program for Traumatic Brain Injury Patients

Where
The Wellness Center
Rancho Los Amigos National Rehabilitation Center

When

- 3 months (From January 2026 to March 2026)
- 2 days/week (Wednesday and Friday)

Duration
40 minutes each session

- 30 minutes exercise
- 5 minutes warm up
- 5 minutes cool down

Physical Movement:
Biking on a stationary bike to maintain your heart rate in a moderate-intensity level

Free Program
The Wellness Center monthly membership **will be covered** during the program.

Contact:
Suwen Pan, FNP-BC
span2@dhs.lacounty.gov
(562)385-6371

EJERCICIO PARA LA SALUD DEL CEREBRO

Programa de ejercicios de ciclismo para pacientes con lesión cerebral traumática

Dónde
El Centro de Bienestar
Rancho Los Amigos Centro Nacional de Rehabilitación

Cuando

- 3 meses (de enero a marzo de 2026)
- 2 días a la semana (miércoles y viernes)

Duración
40 minutos cada sesión

- 30 minutos de ejercicio
- 5 minutos de calentamiento
- 5 minutos de enfriamiento

Movimiento físico
Andar en bicicleta estática para mantener la frecuencia cardíaca a un nivel de intensidad moderada.

El Programa es Gratuito
La membresía mensual del Centro de Bienestar **estará cubierta** durante el programa.

Contacto:
Suwen Pan, FNP-BC
span2@dhs.lacounty.gov
(562)385-6371

Appendix C

Rancho Research Institute Informed Consent

RANCHO RESEARCH INSTITUTE, INC.
RANCHO LOS AMIGOS NATIONAL REHABILITATION CENTER
7601 IMPERIAL HWY, DOWNEY, CA 90242

INFORMED CONSENT FORM

PROJECT TITLE: The Impact of Outpatient Exercise on Cognitive Function: An Intervention for Moderate to Severe Traumatic Brain Injury Populations

PRINCIPAL INVESTIGATOR: Suwen Pan, MSN, FNP-BC

CO-INVESTIGATOR(S): Michelle Sterling, DNP, RN, ACNS-BC

DEPARTMENT and ADDRESS: Rancho Los Amigos National Rehabilitation Center
Ambulatory Care, Neuro-Stroke PCMH
7601 Imperial Hwy, Downey, CA 90242

PHONE No: (562) 385 6371

You are being asked to take part in a research study. Please take as much time as you need to read the consent form. If you find any of the language difficult to understand, please ask questions. If you decide to participate, you will be asked to sign this form.

KEY INFORMATION

The following is a short summary of the study. It contains information that will help you decide whether to join the study. More detailed information is included later in this form.

1. Participation in this research study is voluntary. It is your choice.
2. You are being asked to take part in this research study because you are between 21 and 65 years old and have had a brain injury that affects how you think or remember. The study will look at whether biking exercise can help improve brain function, such as memory, planning, and attention. You will be in the study for 8 weeks but it could be shorter if unexpected changes happen. More detailed information about the study procedures can be found under the "Procedures" section.
3. There are risks from participating in this study. The most common risks are increased heart rate and blood pressure during exercise, tiredness, and muscle or joint pain after exercise. More detailed information about the risks of this study can be found under the "Risks and Discomforts" section.
4. The possible direct benefit to you for participating includes doing exercise at the Wellness Center for two months with the paid monthly fee by the study program. More detailed information about the study benefits can be found under the "Benefits" section.
5. If you decide not to join this study, you can continue your usual daily activities at home or exercise at the Wellness Center or a local gym on your own. You would be responsible for any costs.

Version Date: 2/3/2026
RRI Template rev 4/14/2023

Page 1 of 7



IRB NUMBER: IRB #582
IRB APPROVAL DATE: 02/10/2026
IRB EXPIRATION DATE: 12/14/2026

Appendix D

Health Insurance Portability and Accountability Act (HIPAA) Authorization Form



RANCHO RESEARCH INSTITUTE INC.
RANCHO LOS AMIGOS NATIONAL REHABILITATION CENTER
7601 Imperial Highway, Downey, CA 90242

AUTHORIZATION FOR USE AND DISCLOSURE OF PROTECTED HEALTH INFORMATION FOR RESEARCH PURPOSES

IRB Study #:

Project Title: **Outpatient Exercise Program Effects on Cognitive Function: An intervention for Chronic Moderate to Severe Traumatic Brain Injury Populations**

Name of Principal Investigator: Suwen Pan, MSN, FNP-BC

A federal law known as the Health Insurance Portability and Accountability Act (HIPAA) protects how your health information is used. California State law also gives you certain protections regarding the use and release of your protected health information. "Protected Health Information" means any health information about your past, present or future physical or mental health condition or payment for health care that can identify you. Examples include demographic information, results of physical exams, blood test, x-rays and other diagnostic and medical procedures as well as medical history.

Under these laws, the Rancho Los Amigos National Rehabilitation Center or your health care provider cannot release your health information for research purposes unless you give your written permission. The purpose of this form is to give your permission to the research team to obtain and use your protected health information for use in this research study.

If you sign this document, you give permission to the study doctor and research team at Rancho Los Amigos National Rehabilitation Center to use or disclose (release) your health information that identifies you for the research study.

The health information that we may use or disclose (release) for this research includes:

- Name
- Address
- Phone number
- Date of birth
- Medical history
- All health information collected during your participation in study visits, including results of physical exams, blood tests, x-rays and other diagnostic and medical procedures

Appendix E

The Script for Calling Participants between the Exercise Sessions

Hello, Mr./Mrs./Ms. XXX

I am Suwen Pan, the nurse practitioner who spoke with you and enrolled you in the exercise program at our hospital's Wellness Center.

The purpose of today's call is to remind you of the date and time of your next exercise session at the Wellness Center.

I'll see you on _(date), _(day), at _(time). Please remember to take all medications prescribed by your doctor before coming. Also, remember not to eat for at least 30 minutes before the exercise. Bring water or other drinks to stay hydrated during your workout.

If you have any questions before your appointment, you can call us at (562) 385-6371 from 8 am to 4:30 pm. After hours, please call (562) 385-7111.

TABLE OF EVIDENCE

CITATION	PURPOSE	SAMPLE/SETTING	METHODOLOGY (Design, Interventions, Measures)	RESULTS	DISCUSSION, INTERPRETATION, LIMITATIONS
Ding, K., Tarumi, T., Tomoto, T., Bell, K. R., Madden, C., Dieppa, M., Cullum, C. M., Zhang, S., & Zhang, R. (2021). A proof-of-concept trial of a community-based aerobic exercise program for individuals with traumatic brain injury. <i>Brain Injury</i> , 35(2), 233–240. https://doi.org/10.1080/02699052.2020.1865569	To assess whether an aerobic exercise intervention can fit into a community setting for TBI patients	<u>Sample:</u> 16 chronic mild, moderate, and severe TBI patients; age at injury: - AET group 46 ± 12 - SAT group 47 ± 13 Gender: males (8); females (8) <u>Inclusion:</u> History of TBIs, aged 18–65 years, 6 months to 6 years after initial TBI <u>Exclusion:</u> Current substance abuse, active major psychiatric disorders, uncontrolled hypertension, obesity with a body mass index ≥ 35, severe orthostatic hypotension, history of recurrent epilepsy or stroke, other unstable medical conditions, unable to walk without assistance from another individual, non-English speakers, participated in regular exercise in the past 2 yrs <u>Setting:</u> at home and gym	<u>Design:</u> RCT, single-blind - Aerobic exercise training AET group (9) - Stretching and toning SAT group (7) <u>Procedure:</u> AET group Increase gradually, any modes of AE allowed (50–80% HR reserve); 3x/week, 50 min/session, or 5x/week, 30 min/session, 12 weeks SAT group Stretching and toning exercise ($< 50\%$ HR reserve); same frequency as AET <u>Measurement:</u> VO_{2peak} - Cognitive function -- (NIH Toolbox Cognition Battery (NIH TB)) - Self-reported health-related symptoms	<u>Statistical Analysis:</u> Two-sample t-test Fisher's Exact test ANOVA 95% CI <u>Results:</u> - Improved VO_{2peak} in AET group (8% vs. -4%, $p = 0.059$) - Low adherence rate - Small improvement in mood symptoms in both groups No effects on cognitive function changes for both groups	<u>Discussion:</u> Feasible to conduct exercise training and improve cardiorespiratory fitness for TBI patients in the community <u>Interpretation:</u> - Adherence is 70% due to a tailored community exercise plan - Strategies are needed to improve adherence to exercise regularly - Barriers to participating should be further investigated in future studies. <u>Limitations:</u> - Small sample size - Suboptimal compliance - Baseline cognitive performance is within normal limits

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Klyce, D. W., Pugh, M., & Perrin, P. B. (2021). Factor structure of the Modified Mini Mental State (3MS) exam among participants in inpatient neurorehabilitation. <i>Brain Injury</i>, 35(11), 1425–1432. https://doi.org/10.1080/02699052.2021.1972449	To evaluate whether the Modified Mini Mental State (3MS) Exam can predict and be used as a cognitive screening tool among TBI patients	<u>Sample:</u> 187 inpatient rehab patients with acute neurological injury/illness (116 diffuse pattern; 71 focal injury/illness) Diagnoses: TBI, stroke, hypoxic/anoxic brain injury, CNS infections, and brain tumors Gender: males 64.7%; females 35.3% Inclusion: Age > 18 years, had 3MS data in charts Timeline: 1/1/2014 – 12/31/2015 Diagnoses: TBI (41.7%, mild to severe), stroke (30.5%), hypoxic/anoxic brain injury, CNS infections, and brain tumors Exclusion: Patients had limited English proficiency, severe cognitive/linguistic dysfunction, aphasia <u>Setting:</u> Inpatient brain injury unit in Atlanta, level I trauma center	<u>Design:</u> Retrospective chart review <u>Procedure:</u> Patients' charts were reviewed and screened <u>Measurement:</u> The 3MS scores	<u>Statistical Analysis:</u> Independent sample t-tests or χ^2 tests; Confirmatory factor analysis (CFA); Exploratory factor analyses (EFA) <u>Results:</u> The CFA- poor fit indices, The EFA of the total sample - Orientation/Awareness, Learning/Recall, Executive Functioning, and Psychomotor Ability have good internal consistency The EFA of the diffuse subsample - Attention and Learning/Recall, Psychomotor Ability, and Expressive Language have good internal consistency	<u>Discussion:</u> 3MS provides information about the pattern of cognitive function in neurological injury/illness patients, especially with changes in focal areas <u>Interpretation:</u> Heterogeneous patterns of impairments could be the reason. Caution when using the tool to interpret the level of cognitive ability for focal injury/illness patients, especially during the acute phase <u>Limitations:</u> EFA results for the focal injury/illness may be affected by sample size. Other validated cognitive assessment tools should be administered to confirm the finding in the psychometric analysis.

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López, L.P., Coll-Andreu, M., Torras-García, M., Font-Farre, M., Oviedo, R. G., Capdevila, L., Guerra-Balic, M., Portell-Cortes, I., Costa-Miserachs, D., & Morris, P. T. (2024). Aerobic exercise and cognitive function in chronic severe traumatic brain injury survivors: a within-subject A-B-A intervention study. <i>BMC Sports Science, Medicine and Rehabilitation</i> , 16, 201. https://doi.org/10.1186/s13102-024-00993-4	To examine if aerobic exercise can treat cognitive impairment in TBI populations	<u>Sample:</u> 6 chronic severe TBI patients aged 24-62 years old Gender: males (5); females (1) Inclusion: Severe TBIs, at least 8 months after injury, living at home, aged 18-65 years, can engage in moderate and vigorous physical exercise, and can perform the cognitive tests Exclusion: Can't engage in exercise and perform the tests as mentioned <u>Setting:</u> Outpatient rehabilitation centers, Spain	<u>Design:</u> Single-arm within-subject study; pre- and post-test <u>Procedure:</u> An A-B-A 3 phases study: • A is an outpatient regular rehab program; • B was supervised, added-on moderate to high-intensity aerobic exercise (AE) (60-80% HR reserve) – cycling or cycling with treadmill; 3x/week, 30 min/session, 17 weeks (shortened due to COVID-19 pandemic) <u>Measurement:</u> Primary- • TMT-B • Rey-Osterrieth complex figure test • Berg's Card Sorting Test Secondary- • Physical activity	<u>Statistical Analysis:</u> Linear mixed effects models R-squared, 95% CI, Bonferroni-corrected p-values <u>Results:</u> 5 of 6 patients' TMT-B performance time was improved; 3 out of 6 improved significantly compared with phase A (mean estimate increase: 1.958%, 95% CI: 0.624, 3.29–14.63 min vs 95% CI 4.76, 24.50 min)	<u>Discussion:</u> Executive function may be improved by moderate-to-intensive aerobic exercise Physical activity engagement was improved The supervised cycling approach following routine physical rehabilitation is a feasible exercise protocol. <u>Interpretation:</u> • Adherence is low – individual behavior changes need education, supervision, and improved access • COVID-19 pandemic may affect the data collection and exercise participation • Still confident to make inferences from the results • Further studies are needed to develop exercise protocols for TBI patients <u>Limitations:</u> Not an RCT; Small sample size; Severe TBI patients have difficulty holding exercise intensity

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Plaweck, A., Henderson, C. E., Lotter, J. K., Shoger, L. H., Inks, E., Scofield, M., Voightmann, C. J., Katta-Charles, S., & Hornby, T. G. (2024). Comparative efficacy of high-intensity training versus conventional training in individuals with chronic traumatic brain injury: A pilot randomized controlled study. <i>Journal of Neurotrauma</i>, 41(7-8), 807–817. https://doi.org/10.1089/neu.2023.0494	To assess whether high-intensity training affects TBI patients' outcomes	<u>Sample:</u> 17 chronic TBI patients, Age: HIT group 46 ± 15 and Conventional group 40 ± 22 Gender: males (15) and females (2) Inclusion: aged 18-75 years, > 6 months after initial TBI, able to walk with minimal help Exclusion: Uncontrolled cardiorespiratory or metabolic disease that limited exercise participation, active heterotopic ossification, recurrent history of lower extremity fractures, previous orthopedic or other neurological injury that may affect locomotor function, history of botulinum toxin injection in the upper leg <3 months prior, and current enrollment in physical therapy <u>Setting:</u> Outpatient with supervision	<u>Design:</u> RCT - High-intensity training HIT group (9) - Conventional group (8) <u>Procedure:</u> HIT group Increase gradually, stepping practice (>70% HR reserve); 40 min x15 sessions x 4-5 weeks Conventional group Impairment-based and functional exercises with no restrictions on intensities achieved <u>Measurement:</u> 6-min walk test (6MWT) - Aerobic capacity - Peak treadmill speed - Cognitive assessments – TMT A and B; DSST - Berg Balance Scale 5-times sit-to-stand - Activities-specific Balance Confidence (ABC) scale Medical Outcomes Short Form-36 questions (SF-36) - VO_{2peak}	<u>Statistical Analysis:</u> Wilcoxon Signed Rank Tests ANOVAs Bonferroni corrections <u>Results:</u> Significantly increased 6MWT and peak treadmill speed among the HIT group vs the control group (Δ6MWT: 48 – 41 vs. -2.0 – 40 m; $p < 0.01$); No significant difference in TMT A ($p = 0.10$) and TMT B ($p = 0.08$) scores between the HIT and control group	<u>Discussion:</u> Additional assessments of cognition are needed to confirm if cognitive function has no significant changes between the HIT and conventional groups. No serious events observed, similar to previous studies using HIT <u>Interpretation:</u> HIT elicited greater improvement in 6MWT and peak treadmill speed HIT improved VO_{2peak} <u>Limitations:</u> Small study sample size Lack of blind assessors for specific tests A crossover design may block the HIT effects No specific training parameters, including intensity or specificity of stepping practice

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Shick, T., Perkins, C., Paul, A., Martinez, M., Joyce, J., Beach, K., Swahlan, J., & Weppner, J. (2025). Randomized controlled trial: Preliminary investigation of the impact of high-intensity treadmill gait training on recovery among persons with traumatic brain injury. <i>Neurotrauma Reports</i> , 6(1), 82–92. https://doi.org/10.1089/neur.2024.0169	To evaluate high-intensity gait training can enhance patient recovery after TBI	<u>Sample:</u> 9 subacute or chronic mild, moderate, and severe TBI patients aged 18-39 years old Gender: males (5); females (4) Exclusion: Unstable orthopedic conditions, unstable cardiac conditions, including unstable angina, unstable cardiac dysrhythmias, myocardial ischemia, or hypertension at rest (systolic BP >140 mm Hg and diastolic BP >90 mm Hg, unless cleared by a physician if above this range), acute systemic infection with fever, body aches, or swollen lymph glands, hospitalization for acute cardiac, pulmonary, or metabolic conditions in the past 3 months, any other physical or mental restrictions preventing participation in the research protocol, pregnancy. <u>Setting:</u> Outpatient (at clinic)	<u>Design:</u> RCT - High-intensity gait training HIGT group (5) - Low-intensity physical therapy group (4) <u>Procedure:</u> HIGT group 25 mins high-intensity locomotor training sessions (60-85% HR reserve) + 30 mins low-intensity training (30-50% HR reserve) x 12 sessions x 4-5 weeks Control group Therapeutic exercise (aerobic and strength training types) <u>Measurement:</u> 10-minute walk test 6-minute walk test - Berg Balance Scale - Timed up and go (TUG) - Cognitive assessments – MoCA - Berg Balance Scale 5-times sit-to-stand	<u>Statistical Analysis:</u> mixed-effects analysis with the restricted maximum likelihood model <u>Results:</u> - Improved mobility (5TSTS) ($p < 0.1$) - Significantly improved MoCA ($p < 0.05$) (time to complete the test) - Longer lasting on gait distance, endurance ($p < 0.05$), mobility, and cognitive attention	<u>Discussion:</u> HIGT improved fast-paced walking abilities and endurance. Future studies should consider alternative measures of balance. Uncertain whether HIGT would be beneficial to individuals who experienced a TBI within the first week <u>Interpretation:</u> High-intensity exercise may regulate brain-derived biomarkers after injury to improve cognitive function. <u>Limitations:</u> Small study sample size Relatively young study subjects Participants may engage in aerobic exercise outside of the study without the researchers' knowledge. Did not address the mechanisms explaining how exercise might affect TBI recovery

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Vargas, G. O., Neaves, S., Pham, T., Huang, M., Turki, A. F., Wang, C., Bell, K. R., Juengst, S. B., Zhang, R., Li, M., Driver, S., Behbehani, K., Hynan, L. S., & Ding, K. (2024). Community-based exercise program, self-reported health-related symptoms, and quality of life in persons with traumatic brain injury 45+ years old. <i>Neuro Rehabilitation</i> , 54 (3), 373–381. https://doi.org/10.3233/NRE-230223	To assess whether the designed exercise program affects msTBI patients' QOL and health-related symptoms	<u>Sample:</u> 20 patients, aged 46-73 yrs, chronic, msTBIs: [10 in aerobic exercise training (AET) group 10 in stretching and toning (SAT) group] Gender: males 17; females 3 Inclusion: age 45–80 years, history of msTBI, ongoing cognitive symptoms, > 1-year post-TBI, walking as a primary means of locomotion with no physical assistance, fluency in English Exclusion: Uncontrolled hypertension (> 220/120), arrhythmia, for whom their medical care providers advised not to exercise, and those who were already enrolled in structured or high levels of aerobic exercise programs <u>Setting:</u> Outpatient, in the community	<u>Design:</u> Prospective, RCT - Aerobic exercise training AET group (10) - Stretching/Toning group (10) <u>Procedure:</u> Post-hoc analysis of the same cohort to assess the OoL, cognitive health, emotional health, social health, sleep, and depressive symptoms of the two study groups pre- and post-intervention AET- exercise increased gradually, any modes of AE allowed (didn't mention target HR reserve); 150 min/week, 12 weeks SAT group Stretching and toning exercise (did not mention target HR reserve); same frequency as AET <u>Measurement:</u> - Brain Injury Quality of Life questionnaire (TBI-QOL), PHQ-9 - Pittsburgh Sleep Quality Index (PSQI) 6MWT	<u>Statistical Analysis:</u> non-parametric Mann-Whitney U test to compare the difference between the two groups, Chi-Square or Fisher's Exact test, to compare groups on dichotomous measures, Two-way ANOVA for the interaction effect of 2 groups and time <u>Results:</u> Good compliance AET had significant improvement in cognitive health ($p = 0.014$, $d = 1.21$), especially in communication skills, executive function, and sleep. Emotional/social ($p = 0.35$, $d = 0.43$/$p = 0.34$, $d = 0.38$) health and depressive symptoms were not significantly affected	<u>Discussion:</u> The AET program improved self-report cognition and sleep symptoms among chronic msTBI patients. Sleep quality improved. <u>Interpretation:</u> Aerobic exercise helps improve cognitive assessments; cardiorespiratory fitness had no significant improvement, likely related to the fact that 6 MMWT is not sensitive. Physical and mental impairments may complicate the sleep quality report. <u>Limitations:</u> Small sample size; No investigation was conducted into physiological changes that may interfere with perceived symptoms. Objective cognitive performance and sleep quality can be included. Did not study msTBI patients with notable physical disability

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Wender, C. L. A., Sandroff, B. M., Krch, D., Wylie, G., Ciriigliaro, C. M., Wecht, J., Chiaravalloti, N. D., & DeLuca, J. (2021). The preliminary effects of moderate aerobic training on cognitive function in people with TBI and significant memory impairment: A proof-of-concept randomized controlled trial. <i>Neurocase</i> , 27 (5), 430–435. https://doi.org/10.1080/13554794.2021.1990964	To evaluate whether moderate-intensity aerobic training can enhance TBI patients' cognitive function	<u>Sample:</u> 5 chronic severe TBI patients aged 27-49 years Gender: males (3); females (2) Inclusion: Age 18–55 years, severe TBI ≥1 year prior, no contraindications for MRI or exercise, right-handed, did not currently engage in ≥30 minutes of EX per week, has cognitive impairment, able to walk Exclusion: Not mentioned <u>Setting:</u> Outpatient (at clinic)	<u>Design:</u> RCT • Aerobic exercise training AET group (2) • Stretching/Toning group (3) <u>Procedure:</u> AET group Cycling (60% W), 30 min/session, 3x/week x 12 weeks Stretching/Toning group Therapeutic exercise (aerobic and strength training types) <u>Measurement:</u> • Cognitive assessments – RAVLT, SDMT • MRI • Cardiorespiratory fitness • VO_{2peak}	<u>Statistical Analysis:</u> Independent sample t-tests on pre/post <u>Results:</u> No significant difference was found between the two groups in pre- and post-change scores; however, apparent effects were observed for RAVLT ($d=1.54$) and SDMT ($d=1.58$) based on effect size estimates. increased volume in the left hippocampus ($d=1.49$) and the right thalamus ($d=1.44$)	<u>Discussion:</u> Moderate-intensity exercise may improve memory and processing speed. Exercise promotes hippocampal changes, which in turn improve learning and memory. The replication of the pilot design would be guaranteed for future studies. <u>Interpretation:</u> High-intensity exercise may regulate brain-derived biomarkers after injury to improve cognitive function. <u>Limitations:</u> Small study sample size Cardiopulmonary testing should be conducted before intervention.

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