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RESEARCH ARTICLE



# A retrospective study on the acceptability, feasibility, and effectiveness of LoveYourBrain Yoga for people with traumatic brain injury and caregivers

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## ABSTRACT

**Purpose:** To conduct a mixed methods, pre-post, retrospective study on the feasibility, acceptability, and effectiveness of the LoveYourBrain Yoga program.

**Materials and Methods:** People were eligible if they were a traumatic brain injury survivor or caregiver, age 15–70, ambulatory, and capable of gentle exercise and group discussion. We analyzed attendance, satisfaction, and mean differences in scores on Quality of Life After Brain Injury Overall scale (QOLIBRI-OS) and four TBI-QOL/Neuro-QOL scales. Content analysis explored perceptions of benefits and areas of improvement.

**Results:** 1563 people (82.0%) participated  $\geq 1$  class in 156 programs across 18 states and 3 Canadian provinces. Mean satisfaction was 9.3 out of 10 (*SD* 1.0). Mixed effects linear regression found significant improvements in QOLIBRI-OS (*B* 9.70, 95% CI: 8.51, 10.90), Resilience (*B* 1.30, 95% CI: 0.60, 2.06), Positive Affect and Well-being (*B* 1.49, 95% CI: 1.14, 1.84), and Cognition (*B* 1.48, 95% CI: 0.78, 2.18) among traumatic brain injury survivors (*n* = 705). No improvement was found in Emotional and Behavioral Dysregulation, however, content analysis revealed better ability to regulate anxiety, anger, stress, and impulsivity. Caregivers perceived improvements in physical and psychological health.

**Conclusions:** LoveYourBrain Yoga is feasible and acceptable and may be an effective mode of community-based rehabilitation.

## ARTICLE HISTORY

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## KEYWORDS

Traumatic brain injury; yoga; resilience; meditation; community-based rehabilitation; caregiver; quality of life

## ► IMPLICATIONS FOR REHABILITATION

- People with traumatic brain injury and their caregivers often experience poor quality of life and difficulty accessing community-based rehabilitation services.
- Yoga is a holistic, mind-body therapy with many benefits to quality of life, yet is largely inaccessible to people affected by traumatic brain injury in community settings.
- Participants in LoveYourBrain Yoga, a six-session, community-based yoga with psychoeducation program in 18 states and 3 Canadian provinces, experienced significant improvements in quality of life, resilience, cognition, and positive affect.
- LoveYourBrain Yoga is feasible and acceptable when implemented on a large scale and may be an effective mode of, or adjunct to, community-based rehabilitation.

## Introduction

Traumatic brain injury (TBI) is a prevalent, chronic health condition defined by wide-ranging cognitive, physical, emotional, and behavioral symptoms that compromise quality of life [1]. Each year in the United States, about 2.8 million people experience a TBI [2], which can range in severity from mild to severe. According to the World Health Organization, the ultimate goal of rehabilitation is functional independence for participation in daily living (e.g., work, leisure, community) [3]. However, across all severity levels, impairments to cognition (e.g., attention control, memory, executive functions [4]) and physical health (e.g., compromised balance [5], gait difficulties [6], weakness [7]) can make it difficult for people to engage in activities they find meaningful [8–13]. Also, psychiatric and mood disorders are common post-TBI, ranging from 6% to 77% for depression and 18% to 60% for anxiety [14]. These conditions, which are often accompanied by

poor coping strategies [15], can adversely impact quality of life for decades following the injury [16].

While evidence-based treatments for physical therapy [17], psychotherapy [18], and cognitive rehabilitation for TBI exist [19–21], they are frequently offered during shorter-term rehabilitation and are typically not available on a continuing basis in the community. This is problematic given that people are now living longer after TBI and, as a result, require ongoing rehabilitation to regain health and wellbeing [22]. Indeed, as many as 5.3 million people in the United States are estimated to be living with the challenges of long-term TBI-related disability [23]. Research has found that people with long-term disabilities, including TBI, report feeling ill-prepared for the emotional challenges of adjusting to a long-term condition and, once discharged from rehabilitation, often face isolation, difficulty identifying and accessing community services [24–26], and other unmet needs [27]. As a result, spouses, parents,

or other family members often assume a caregiving role, which is associated with a range of adverse effects, including anxiety, depression, poor physical health, and lowered quality of life [28].

Yoga is a holistic modality involving physical movement, breathing exercises, meditation practices, and moral principles that is increasingly being offered in community settings for clinical populations [29,30]. Its emphasis on mind-body connection [31] and adaptive conceptions of the self [32] may be particularly relevant to people with TBI who often continue to struggle with these areas post-injury [33]. A growing body of research has shown that yoga interventions can improve a range of outcomes from TBI (e.g., quality of life [34], physical functioning [35], emotional regulation [36], and psychological wellbeing [37]). For example, a study of 31 people with brain injury, including 26 with TBI, found that people ( $n=16$ ) who attended an 8 week yoga program in their community experienced significant improvements in Quality of Life After Brain Injury (QOLIBRI) scores, while no improvements were found among the control group ( $n=15$ ) [34]. A case study of three people with TBI who completed one-on-one yoga classes twice a week for 8 weeks found that, on average, participants had a 16% improvement in Difficulty in Emotional Regulation Scale scores and 6% improvement in QOLIBRI scores [36]. Finally, a study of 19 veterans with TBI attending weekly group-based mindfulness/yoga classes at a residential rehabilitation program found that many participants reported deep breathing as helpful for managing stress and mood [38]. Notably, none of these interventions included caregivers, although caregivers in other medical settings have benefited mentally and physically from yoga [39]. In general, group interventions for caregivers of people with brain injury offer greater benefits than individual interventions for enhancing social support [40], which is one of the strongest predictors of overall family functioning and reduced caregiver distress [41]. Therefore, group-based yoga is a potential solution to addressing a range of symptoms and effects of TBI for both the patient and caregiver, yet yoga specifically adapted to accommodate the complexity of TBI is largely inaccessible in community settings.

To address this gap, the LoveYourBrain Foundation developed a group-based yoga program for people with TBI and their caregivers in community settings. Designed based on the positive results of a pilot study [34], LoveYourBrain Yoga is a six session, manualized curriculum that includes breathing exercises, gentle yoga, guided meditation, and psychoeducation with group discussion. The ultimate goal of the program is to improve quality of life, promote community reintegration, and build skills in resilience, a quality associated with improved coping and adjustment post-injury [42,43]. As such, since 2015, the LoveYourBrain Foundation has partnered with yoga studios and trained certified yoga teachers to implement LoveYourBrain Yoga in community settings across the United States and Canada with a goal of expanding to all 50 states by 2021. LoveYourBrain employs a variety of methods to promote participation, including educating health professionals on the evidence-based benefits of yoga and how eligible patients can access the program, appointing clinical and community champions to raise awareness about the program, engaging press outlets, and participating in Brain Injury Association/Alliance conferences. A qualitative evaluation of 13 people with TBI and 3 caregivers' experience in LoveYourBrain Yoga found that participants reported diverse and meaningful physical (e.g., strength, balance, flexibility), cognitive (e.g., attention control), psychological (e.g., optimism, ability to cope with negative emotions and stress), and social health benefits (e.g. community connection) [44]. However, the qualitative design and

small sample of this study limit inferences about the acceptability and feasibility of LoveYourBrain Yoga on a larger scale and its potential effectiveness as a mode of community-based rehabilitation. Therefore, the aim of this mixed methods, pre-post, retrospective cohort study was to evaluate the acceptability, feasibility, and effectiveness of the LoveYourBrain Yoga program.

## Materials and methods

The study received approval from the Dartmouth College Committee for the Protection of Human Subjects (#31263). We adhered to the STROBE reporting guidelines for cohort studies [45].

### Design

This mixed methods, pre-post, retrospective study evaluated data collected by the LoveYourBrain Foundation before and after people participated in the LoveYourBrain Yoga program. A concurrent triangulation mixed methods design was chosen so as to be able to expand upon the quantitative data findings through collection of open-ended qualitative data [46]. Specifically, both quantitative and qualitative data were collected simultaneously, analyzed separately, and then combined to provide a richer understanding of acceptability, feasibility, and effectiveness domains.

### Participants

Participants were eligible for the study if they had participated in LoveYourBrain Yoga between September 2016 and December 2018, were 15–70 years of age, and gave their permission to LoveYourBrain for their data to be used for research purposes. Permission was requested both when participants completed the eligibility form and when they completed the feedback form, so data could have been included from just one or both forms. To be eligible for participating in LoveYourBrain Yoga, people must have self-identified as having experienced a TBI or being a caregiver of someone who experienced a TBI, were 70 years of age or younger, were ambulatory (i.e., not rely on an assistive device for movement), had not been told by a medical professional to avoid gentle exercise, were open to participating in group discussion, and could follow instructions.

### Intervention

Since 2015, the LoveYourBrain Foundation has offered a free, 6-week yoga with psychoeducation program for groups of individuals with a TBI and caregivers. Detailed information about the curriculum design can be found elsewhere (curriculum available upon request) [44]. Briefly, each class is 1.5 h and has a specific structure: 10 min of breathing exercises (pranayama) to calm the nervous system, 45 min of gentle yoga (asana) to improve strength, flexibility, and balance, 15 min of guided meditation to enhance attention control, emotional regulation, and self-efficacy, and 20 min of facilitated discussion with psychoeducation to cultivate skills in resilience. Psychoeducation involves the provision of information and activities to enable patients to better understand and cope with their injury [47], which, in this context, included didactic material, question prompts, and exercises (i.e., role model identification, mental flexibility, realistic optimism, facing fear, social support, meaning and purpose) to build skills in resilience and community connection [48].

Two experienced certified yoga teachers from LoveYourBrain conduct 18-h trainings for certified yoga teachers to learn how to deliver the curriculum in yoga studios that partner with LoveYourBrain. To teach the curriculum, yoga teachers must have a minimum of a 200-h yoga teacher certification, have experience teaching gentle yoga, meditation, and pranayama, have experience or a strong interest in teaching people with TBI and physical and/or cognitive limitations, complete an assessment following the training, complete a professional conduct agreement, and have insurance. LoveYourBrain pays one primary and one assistant teacher to teach each program. The curriculum is outlined in a manual that teachers use to guide each class as a strategy to promote intervention fidelity. LoveYourBrain also requires the primary teacher to submit an audio recording of themselves teaching the first class to LoveYourBrain staff for feedback and schedule 'mentorship calls' after the first, third, and final class to discuss any unforeseen challenges and receive individualized support. Programs are offered four times a year and only run if a minimum of seven participants sign up to ensure sufficient participation for a meaningful group discussion and for LoveYourBrain's financial viability. A maximum of 13 people are allowed to facilitate equitable participation in the group discussion and to maintain a low student to teacher ratio. People can participate in the series multiple times at no cost.

LoveYourBrain is intentional about partnering with yoga studios dedicated to offering inclusive, accessible yoga that meet certain Americans with Disabilities Act standards (e.g., ground-level or elevator access) and environmental conditions (e.g., low lighting, minimal noise, not very crowded), commit to offering the LoveYourBrain Yoga four times a year, nominate four or more certified yoga teachers to attend the LoveYourBrain Yoga teacher training, and appoint a program champion to maintain communications with LoveYourBrain staff. Population density and access to public transportation are also key considerations, with strong preference for locations that have sufficient demand (i.e., if located rurally, must be near a neurorehabilitation facility that offers outpatient services for TBI). Once a partnership is established, which includes signing a Memorandum of Understanding and Liability Waiver to clarify partnership expectations and roles, LoveYourBrain conducts a site visit to cultivate relationships with the yoga studio program champion, owner/manager, staff, and yoga teachers and provide an hour-long training on key program goals and logistics (e.g., program scheduling, attendance tracking and reporting, etc.).

### **Measures and data collection**

Data included in this study comprised self-reported quantitative and qualitative data collected electronically in eligibility and feedback form surveys. Specifically, to participate in LoveYourBrain Yoga, people are required to complete an electronic eligibility form (see [Supplementary Appendix](#)) up to 6 weeks before the start of the program. This form takes approximately 10–15 min to complete and asks prospective participants to answer questions about their eligibility for the program, demographic characteristics, injury history, five clinical outcomes, where they learned about the program, and whether they give LoveYourBrain permission to use their data for research purposes, and to provide a waiver of liability. At the end of the program, participants who took one or more classes are sent an electronic feedback form and asked to complete it within 3 weeks. The feedback form takes about 10 min to complete and includes the same five outcomes assessed in the eligibility form. Unique questions are presented to

participants who completed the program (defined by LoveYourBrain as those who took at least four out of six classes) including the perceived program quality, benefits, and areas for improvement, as well as to people who do not complete the program (defined as those who attended less than four classes), including why they did not complete the program. Feedback forms are not sent to participants who were "no shows" or canceled before the program started. Participants received two automated follow-up emails requesting that they complete the feedback form at 1 week intervals.

### **Sociodemographic characteristics and injury history**

The LoveYourBrain Yoga eligibility form collected data on age, gender, and whether the participant identified as a TBI survivor or caregiver. People who experienced a TBI were asked to report age at injury, etiology of injury [23], injury severity (i.e., mild, moderate, or severe), and duration of loss of consciousness [23]. They were also asked to respond to the question, "Do you currently experience any of the following conditions?" with an option to select any of the following symptoms: light sensitivity, hemiparesis, post-traumatic stress or PTSD, paralysis on one side of the body, post-concussion syndrome, and/or seizures.

### **Feasibility**

Feasibility is defined as the extent to which an intervention can be successfully conducted within a specific setting as reflected by participation and retention rates [49]. To assess feasibility of LoveYourBrain Yoga, we described the total number of people who signed up, the number of classes attended by participant (i.e., 1–6 classes), the number of participants who canceled or were "no shows", the number of participants who participated more than once, the mean attendance per program, the number of programs offered, the number of programs canceled due to low enrollment (i.e., less than seven people), and the mode of referral to the program. The LoveYourBrain Foundation also provided information on the number and location of yoga studios that offered the program and that stopped offering the program during the study timeframe.

### **Acceptability**

Acceptability is the perception among implementation stakeholders that components of the intervention (e.g., content, complexity, or comfort) are agreeable or satisfactory [49]. To assess participants' perceptions of the acceptability of LoveYourBrain Yoga, participants who had completed at least four out of the six classes were asked to respond to the question, "On a scale from 1 to 10, how would you rate this series?" (1 'poor'–10 'excellent'). These participants were also to respond to open text questions about their (i) perceptions of the benefits of participating (What are three things you found most helpful from this series? Did you notice any impact on the day-to-day quality of life of the person with a TBI whom you support? Did you notice any impact on your day-to-day quality of life?), and (ii) and perceptions of any areas for improvement (What are three things you feel could be improved about this series?). Participants who had taken less than four out of the six classes were asked to respond to the question, "Why did you not attend or complete the LoveYourBrain Yoga program?", by selecting among four options (i.e., "My schedule changed", "I experienced medical complications that I didn't anticipate", "I didn't like the class", "I changed my mind and

decided it wasn't for me", "I couldn't find transportation") or to select "other" and input their reason.

### **Effectiveness**

Five self-reported clinical outcomes were used to assess the effectiveness of LoveYourBrain Yoga for people with TBI. Outcome data were not collected for caregivers due to the limitations in reliability and validity of health-related quality of life outcomes specific to caregivers of the TBI population at the time of study design [50].

### **Quality of life**

Quality of life was assessed using the Quality of Life After Brain Injury overall scale (QOLIBRI-OS), which has good reliability (Cronbach's  $\alpha = 0.86$ , test-retest reliability = 0.81) in patients with TBI [51]. Participants were presented with an opening statement, "These questions are about how you feel overall *now (including in the past week)*" and rated 6 questions on a 1–5 Likert scale (1 "Not at all", 2 "Slightly", 3 "Moderately", 4 "Quite", and 5 "Very"). The responses were summed to give a total, then divided by the number of responses to give a scale mean (range 1–5), and finally converted to a 0–100 scale.

### **Emotional and behavioral dysregulation**

Emotional regulation defined as 'set of disease and/or treatment related to manifestations including disinhibition, emotional ability, irritability, impatience, and impulsiveness', was assessed using the Emotional and Behavioral Dysregulation v1.0 SF8 from the Neurology Quality-of-Life measurement initiative (Neuro-QOL), a psychometrically robust outcomes tool in clinical trials research and includes item banks assessing Physical, Emotional, Cognitive, and Social Health [52]. Participants were presented with an opening statement, "In the past seven days..." and rated 8 questions on a 1–5 Likert scale (1 "Never", 2 "Rarely (once)", 3 "Sometimes (two or three times)", 4 "Often (about once a day)", and 5 "Always (several times a day)").

### **Cognition**

Cognition, defined as 'perceived difficulties in cognitive abilities (e.g., memory, attention, and decision making), or in the application of such ability to everyday tasks (e.g., planning, organizing, calculating, remembering and learning)', was assessed using the Cognition: General Concerns v1.0 SF10a from the TBI-QOL [53]. TBI-QOL are a set of self-report measures adapted from the Neuro-QOL measures specific to the TBI population. TBI-QOL item banks have demonstrated validity [54], responsiveness to change, and measurement stability [55]. Participants were presented with an opening statement, "In the past seven days..." and rated 10 questions on a 1–5 Likert scale (5 "Never", 4 "Rarely (once)", 3 "Sometimes (two or three times)", 2 "Often (about once a day)", and 1 "Always (several times a day)").

### **Positive affect and well-being**

Positive affect, defined as 'aspects of a person's life that relate to a sense of well-being, life satisfaction or an overall sense of purpose and meaning', was assessed using the Positive Affect and Well-being v1.0 SF 9a from the TBI-QOL. Participants were presented with an opening statement, "Lately..." and rated

9 questions on a 1–5 Likert scale (1 "Never", 2 "Rarely", 3 "Sometimes", 4 "Often", and 5 "Always").

### **Resilience**

Resilience, defined as the ability to adapt to and/or overcome adversity [48], was assessed using the Resilience v1.0 SF 10a from the TBI-QOL. Participants were presented with an opening statement, "Lately..." and rated 10 questions on a 1–5 Likert scale (1 "Never", 2 "Rarely", 3 "Sometimes", 4 "Often", and 5 "Always").

For all TBI-QOL scales, the internal consistency is good, ranging from Cronbach's  $\alpha$  of 0.952 to 0.974 [53]. The raw scores were summed and then converted to a T-score, and a higher score represents better functioning.

### **Data analysis**

#### **Quantitative analysis**

Analyses of feasibility and acceptability included people who submitted an eligibility form and/or a feedback form. To analyze feasibility, we used descriptive statistics to report attendance, the number of programs offered and canceled, the mode of referral, and yoga studio participation. Based on LoveYourBrain's minimum requirement of seven participants to operate a program, we considered LoveYourBrain Yoga to be feasible if at least 80% of programs met this threshold. To analyze acceptability, we used descriptive statistics to assess the mean quality rating overall and separately for people with TBI and caregivers. We considered LoveYourBrain Yoga to be acceptable if the mean satisfaction rating was at least 8.0 overall and per subgroup. We used descriptive statistics to describe the reasons why people reported not completing the program.

Analyses of effectiveness comprised non-missing, linked outcome data in eligibility and feedback forms from unique participants with TBI. If people had missing outcome data (e.g., due to failure to submit a feedback form, permission not granted for data to be used for research on either the eligibility form or the feedback form) participants were excluded listwise. If people participated in a program more than once, data from their first time participating were included and data from subsequent times were excluded. For each of the five outcomes, we conducted univariate linear regression to assess significant differences in mean scores across time. We then conducted mixed effects linear regression to control for demographic and injury-related characteristics. We tested interactions between each of the covariates and time to examine whether the effects were moderated by demographic and injury-related characteristics. To account for the multiple comparisons, statistical significance was assessed at a  $p < 0.01$  level [56]. All analyses were conducted using Stata 15.

#### **Content analysis**

We used directed content analysis to explore the themes from open text responses to questions about caregivers' and TBI survivors' perceptions of the program's benefits and areas of improvement [57]. In a directed content analysis, initial coding categories are derived from an existing theory or prior research, rather than exclusively from the text. Specifically, the themes identified in the qualitative evaluation of the LoveYourBrain Yoga program (i.e., ease of participation, belonging, sustaining community connection, physical health, self-regulation, self-efficacy, and resilience) [44] informed the initial coding structure used to explore participants' perceptions of how they personally benefited and how



their experience could have been improved. We also explored caregivers' perceptions of how the person with a TBI whom they supported benefited and whether TBI survivors' perceived benefits were consistent with or deviated from the quantitative findings. Qualitative data was analyzed in Dedoose version 8.1.8.

Two members of the research team (KZD and AS) immersed themselves in the data and collaboratively expanded upon the initial coding structure. This process was intended to ensure consistency in the interpretation of the data and also to include the perspectives of a researcher with content expertise in adapting yoga for TBI (KZD) and a researcher with expertise in qualitative research (AS). The resulting coding framework was applied separately to each group whereby AS coded all caregiver text responses and KZD coded all TBI survivor text responses. The research team iteratively expanded and refined the coding structure and emerging themes, and met periodically to compare their findings, share perspectives, and reconcile discrepancies. Content memos were kept to define the codes and methodological memos were written at the end of each coding session to track analytic development. The final interpretation and descriptions of the codes and emerging themes were presented to a third researcher not involved in data analysis for an inquiry audit [58]. The authors then compared and integrated these findings with the quantitative results by using the qualitative data to illustrate, triangulate, and further expanded upon quantitative effects [59]. We applied Lincoln and Guba's criteria for enhancing the trustworthiness of our qualitative data analysis and interpretation [60]. Specifically, to address credibility, we triangulated data from quantitative and qualitative sources and from participants with TBI and caregivers, and used peer-debriefing/inquiry audit. For transferability, we provided thick descriptions of the LoveYourBrain Yoga program delivery context and process. To address dependability, we maintained an audit trail to keep notes about decisions made during data analysis (e.g., trends and interpretations of themes and subthemes) [60].

## Results

### Feasibility

Over the study timeframe, LoveYourBrain trained yoga teachers from 45 yoga studios to offer the LoveYourBrain Yoga program in three provinces in Canada (i.e., Quebec, Manitoba, Ontario), and 18 states in the United States, including six in the Northeast (i.e., Massachusetts, New Jersey, Pennsylvania, Vermont, New York, New Hampshire), two in the South (i.e., Virginia, Georgia), five in the Midwest (i.e., Nebraska, Michigan, Colorado, Texas, Illinois), and five in the West (i.e., New Mexico, California, Washington, Oregon, Arizona). Factors that contributed to successful partnerships included an engaged program champion, typically due to a personal connection to TBI (either direct experience or close friend/family), achieving high attendance, which served as a motivator to the yoga teaching team, and LoveYourBrain Foundation staff managing communications and program implementation processes (e.g., registration, questions from potential students), which minimized logistical burden on yoga studios. Partnerships were ended with six yoga studios. LoveYourBrain chose to end partnerships with three yoga studios located in rural areas because they did not experience sufficient demand. One studio closed for financial reasons. Two studios chose to end the partnership with LoveYourBrain because they were not satisfied with their involvement in the program.

Our of a total of 168 programs that were opened for registration, 156 programs were successfully implemented (92.9%) and 12

were canceled (7.1%) due to low enrollment. Overall, 2050 people signed up for the LoveYourBrain Yoga, including 1905 people who were eligible for this study. People most often reported that they had heard about the program from a family or friend, from a health care professional, LoveYourBrain website or social media, brain injury support group, or a yoga studio. 1565 of eligible people had signed up for the program once, 246 people had signed up twice, 61 people had signed up three times, 30 people had signed up four times, and three people had signed up five times. Eighty two percent ( $n = 1563$ ) of eligible people who signed up had participated in at least one class, while the remaining 18.0% ( $n = 342$ ) canceled or were "no shows". Specifically, 21.7% ( $n = 414$ ) people had attended six classes, 20.2% ( $n = 385$ ) people had attended five classes, 15.5% ( $n = 296$ ) people had attended four classes, 7.9% ( $n = 151$ ) people had attended three classes, 6.7% ( $n = 128$ ) people had attended two classes, and 9.9% ( $n = 189$ ) people had attended one class. The mean class attendance was 7.3 people ( $SD 2.3$ ).

Content analysis revealed that participants most commonly reported barriers to accessing the program if it was scheduled during work hours, peak traffic, or too early in the morning, and if the location required a far commute (i.e., over an hour of driving), which triggered symptoms for people with TBI. In contrast, a few participants noted that their success in navigating public transportation was empowering. As one participant shared, "being able to take public transportation to class during rush hour was a massive accomplishment!!! Gave me hope that I will be able to tackle other everyday tasks with better success!" The factors most commonly reported to facilitate participants' involvement included that the program was free of cost, had a weekly routine schedule that kept people accountable, had two instructors to provide additional support (e.g., modification suggestions, props, demonstrate the poses, gentle touch), and provided email communications reminding them to attend.

### Acceptability

The LoveYourBrain Foundation sent 1671 feedback forms to all people who had attended one or more classes. 68.5% ( $n = 1145$ ) of people submitted a feedback form, including 1124 people who were eligible for this study. 1116 of eligible people had participated in the program once and eight people had participated twice. People who attended at least four out of six classes ( $n = 1095$ ) had been asked to rate the quality of the program. On average, the satisfaction with the program was rated 9.3 out of 10 ( $SD 1.0$ ), which was similar in both groups: 9.3 for people with TBI and 9.4 for caregivers. People who attended less than four classes ( $n = 468$ ) had been asked to report a reason for low attendance, of whom 43.3% ( $n = 203$ ) of this group gave a reason, including, most commonly, scheduling conflict ( $n = 77$ , 37.9%), unanticipated medical complications ( $n = 57$ , 28.0%), and, least commonly, dissatisfaction ( $n = 7$ , 3.4%).

Content analysis revealed that the program was highly acceptable to participants, particularly the integration of movement, relaxation, group conversation, and meaningful quotes. TBI survivors frequently mentioned the perceived safety of the program environment, including the welcoming, non-judgement tone of the teachers, and the exclusivity of the program to only people from the TBI community, which was perceived to foster a depth of social connection. As one participant shared, "it was great to get out of the house and be in a 'safe' environment where I didn't have to explain my little TBI quirksness." They also shared a range of accommodations that enabled them to practice safely

and without exacerbating symptoms, including certain modifications (e.g., keeping head above heart to avoid forward folds, minimizing movement of the head, such as when moving from cat pose to cow pose), use of props (e.g., chairs to avoid transitions from standing to floor, blankets under the head in supine positions, such as bridge pose, to reduce pressure or pain, blocks to facilitate transitioning from all fours to standing, and the wall to support balance poses like tree), the slow, step-by-step, and repeated instruction, use of landmarks instead of 'left' and 'right' (e.g., "leg closest to the windows"), and the gradual build up to more challenging poses. For some people, LoveYourBrain Yoga was the first non-medical activity they had participated in since their TBI occurred, which generated an immense sense of accomplishment and normalization.

While some participants had no suggested improvements to the program, of those who did, a majority recommended either increasing the program to 8 weeks, extending the class duration to allow more time for group discussion, or improving environmental factors, such as regulating the temperature, minimizing noise, keeping the light low (or encouraging people to bring earplugs or wear sunglasses). A few participants with more recent injuries shared that, even with the modifications, some of the poses caused dizziness, nausea, discomfort, and/or cognitive fatigue, and suggested shorter classes with more breaks, minimizing pressure on the forehead or back of the head by using blankets, or incorporating more restorative poses. In contrast, a small group of participants suggested a more challenging class that incorporated more physically rigorous and diverse sequences. Occasionally, participants expressed frustration with people whose behavior was distracting (e.g., speaking out during meditation) or intrusive (e.g., talking too much during the group discussion at the expense of others). As one caregiver explained, "It's a very emotionally charged group and I often felt bad for those trying to share and someone at a different phase in their journey would intervene in a way that may have felt abrupt."

### Effectiveness

A total of 857 people, including 152 caregivers and 705 people with TBI, submitted both eligibility and feedback forms with non-missing outcome data from the first time they had participated in LoveYourBrain Yoga.

### Caregivers

The 152 caregivers were predominantly female (84.9%,  $n = 129$ ) and on average were 49 ( $SD = 13.1$ ) years old. Content analysis found that caregivers most commonly perceived improvements in their ability to relax, in their sleep quality, and in their physical strength from participating in LoveYourBrain Yoga. Some caregivers also reported enhanced self-care from making time for themselves during the yoga practice. One caregiver explained, "I came out feeling so cared-for and grounded, and eager to do more activities that cultivated my bodily awareness". Some caregivers, notably more men than women, reported increased compassion for people with TBI, which they described as a greater understanding of the challenges faced from living with a TBI. Finally, LoveYourBrain Yoga sometimes served as a unique bonding experience for caregivers and TBI survivors in spousal relationships, with one caregiver describing that it was the one activity they could do together that was not related to "business," such as medical appointments or therapy.

Table 1. Demographic characteristics and injury history for people with TBI in the analyses of effectiveness ( $n = 705$ ).

Characteristic	Freq. (%)
Age	
15–34	213 (30.3)
35–54	326 (46.3)
55–70	165 (23.4)
Missing	1
Sex	
Male	173 (24.6)
Female	530 (75.4)
Missing	2
Severity	
Mild	326 (46.3)
Moderate	181 (25.7)
Severe	197 (28.0)
Missing	1
Duration of loss of consciousness	
None	295 (42.2)
Less than 30 min	166 (23.8)
30 min–1 day	37 (5.3)
More than 1 day	117 (16.7)
Not sure	84 (12.0)
Missing	6
Etiology of TBI	
Assault	29 (4.3)
Fall	127 (18.6)
Motor vehicle accident	245 (35.9)
Sports-related	101 (14.8)
Struck by or against	104 (15.2)
Work-related	31 (4.5)
Other	46 (6.7)
Missing	22
Years since injury (mean $SD$ )	4.8 (7.7)

Some caregivers reported observing improvements in functioning in the person with TBI for whom they cared, such as stress reduction, decreased anxiety, better sleep, and greater confidence when speaking with others. However, two caregivers mentioned that the person with TBI whom they accompanied to the program had negative experiences during the yoga classes, but did not elaborate. There were also reports that caregivers noticed TBI survivors using tools learned in the program in daily life, such as taking deep breaths to calm down and/or regulate intense emotions.

### People with TBI

The 705 participants with TBI (see Table 1) were on average 43 years of age ( $SD = 12.8$ ) and had experienced their injury on average 4.8 ( $SD = 7.7$ ) years previously. The demographic and injury characteristics of these participants were comparable to non-responders (i.e., those who did not submit a feedback form and/or had missing outcome data). Most people ( $n = 618$ ) reported a variety of symptoms, including post-concussion syndrome ( $n = 438$ , 62.1%), photophobia ( $n = 434$ , 61.6%), seizures ( $n = 38$ , 5.4%), paralysis ( $n = 14$ , 2.0%), PTSD ( $n = 229$ , 32.4%), and hemiparesis ( $n = 107$ , 15.2%). A minority ( $n = 87$ , 12.3%) reported none of the above symptoms.

Univariate analyses found that the 705 participants with TBI experienced significant improvements in their scores on the QOLIBRI-OS ( $M = 44.9$  ( $SD = 17.6$ ) to  $M = 54.6$  ( $SD = 17.6$ ),  $p < 0.0000$ ), Resilience ( $M = 45.1$  ( $SD = 2.8$ ) to  $M = 46.4$  ( $SD = 2.8$ ),  $p = 0.0004$ ), Cognition ( $M = 34.4$  ( $SD = 1.9$ ) to  $M = 35.9$  ( $SD = 1.8$ ),  $p < 0.0000$ ), and Positive Affect and Well-being measures ( $M = 48.8$  ( $SD = 2.0$ ) to  $M = 50.3$  ( $SD = 2.0$ ),  $p < 0.0000$ ) from baseline to post-intervention. No significant improvements were found in Emotional and Behavioral Dysregulation over time ( $M = 52.5$  ( $SD = 2.5$ ) to  $M = 52.5$  ( $SD = 2.5$ ),  $p = 0.9997$ ). After controlling for

**Table 2.** Multivariate linear regression analyses of effectiveness of participating in LoveYourBrain Yoga on QOLIBRI-OS, resilience, positive affect and well-being, and cognition.

Outcome	QOLIBRI-OS		Resilience		Positive affect and well-being		Cognition	
	<i>B</i>	95% CI	<i>B</i>	95% CI	<i>B</i>	95% CI	<i>B</i>	95% CI
Time								
Baseline	Ref		Ref		Ref		Ref	
Post-intervention	9.70***	8.51, 10.90	1.30**	0.60, 2.06	1.49***	1.14, 1.84	1.48***	0.78, 2.18
Age								
15–34	Ref		Ref		Ref		Ref	
35–54	−4.79***	−7.43, −2.15	−0.81	−1.67, 0.06	−0.75	−1.67, 0.18	−1.38***	−2.21, −0.56
55–70	−0.56	−3.78, 2.66	0.17**	−0.89, 1.22	−0.42	−1.55, 0.70	−0.55	−1.55, 0.45
Sex								
Female	Ref		Ref		Ref		Ref	
Male	−0.95	−3.69, 1.80	0.04	−0.86, 0.93	0.02	−0.94, 0.98	−0.43	−0.94, 0.98
Severity								
Mild	Ref		Ref		Ref		Ref	
Moderate	−2.16	−4.41, .097	−0.61	−1.52, 0.30	−0.60	−1.58, 0.37	−.86	−1.73, 0.01
Severe	4.91***	2.75, 7.06	1.38**	0.43, 2.34	1.35**	0.33, 2.38	1.77***	0.86, 2.68
Years since injury	0.08	−0.08, 0.24	0.08	.02, 0.13	−0.003	−0.06, 0.05		
#Classes taken								
1	Ref		Ref		Ref		Ref	
2	−1.77		−0.63	−2.82, 1.55	−0.85	−3.19, 1.49	−1.97	−4.05, 0.11
3	−1.80		−0.16	−2.22, 1.91	−0.64	−2.85, 1.57	−0.53	−2.50, 1.43
4	−3.18		0.08	−1.75, 1.90	−1.08	−3.04, 0.89	−0.78	−2.53, 0.96
5	−2.12		−0.57	−2.33, 1.18	−0.93	−2.80, 0.95	−1.44	−3.11, 0.23
6	−3.05		−0.08	−1.81, 1.66	−0.62	−2.48, 1.24	−2.26	−3.91, −0.60

*p* Values \*0.05; \*\*<0.01; \*\*\*<0.001.

Note. Numbers differed across analyses due to missing data. Sample sizes ranged from 696 to 705.

age, injury severity, gender, years since injury, and number of classes taken, people who participated in LoveYourBrain Yoga continued to demonstrate significant improvements in their scores on the QOLIBRI-OS, Resilience, Positive Affect and Well-being, and Cognition measures (see Table 2).

For the QOLIBRI-OS, there was a significant interaction between people 55 and 70 years of age and time (*B*: −6.79 95% CI: −11.76, −1.8, *p* = 0.007), suggesting that the positive impact of LoveYourBrain Yoga on quality of life may be less for older people as compared to younger people. For Positive Affect and Well-being, there was a significant interaction between gender and time (*B*: 0.82 95% CI: 0.01, 1.62, *p* = 0.047), suggesting that the impact of LoveYourBrain Yoga on positive affect may be slightly more for women as compared to men. No significant interactions were found between time and covariates for Resilience or Cognition.

Similarly to the quantitative analysis, content analysis found that people with TBI perceived improvements in their quality of life, positive affect, resilience, and cognition. For example, participants commonly reported developing a more positive, joyful, grateful, and hopeful mindset and feeling greater self-worth, confidence, agency, and self-acceptance. As one participant shared,

It's been integral to my healing and added so much value/perspective to my life. Even if I never return to my former self, I still have so much worth and value to offer to the world and I think this program helped me to realize that.

The opportunity to connect with and learn from others affected by TBI brought immense comfort to a majority of participants. People often reflected how valuable it was for them to normalize their TBI experience, to feel no longer "alone", and to gain new perspective about the healing process. As one participant shared,

One of the things I learned during the series was to not think about 'recovering' (i.e., going back to who I was) but rather to focus on rebuilding. Focusing my energy and thoughts on how I can put my life back together in a way that's even healthier and happier than before. This changed my life.

Finally, some people with TBI reported cognitive improvements in their memory, concentration, and self-awareness.

In addition, content analysis found that people with TBI often perceived physical improvements, specifically in their balance, strength, flexibility, mobility, pain management, overall energy, and confidence in their physical abilities. One participant shared, they experienced:

a general brain clarity along with a new capacity for physical activity. Because of the LoveYourBrain program, I was able to overcome my concerns and push myself physically. It's been so lovely to be active again and feel confident that I'm not hurting myself anymore.

For some, the pairing of greater physical confidence and self-efficacy translated into greater motivation to participate in other activities in the community, pursue work, and engage socially. Lastly, improvements in symptoms, including auditory sensitivity, sleep disturbances, headache, "brain fog", dizziness, and chronic pain were also reported.

In contrast to the quantitative findings, it was common for people with TBI to report improvements in their emotional and behavioral dysregulation. Specifically, people reported feeling better able to regulate anxiety, anger, stress, and impulsivity. Some of the components of the program, like mindfulness, breathing exercises, self-compassion, and positive reframing, were also mentioned as helpful tools that people used when faced with challenging situations or overwhelming environments. As one participant explained "the ability to sense when my body was getting stressed allowed me to note the stress instead of just acting on impulse".

## Discussion

LoveYourBrain Yoga was successfully delivered to 1563 people with TBI and caregivers in 45 yoga studios across 18 states and three Canadian provinces, and produced statistically significant improvements in quality of life, resilience, positive affect, and cognition among those living with TBI who participated in the



program. These findings have several implications. First, improvements in clinical outcomes suggest that LoveYourBrain Yoga may be an effective mode of, or adjunct to, community-based rehabilitation for TBI. For instance, enhancing resilience among people with TBI is associated with increased motivation and capacity to manage symptoms and to improved functional outcomes [61–63]. Employment status, social engagement, and overall wellbeing have also been associated with some of the psychosocial and cognitive improvements reported by participants in this study, including optimism [64], memory [65], attention [66], and self-awareness [67]. Notably, these diverse improvements were not moderated by TBI severity or years since injury, which supports the generalizability of the results and accessibility of the program. However, efforts to further adapt LoveYourBrain Yoga for older people and men, who benefited less from LoveYourBrain Yoga, may be important given that these groups are particularly susceptible to TBI [68]. Further research should investigate whether women, who traditionally predominate the yoga industry [69], may have different perceptions of yoga's benefits [70] and symptom experience [71] than the men who participate in LoveYourBrain Yoga, and whether the increased likelihood of pre-existing comorbidities (e.g., less joint range of motion, frailty, poorer balance) among older adults [72] may make a mat-based yoga practice (as taught most commonly in the LoveYourBrain Yoga program) less appealing. If so, yoga teachers could offer exclusively chair yoga for older adults and more explicitly engage men in setting goals for how they want to benefit from the program [73]. Because the diverse benefits of LoveYourBrain Yoga occurred following a format of six, weekly, 1.5 h classes, in contrast to other more intensive yoga interventions (e.g., 8, biweekly, 1 h classes [34,36]; 36, weekly, 30 min [37]), additional research on the comparative effectiveness of this intervention is warranted.

Our findings also suggest the LoveYourBrain Yoga may enhance adjustment to life with TBI for both caregivers and those living with the injury, which has implications on improving quality of life [15]. For example, people with TBI commonly reported that they developed a more compassionate, patient, and accepting perspective about themselves and their abilities, which previous research has found to be crucial to coping with the injury [74,75]. While we did not find significant changes in Emotional and Behavioral Dysregulation scale scores, content analysis revealed many participants perceived increased self-awareness and use of breathing exercises enabled them to better manage anger, anxiety, stress, and impulsivity in daily life, which is consistent previous yoga research [36,44,76]. Other group-based interventions with psychoeducation and skills building components for people with TBI that have found significant improvements in emotional and behavioral regulation have been longer in duration (e.g., 24 sessions [77], 8 sessions [78]) suggesting that future research should consider expanding the duration of LoveYourBrain Yoga beyond six sessions. However, the discrepancy between our quantitative and qualitative results could also be explained by our use of a brief 8-item scale, which may not have had sufficient sensitivity to capture meaningful differences in the wide variety of emotional and behavioral problems that can manifest post-injury (e.g., internalizing emotional problems such as depression or anxiety as well as externalizing problems such as aggression) [79], as compared to more comprehensive measures (e.g., 36-item Difficulties in Emotion Regulation Scale [80]) that have shown significant changes in this outcome in other TBI-specific yoga and mindfulness research [36,76]. Our study also found that caregivers observed changes in the ability of the person with TBI to self-regulate, which is important given that behavioral and emotional

changes of the patient are strong predictors of subjective caregiver burden [81]. Caregivers also reported personal physical and psychosocial benefits from participating in LoveYourBrain Yoga, whereas other interventions designed to support or involve caregivers have produced mixed results [82]. The psychosocial health of the caregiver has a reciprocal relationship with the individual who is under their care [83], thus caregivers' perceived gains in relaxation, sleep quality, social engagement, and relationship connection may have far reaching impacts on family functioning [41]. These qualitative findings point to the importance of using caregiver-specific outcomes of quality of life [50] as a topic of future research to more reliably investigate the effectiveness of LoveYourBrain Yoga for this group.

High attendance and satisfaction ratings suggest LoveYourBrain Yoga is acceptable and feasible to implement on a large scale in diverse locations, which has implications on the delivery of community-based rehabilitation services more broadly. In particular, participants reported that the program's lack of cost, weekly routine, acceptance of and adaptability to individual needs, and combination of structured movement, relaxation, and peer support from people with shared experiences of TBI and/or caregiving facilitated successful social participation and motivated them to engage in other community activities. These findings align with other research that has called for rehabilitation efforts to focus on enabling people with TBI to engage in activities that promote social participation, which, in turn, can improve their ability to reintegrate into their community and their quality of life [84,85]. While group rehabilitation is typically highly acceptable to people with TBI [86] and may confer benefits over individualized therapy (e.g., normalization, reduced isolation, enhanced awareness of impairments [87–89]), group rehabilitation interventions are rarely designed for people with TBI and caregivers together and often target singular outcomes (e.g., resilience [90], coping skills [91], communication [92], reduced caregiver burden [93]) instead of being holistic. This is a problem because the biopsychosocial model—the leading model in rehabilitation care—endorses providing physical, psychological, social, emotional, and motivational components as best practice for advancing functional independence [94]. Research has also found that rehabilitation services delivered to individuals with TBI and their caregivers within their local environment maximizes community reintegration [84,95,96] and may even mitigate post-acute cognitive decline [97,98]. To address the few reported cases of negative experiences, yoga teachers may benefit from additional training on modifications used in other TBI group yoga/mindfulness interventions to manage behavioral challenges (e.g., ignoring/re-orienting [38]), to accommodate vestibular symptoms (e.g., providing more seated/chair options for postures [38]), and to address memory deficits (e.g., visual aids, recommending out-of-session practice, simplifying language [99]). Taken together, our results suggest that LoveYourBrain Yoga has potential to help address the dearth of community-based services that address multiple complications of TBI [25,26] and caregiver distress [82].

There are several limitations of this study. First, the pre-post, single-arm design is subject to confounding, therefore we recommend future studies utilize more robust study designs, such as a randomized controlled trial, to more reliably assess the extent to which outcome changes can be attributed to the intervention [100]. Second, the convenience sample comprised people who chose to sign up for LoveYourBrain Yoga on their own volition, therefore the results may be generalizable to only people who are motivated to participate in holistic health programming. Third, despite receiving three reminder emails, the cohort of participants

who did not respond to the feedback form may have introduced non-response bias. However, the injury and demographic characteristics of the non-responders were comparable to study participants, suggesting that non-response bias may not have been a concern. Fourth, due to the retrospective study design, we were not able to include caregiver-specific outcomes of quality of life [50], well-established measures of community reintegration [101] and TBI symptoms (i.e., post-concussion syndrome [102], PTSD) or a follow-up assessment to examine maintenance of improvement for people with TBI. Therefore, additional research is needed to investigate the longer term effectiveness of LoveYourBrain Yoga, including for caregivers, and the prevalence and association of symptoms with participants' experience [71] using validated measures. Finally, because the data was collected outside of a research setting, we were unable to ascertain if a caregiver helped people with TBI respond to the survey, which may have biased their answers. These limitations, however, are balanced by several strengths. First, our study included a large sample size and diverse levels of TBI severity, which enhances the generalizability of our findings and addresses concerns about external validity in previous yoga research for this population [36]. It was also conducted in a 'real world' setting, therefore maximizing the ecological validity of the results and avoiding volunteer bias intrinsic to randomized controlled trials [103]. Second, although the adaptable and individualized nature of yoga itself makes it problematic to adapt into a scientific setting [104], several strategies (i.e., audio recorded classes, periodic oversight through 'mentorship calls') were employed to promote delivery of the intervention as intended. Notably, the manualized format for LoveYourBrain Yoga is an effective strategy for ensuring fidelity [105] and for facilitating knowledge translation in health services [106]. Third, the concurrent triangulation mixed methods design allowed us combine quantitative and qualitative data to produce more comprehensive results, as well as to triangulate data from caregivers and people with TBI to help address potential recall bias from memory deficits. Finally, while the data was collected outside of a research setting, the monitoring and evaluation system for the LoveYourBrain Yoga program was established by a doctoral-level staff member with content expertise in health services research and survey research methods.

## Conclusions

LoveYourBrain Yoga, a 6-week, community-based yoga with psychoeducation program for people with TBI and caregivers, is feasible and acceptable when implemented on a large scale in diverse locations. The significant improvements in quality of life, resilience, positive affect, and cognition among people with TBI suggest that it may be an effective mode of, or adjunct to, community-based rehabilitation. By facilitating greater compassion, self-awareness, community connection, and skills in regulating emotions, LoveYourBrain Yoga also appears to enhance coping skills, which has implications on improving quality of life for both TBI survivors and caregivers. Further investigation of LoveYourBrain Yoga in comparative effectiveness research is suggested.

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## Disclosure statement

All authors have reviewed the ICMJE uniform disclosure form and declare: KZD is employed by the LoveYourBrain Foundation, a nonprofit, for whom she led the design of the curriculum for the LoveYourBrain Yoga program. KZD is married to the Executive Director of the LoveYourBrain Foundation. PJB, MB, KB, AS, and RP have no relationships or activities that could appear to have influenced the submitted work. The authors alone are responsible for the content and writing of the paper.

## Authors' contributions

KZD is the guarantor. KZD led the conception and design of the study, data analysis and interpretation, and drafted the manuscript. PJB, AS, and MB contributed to data analysis and interpretation and provided revisions on the draft manuscript. KB and RP contributed to the implementation of the study intervention, data collection systems, and provided revisions on the draft of the manuscript. All authors approved the final manuscript.

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