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"Hidden Gains"? Measuring the Impact of Mindfulness-based Interventions for People with mild Traumatic Brain Injury: a Scoping Review

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Abstract

Background: Mindfulness-based interventions can support recovery from mild traumatic brain injury (mTBI). Although measurement is a key determinant of outcomes, there is no comprehensive assessment of measurement approaches used to capture outcomes of these programs. Here, we review the domains targeted, measurement techniques used, and domains and techniques most affected by mindfulness-based interventions for mTBI.

Methods: We conducted a scoping review. After screening and full-text review, we included 29 articles and extracted data related to measurement domains, techniques, and results.

Results: We identified 8 outcome domains, each with multiple subdomains. The most common domains were cognitive symptoms and general health/quality of life. No quantitative studies directly assessed sleep, physical-function, or pain-catastrophizing. Self-report was the most common measurement technique, followed by performance-based methods. Coping, somatic symptoms, emotional symptoms, stress response, and domains of cognition (particularly attention) were the most frequently improved domains. Qualitative results described benefits across all domains and suggested novel areas of benefit. Biomarkers did not reflect significant change.

Conclusions: Mindfulness-based interventions for mTBI impact a range of clinical domains and are best captured with a combination of measurement approaches. Using qualitative methods and expanding the breadth of outcomes may help capture underexplored effects of mindfulness-based interventions for mTBI.

Keywords

mild traumatic brain injury; mindfulness; meditation; outcome measurement

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DISCLOSURE STATEMENT

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Introduction

Mild traumatic brain injury (mTBI) accounts for 70–90% of all brain injuries, with an annual prevalence upwards of 600 for every 100,000 people worldwide (1). mTBI can impact multiple domains of functioning, including cognition (e.g., processing speed and difficulty concentrating), physical and somatic symptoms (e.g., headaches, light/noise sensitivity, fatigue, dizziness/nausea), and psychological or emotional health (e.g., increased irritability, depressed mood, restlessness) (2). For many individuals, mTBI symptoms resolve within a few weeks or months. However, a considerable number of individuals report persistent symptoms at six months and beyond (1). These symptoms can cause devastating negative impacts on function, wellness, and life participation (3,4).

Accumulating evidence suggests that psychosocial interventions, specifically mindfulness-based interventions, may facilitate recovery following mTBI. Mindfulness-based interventions can target multiple symptom and functional domains (5,6) and may be particularly beneficial for addressing the diverse clinical presentations of individuals with mTBI (7,8). Previous research, including meta-analyses (9,10), has reported the effects of mind-body interventions, including mindfulness-based interventions, on several physical, cognitive, and mental-health related outcomes for people with mTBI and other brain injury types. However, despite being potentially important determinants of outcomes (11), little empirical attention has been paid to the role played by measurement approaches for outcome assessment in mindfulness-based interventions for mTBI.

Gaining a comprehensive understanding of the outcome domains targeted by mindfulness-based interventions and the nature of measurement techniques (e.g., self-report, performance-based, qualitative interviews) is important for optimizing mindfulness-based interventions for this population, identifying active treatment ingredients, and predicting which potential subpopulations within mTBI could most benefit from participation. To address this, we conducted a scoping review of mindfulness-based intervention studies targeting mTBI. We sought to answer 3 questions: a) what clinical domains are being assessed in the research on mindfulness-based interventions for mTBI? b) what techniques and instruments are being utilized to measure these domains? And c) what assessment domains, techniques and instruments are most impacted by mindfulness-based interventions?

METHODS

Type of review

While systematic reviews of interventions often aim to establish their feasibility, appropriateness or effectiveness using critically appraised evidence, scoping reviews seek to provide a map of the evidence available, identify sources of available evidence, and describe how research is being conducted to advance our understanding of a concept or field, particularly where evidence is not yet well established (12–14). Given the novel focus of this study on measurement in mindfulness-based interventions for people with mTBI, we chose to conduct a scoping review to answer our research questions.

We used the PRISMA Extension for Scoping Reviews (PRISMA-ScR) to guide the steps and rationale for our approach (15). After the research questions were defined, we initiated a search of the literature to identify pertinent studies, extract relevant data from these studies, and summarize results.

Data Sources and Search Strategy

We searched the following 3 electronic databases for relevant research articles up to August 2021: PubMed (including MEDLINE), CINHAL, and PsychInfo. Our key words and initial search strategy were developed in collaboration with an experienced health sciences librarian. We identified search terms using PubMed Boolean operators to refine the search results. We checked initial results by hand to be sure known, relevant articles were captured in this search. Once finalized, search terms were then translated into formats for each of the other databases. The search strategy and specific key words can be found in Table 1.

The final search results were exported into Covidence, a systematic review tool (16). Two authors (BL and MK) then screened the titles and abstracts of the citations to determine if they met criteria for the present review. Citations that were accepted by both reviewers were advanced to full text review. Disputes were resolved via discussion (BL, MK, and JG) and full text review until consensus was reached.

Study Selection

Our inclusion criteria consisted of studies that were longitudinal and described examination of the effects of mindfulness-based interventions for individuals following traumatic brain injury (TBI). While our primary interest was populations with mTBI, we included studies with participants with any type of acquired TBI, with any severity, for several reasons. First, there is considerable overlap across the mTBI/TBI continuum (9), particularly in terms of assessment techniques. Second, there is a relatively small number of studies available in this area, and many relevant studies include participants with mild to moderate-severe TBI or do not report on severity level of their participants' injuries using validated instruments. Applying such an inclusive approach is consistent with previous reviews focusing on mTBI (9), as well as with evidence indicating that mTBIs constitute the large majority (up to 90%) (1) of TBIs. We included peer reviewed studies and dissertations published in English in any year. We excluded conference presentations and posters, cross-sectional studies, and studies where no intervention was applied.

Data Extraction

Based on recommendations of Levac et al. (13), we developed the data charting system and identified variables of interest via collaboration amongst the research team. Two members of the research team (BL and JG) independently generated a data charting form with specific variables to answer the research questions. We compared and discussed these documents, and a final data extraction form was established once the researchers reached consensus.

Two reviewers (BL and MK) extracted data from 20% of the studies (n=7) and compared results to explore interrater reliability. Once consensus was achieved, each reviewer extracted data from half of the remaining studies. We extracted data on domains assessed

(e.g., “pain”, “mindfulness”, “executive function,” “depression”, etc.), measurement techniques utilized (self-report survey, performance-based assessment, qualitative methods, family and friend report, behavioral observation, or biomarkers), specific assessment tools administered, and results of each assessment (statistical significance of change in scores and effect size for quantitative data, and themes for qualitative data). Based on the PRISMA-ScR, critical appraisal of individual sources of evidence was not indicated and thus was not performed.

Data Synthesis and Analysis

First, we reviewed each paper, generated a summary of relevant data and entered it into a table (publication type, study design, participant characteristics, research aims, etc.). We then recorded each of the instruments administered in each study along with their intended domain area and results as an entry in a separate table. We based the classification of assessment domains on those commonly used in mTBI research, including physical/somatic, cognitive, and behavioral/emotional symptoms (2,17) in addition to other domains known to be impacted by mindfulness-based interventions (e.g., coping, overall health and wellness).

To explore the benefits of interventions, we coded scores for quantitative measures that improved with statistical significance ($p < 0.05$) and/or had a confidence interval that did not include zero as “significantly improved” (+). In instances where some, but not all subtests of a quantitative measure were significantly improved we coded the items as (±). In instances where scores improved but did not reach statistical significance or did not change from pre-treatment we coded entries as (=). In instances where the authors of the original paper did not analyze data from the measure, or did not describe statistical significance of the results, we coded the item as (o). The one instance where score declined, we coded as (−). We coded qualitative measures as (q) and provide a more detailed summary of qualitative results in Table 3. When reported, we classified effect sizes as small, medium, or large based on standard ranges for Cohen’s d, Pearson r, and Partial eta squared coefficients.

RESULTS

We identified a total of 325 abstracts through initial database searches. We discovered two additional articles via hand searching and general web searches (18,19). After duplicates were removed, 257 studies were left for screening. Of these, we determined that 220 were irrelevant based on their titles or abstracts leaving 37 articles for full text review. During full text review, we excluded an additional 8 articles for several reasons. Three publications were not longitudinal intervention studies (review or book chapter). Two were publications describing an already included study (e.g., a feasibility study and an efficacy study describing the same group of participants) in which case we chose the efficacy study for data extraction. Three were dissertations which were later published in a peer reviewed journal. Ultimately, we included 29 articles for data extraction and analysis in this scoping review. See the Figure for a PRISMA-ScR flow diagram.

Synthesis of results

Outcome Domains Measured in Mindfulness-based Interventions for mTBI

—We categorized measurement tools into 8 different broad symptom domains, each with several more specific subdomain areas (e.g., Domain: coping; Subdomains: general coping skills, emotional regulation, mindfulness, self-compassion, self-efficacy, and pain interference). We included a ninth domain, titled “Other”, for measurements that did not fit into any of the other domain areas.

Cognitive symptoms and general health/quality of life (QoL) were the most commonly assessed domains. Our review identified 36 measures of cognition present within twelve papers (41%). Within the domain of cognition, the most common subdomains were attention and working memory, assessed by nearly all papers which included cognitive assessments (ten papers). Four papers tested executive function, the second most common subdomain (11%). Only one paper included assessment of insight (20). Only two papers included assessment of general cognitive status. Measurements of the general health and QoL domain were assessed 24 times in this review embedded within 15 papers (52%). Quality of life was assessed eight times and health and wellness was assessed 10 times. There were five assessments of life participation and community integration.

The next most common domains were coping and emotional symptoms. Each of these domains was tested 20 times across papers in this review. The most common subdomains within coping were self-efficacy and mindfulness. Despite mindfulness being the most frequently assessed subdomain within the coping domain, only five papers in this review of mindfulness-based intervention included tools specifically designed to measure mindfulness (17%). Assessment of emotional symptoms focused most frequently on depression (9 measurement occurrences), anxiety (2 measurement occurrences), or both (4 measurement occurrences). Eight papers (26%) assessed somatic symptoms. Seven (23%) utilized concussion symptom scales.

No papers included quantitative measurement of pain catastrophizing. No studies assessed physical function/disability, although one study included a measure of adaptability (20). Quantitative assessment of sleep was limited to several items on a mixed methods questionnaire in a single study (21). In contrast, three of the eight papers that included qualitative data reported that participants experienced improvements in sleep quality and/or duration.

In most cases when qualitative methods were used, researchers tended not to inquire about a specific outcome domain. Rather, they aimed to generally explore participants perceived gains, functional changes, or impact on daily life (50%), perceptions and experiences of the mindfulness-based interventions (50%) or program satisfaction (50%) with open ended questioning. One study included interview questions focused on specific symptom domains including mood, sleep, anxiety, relationships, physical health, and other aspects of health (22).

Measurement Techniques and Instruments Utilized in Mindfulness-based Interventions for mTBI

Techniques: There were six different measurement techniques identified in this body of literature: self-report, performance-based, qualitative, biomarkers, behavioral observations, and family/friend report. The great majority of measurement tools used were self-report surveys (total of 55 out of 85, 65%). Eight papers included qualitative methods (28%), either expressly (n=3) or as part of a mixed methods battery of assessment (n=5). Three papers included assessment of biomarkers (oxygen uptake, heart rate variability, and brain activity measured using the Muse device).

Self-report survey tools were favored in almost all domains except for cognition, where performance-based measures (n=19) were used more frequently than self-report survey (n=4). More than half (59%) of the papers utilized a combination of measurement techniques. The most common combination of methods was self-report and performance-based (31%), primarily on studies testing cognitive changes. One of these papers also included qualitative methods. Three papers used self-report and behavioral measures, and two used self-report and biomarkers. The remainder of studies with a combination of techniques used self-report and qualitative methods.

Instruments: We identified 85 unique measurement tools used. There was little consensus across studies regarding which tool to use to measure a given domain. For example, four different tools were used to assess self-efficacy, five to assess mindfulness, and five to assess QoL. Six different tools assessed general health, and twelve different tools assessed attention and working memory across the sample.

Studies using qualitative methods were the only ones directed at benefits not pre-determined by researchers. One exception to this was the study by Lilliecrutz et al. (23), who administered the Canadian Occupational Performance Measure (COPM), enabling participants to identify specific functional goal areas in which they felt they improved.

Effects of Mindfulness-based Interventions—Overall, we observed statistically significant improvements in each of the targeted domains, though none of these demonstrated statistically significant improvement in all studies. Coping (70%), somatic symptoms (70%), emotional symptoms (70%), and stress response (60%) were the domains in which statistically significant improvement was demonstrated most frequently (on one or more subtests of measures within each domain). Mindfulness, under the coping domain, demonstrated significant improvements in 70% of instances.

Emotional symptoms and coping demonstrated the most frequent occurrence of large effect sizes ($d > .8$), particularly in the subdomains of depression, anxiety, PTSD, emotional regulation, self-efficacy, and mindfulness. Large effect size was noted on one instance of the Perceived Stress Scale. Certain subdomains of cognition demonstrated medium or large effect sizes including attention, and new learning. QoL as measured by the Perceived Quality of Life Scale, but no other measures of QoL, improved with a medium or large effect size.

Mental fatigue, measured by the Mental Fatigue Scale, improved in all studies where it was used. The Beck Depression Inventory similarly demonstrated statistically significant improvement in all studies that used it.

There was no clear pattern or difference in improvement between the most commonly used quantitative assessment techniques (self-report and performance-based techniques). There was a similar frequency of significantly improved scores for both performance-based (45%) and self-report (57%) tools. None of the biomarker assessments demonstrated statistically significant improvement in scores.

Qualitative results described perceived meaningful benefits in essentially all assessed domains, as well as additional areas such as sleep, interpersonal skills and relationships, and a sense of community/belonging. Similar to quantitative results, qualitative results frequently demonstrated benefits in the emotional domain (mood, anxiety, emotional wellbeing, and positive affect), and the coping domain (mindfulness skills, acceptance, and resilience). Qualitative results also described improvements in subdomains of cognition including focus, memory, concentration, self-efficacy, self-awareness, and impulsivity. Qualitative results offered information that was often beyond the scope of the used quantitative measures, including the ways participants were able to generalize the skills gained into their daily lives.

DISCUSSION

This scoping review aimed to identify the clinical domains assessed in research on mindfulness-based interventions for mTBI, the measurement techniques and instruments used to capture them, and what domains and techniques are most impacted following these interventions. Of 29 studies measuring the impact of mindfulness-based interventions for people with mTBI, we identified eight symptom domains, six measurement techniques, 85 unique tools, and present a detailed account of the domains, tools, and techniques that were most affected by mindfulness-based interventions.

Per our first aim, to assess what mTBI outcome domains are measured following mindfulness-based interventions, we identified the following clinical domains: concussion symptoms, somatic symptoms, cognitive function/symptoms, emotional symptoms, coping, stress response, general health and QoL, open questioning on participants experiences in mindfulness-based interventions, as well as other, less prevalent domains. Each domain included several subdomains. The most frequently assessed domains were cognitive symptoms, specifically attention and working memory, and general health and QoL. Emotional symptoms and coping were also commonly assessed. This supports previous work utilizing mindfulness-based interventions as a means of promoting such outcomes in other populations (24,25). Deficits in these domains contribute to functional challenges in daily life and can persist longer than 3 months in up to half of individuals with mTBI(26). Importantly, certain outcome domains of seeming high relevance to both mTBI and mindfulness-based interventions were under-investigated. There were no direct measures of sleep quality or duration, a common concern for individuals with mTBI (27) and an important factor in mTBI recovery (28). Sleep quality, duration, and daytime fatigue can all improve following mindfulness-based interventions for other

populations (29) including those with self-reported sleep disturbance (30). Further, no studies investigated pain catastrophizing, a correlate of persistent mTBI symptoms (31). Mindfulness-based interventions can effectively address pain catastrophizing (32–34) which may help facilitate positive outcomes in this population (35–37). No studies included direct quantitative assessment of physical-function or disability which are core outcome domains in rehabilitation research (38,39) and could be impacted by mindfulness training in other populations such as chronic pain (40). Interestingly, only a small number of the studies testing mindfulness-based interventions report evaluation of mindfulness. This may be due, in part, to the challenge of accurately assessing mindfulness (41). Future studies may benefit from including direct assessment of pain catastrophizing, sleep quality and duration, physical-function, and trait mindfulness to help advance our understanding of the role of mindfulness-based interventions in managing these important clinical factors.

Our second aim was to identify the assessment instruments and techniques utilized in research on mindfulness-based interventions for mTBI to measure outcomes. We observed six methods of assessment: self-report surveys, performance-based measures, qualitative methods, biomarkers, behavioral observation, and friend/family report. Qualitative methods included focus groups, 1:1 interviews, and open ended written responses. Self-report methods were the most common in all domains except cognition, where performance-based measures were most frequently used. Three studies assessed biomarkers: oxygen uptake, heart rate variability, and stress response via brain activity. Behavioral observation methods were used to assess medication use, behavioral misconduct in prisons, and head movements during meditation.

Utilizing self-report measures to capture outcomes following mindfulness-based interventions for mTBI has potential benefits, including low cost and resource demand as well as providing important information on participants' experiences and perceptions. However, many have criticized sole reliance on self-reported measures due to an increased risk of bias, social desirability, demand characteristics and memory-related confounds (42). Performance-based measures have the advantage of providing output that is more objective and independent of specific context, though they may miss important information about individuals' experiences, and may fail to capture limitations related to people's daily life and real-world environment (43). Utilization of biomarkers may provide important insight regarding the physiological effects of mindfulness practice for individuals with mTBI, though such data may be more resource intensive and face potential large scale implementation barriers (44). While the debate on the relative advantages and drawbacks of different assessment techniques in rehabilitation research is still ongoing (45–47), there is growing emphasis on the advantage of combining assessment techniques for patients with mTBI (47). Doing so within the context of mindfulness-based interventions may be of particular importance given its multifaceted effects (5,6). Qualitative methods were scarcely used in the reviewed papers and have the potential to demonstrate benefits that are not being captured by quantitative researcher designed methods. In addition to identifying these benefits, qualitative methods can more comprehensively characterize the impact interventions have on participants lives and explain associations between the skills learned and the specific outcomes appreciated (48).

Our third aim was to identify the domains, assessment techniques, and instruments most impacted by mindfulness-based interventions for mTBI. Coping, somatic symptoms, emotional symptoms, and stress response were the most frequently significantly improved domains. However, there was great variability amongst the subdomains. Emotional symptoms (particularly depression, anxiety, and PTSD), subdomains of coping (e.g., self-efficacy, emotional regulation and mindfulness as measured by the MAAS and FMI), one measure of QoL (PQoL) and certain subdomains of cognition (attention, and new learning) demonstrated medium or large effect sizes. Smaller but significant effect sizes were found for executive function skills, social problem solving, post-concussion symptoms, and mental fatigue. Mindfulness-based interventions are thus a promising means to improve these symptoms, which are particularly burdensome and prevalent in this population (1,26).

Certain outcome domains appeared to be less frequently affected by mindfulness-based interventions in the reviewed studies. General health and QoL, which included community integration and participation, only significantly improved on 50% of studies, and cognitive symptoms were significantly improved on only 44% of studies. It is possible that mindfulness affects these constructs to a lesser degree in this population. It is also possible that this may have been influenced by factors such as small sample sizes (49), or the selected instruments limited reliability, sensitivity, or specificity for the mTBI population (24). Investigation of the psychometric properties of each tool used in this body of literature is outside the scope of this current review but might generate helpful insight into the pattern of results observed.

Measurement techniques were not evenly distributed across the 8 domains, as only cognition included performance-based measures, and the other techniques other than self-report were rare and scattered across the domains. Within the cognition domain, performance-based measures and self-report measures yielded a similar pattern of significant results, supporting the impact of mindfulness-based interventions on both types of techniques.

Qualitative studies highlighted the consistently positive perceived impact of mindfulness-based interventions in specific areas that were not fully captured by quantitative measurement tools, including participants' impressions of their improved sense of belonging, interpersonal skills, and sleep quality. Qualitative results also described improvements in cognition, but often in more applied terms. For example, results indicated improvement in focus, memory, and concentration, as opposed to more limited improvements in attention and working memory, evident in quantitative measures. Qualitative findings also illustrated novel perceived associations between mindfulness training and additional outcomes. For example, participants described becoming more aware of the link between their mindset and their physical symptoms, and how acceptance promoted recovery. We present exemplar quotes in the Supplemental Table to illustrate these patterns. In some studies where mixed methods were employed, we observed qualitative improvements in domains that were also directly assessed with quantitative measures which failed to show significant change (22). This is in line with prior research using mixed methods in similar populations (50). Increased use of qualitative methods or mixed methods may better understand participants' own perspectives and experiences of the effects of mindfulness-based interventions. This may help optimize such interventions using a

"bottom up" approach informed by participants' personal experiences rather than a strictly researcher-determined "top-down" one (51).

Although objective, physiological, biomarker and neuroimaging measures were less commonly employed among the papers included in this review, they mostly did not demonstrate significant change. While there is no support from available evidence that mindfulness-based interventions meaningfully impact such measures among people with mTBI, the paucity of studies, and promising evidence from other clinical populations (52–54) suggest that more research in this field is needed.

Limitations

Some limitations of this study should be considered. First, we did not complete a formal evaluation of the quality of the studies included in the review. This is consistent with common practices for scoping reviews (15). Second, due to the small number of publications available and other reasons (see Study Selection), we included studies testing traumatic brain injury of differing severities, not only mTBI. More research is needed to explore whether people with mTBI specifically may respond differently to mindfulness-based interventions. Given the limited inclusion of racial and ethnic minorities in these studies, future research may include more diverse samples (55,56). Finally, only articles which were published in English were included. At least one study was identified for which an English translation was not available. Important work may be done in other languages/cultures that was not included in this review. This is particularly relevant for work around mind body techniques, which often originate in non-western cultures. Mindfulness originated as a non-secular practice drawn from the Buddhist tradition. Moving forward it would be ideal to include non-English voices to avoid biases in interpretation and application of this intervention technique.

Conclusions

This scoping review summarized the outcome domains assessed, the tools and measurement methods utilized, and the domains and measurement techniques most affected by mindfulness-based interventions for people with mTBI. Benefits were demonstrated across all symptom domain areas. Coping, somatic symptoms, emotional symptoms, and stress response were the most frequently significantly improved domains on quantitative assessments, and greatest effect sizes were observed in coping, emotional symptoms, stress response, and certain subdomains of cognition. Qualitative results highlighted additional key perceived areas of improvement, associations between mindfulness skills and perceived effects, and functional benefits in daily life. Results indicate that mindfulness-based interventions may meaningfully aid recovery from mTBI and facilitate improvement in domains often not directly or completely targeted via standard rehabilitation techniques. Future research should include outcomes such as sleep, physical-function, and pain catastrophizing, which are key factors in mTBI and can be improved following mindfulness-based interventions but were not assessed in any of the studies included in this review. Researchers should consider including multiple types of assessments (mixed methods techniques) to help capture comprehensive information on target outcomes and elucidate important yet overlooked clinical gains following mindfulness-based interventions for

mTBI. This knowledge may capture a more comprehensive range of the effects of these intervention programs to enhance our understanding of what clinical needs can be addressed and the best means to address them.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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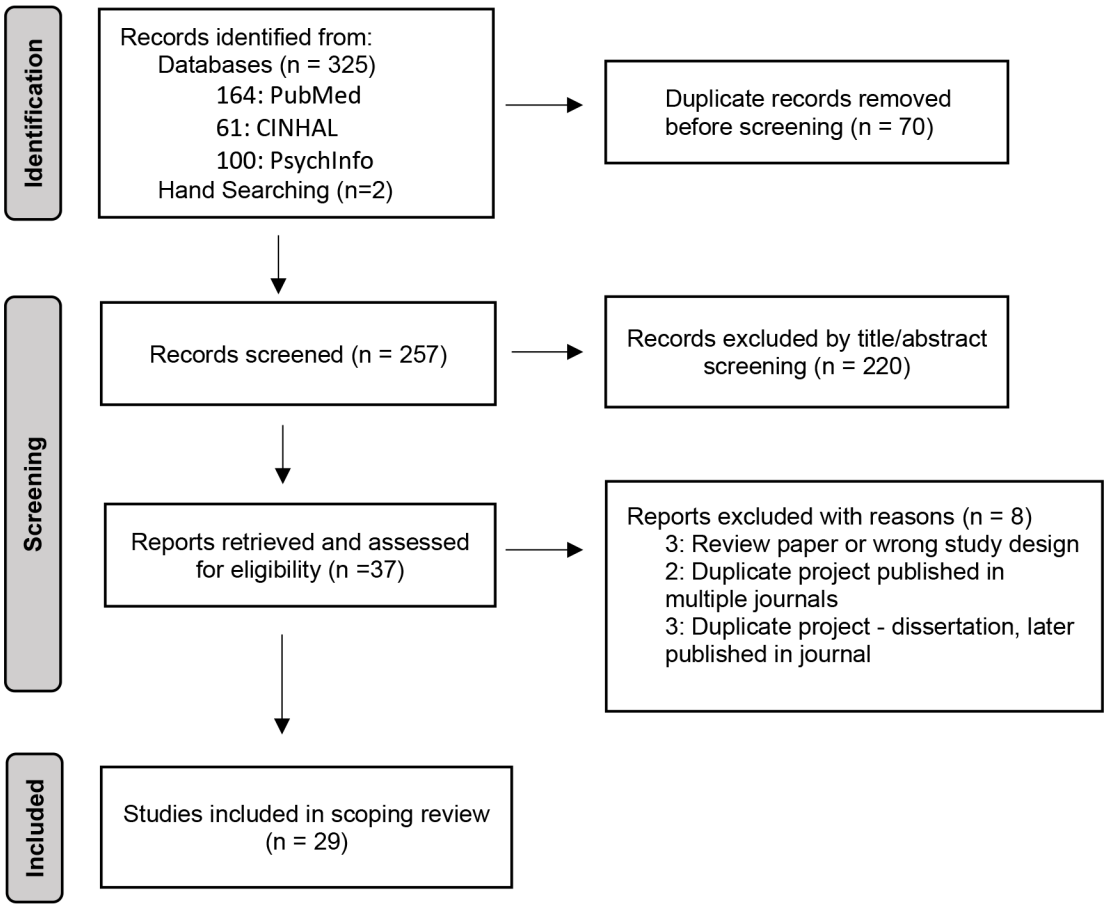

Figure 1: PRISMA-ScR Flow Diagram
From: Page et al. (57)

Table 1:

Search Strategies

Database	PubMed (Medline)	CINHAL	PsychInfo
Search terms	(mindfulness or meditation or “mindfulness”[Mesh] or “meditation”[Mesh]) and (“brain injur*” or “post-concussion syndrome”[mesh] or “brain concussion”[mesh] or concuss* or TBI or mTBI or “brain injuries, traumatic”[Mesh])	(mindfulness or meditation or MH “mindfulness” or MH “meditation”) and (“brain injur*” or MH “postconcussion syndrome” or MH “brain concussion” or concuss* or TBI or mTBI)	(mindfulness or meditation or Mindfulness/ or Mindfulness-Based Interventions/ or Meditation/) and (brain injur* or postconcussion syndrome or post concussion syndrome or brain concussion/ or concuss* or Traumatic Brain Injury/ or TBI or mTBI)
Results	164	61	100

Table 2:

Domains Assessed/ Specific Measures Used

Domain	Measurement Tools	Technique	Citation	Signif. Improve	Effect Size
Concussion Symptoms					
	Rivermead Post Concussion Symptom Questionnaire (RPQ)	Self-report	Mitchell et al. (58)	=	sm
			McMillan et al. (59)	=	nr
			Bay et al. (60)	±	v sm
	Post-Concussion Symptom Inventory (PCSI)	Self-report	Paniccia et al. (61)	+	nr
	Neurobehavioral Symptom Inventory (NSI)	Self-report	Azulay et al. (62)	=	sm
			Azulay et al. (19)	+	med
			Polich et al. (63)	+	nr
Somatic Symptoms					
Pain Intensity	Visual Analogue Scale (VAS)	Self-report	Nassif et al. (18)	+	nr
			Bedard et al. (64)	±	nr
			Bédard et al. (20)	o	nr
	The Brief Pain Inventory (BPI- I)	Self-report	Nassif et al. (18)	=	nr
	Defense and Veterans Pain Rating Scale (DVPRS-I)	Self-report	Nassif et al. (18)	=	nr
Fatigue	Mental Fatigue Scale (MFS)	Self-report	Lilliecrutz et al. (23)	+	nr
			McHugh & Wood (65)	+	nr
			Johansson et al. (66)	+	nr
			Johansson et al. (67)	+	sm
			Shirvani et al. (68)	+	nr
Cognitive Function/Symptoms					
General Cognitive Status	Cognitive Failures Questionnaire	Self-report	McMillan et al. (59)	+	nr
	Wechsler Test of Adult Intelligence (WTAR)	Performance	McHugh & Wood (65)	o	nr
Attention/Working Memory	WAIS - IV Coding stepwise	Performance	Lilliecrutz et al. (23)	+	nr
	WAIS - IV Digit Span Forward and Backward	Performance	Polich et al. (63)	=	nr
	WAIS - III NI Block Repetition	Performance	Lilliecrutz et al. (23)	=	nr
	Paced Auditory Serial Addition Test (PASAT)	Performance	Azulay et al. (62)	+	sm
			Azulay et al. (19)	+	sm
			McMillan et al.(59)	=	nr
			Lillicrutz et al. (23)	=	nr
	Test of Everyday Attention (TEA)	Performance	McMillan et al. (59)	=	nr
	D-KEFS Trail Making Test (TMT)	Performance	Lilliecrutz et al. (23)	±	nr
			Polich et al. (63)	=	nr
	Trail Making Test A and B (Reitan et al., 1985)	Performance	Johansson (67)	=	sm
			Johansson et al. (49)	o	nr
			McHugh & Wood (65)	=	nr
	Trail Making Test (Lezak, 1995)	Performance	McMillan et al. (59)	=	nr

Domain	Measurement Tools	Technique	Citation	Signif. Improve	Effect Size
	Cogstate	Performance	Cole et al. (69)	+	med
	Attentional Blink Task	Performance	Johansson et al. (66)	±	nr
	Continuous Performance Test of Attention (CPT)	Performance	Polich et al. (63)	=	nr
			Azulay et al. (62)	+	med
			Azulay et al. (19)	+	sm
	Listening Span	Performance	Lilliecrutz et al. (23)	=	nr
Executive function	Barratt Impulsivity Scale (BIS)	Self-report	Kristofersson (22)	=	nr
	WAIS-III Symbol-Digit Coding (SDC)	Performance	Johansson et al. (49)	±	nr
			Johansson et al. (66)	+	sm
			Johansson et al (67)	+	nr
Problem Solving	Social Problem-Solving Inventory Revised Short Form	Self-report	Azulay et al. (62)	+	sm
			Azulay et al. (19)	+	sm
Memory	Adult Memory and Information Processing Battery	Performance	McMillan et al. (59)	=	nr
	Sunderland Memory Questionnaire	Self-report	McMillan et al. (59)	=	nr
New Learning	California Verbal Learning Test-II (CVLT-II)	Performance	Azulay et al. (62)	=	sm
			Azulay et al. (19)	=	med
Language	DLS reading speed test	Performance	Lilliecrutz et al. (23)	+	nr
	Reading Speed (Dyslexia Test)	Performance	Johansson et al. (49)	=	nr
	FAS Verbal Fluency Test	Performance	Johansson et al. (49)	+	nr
Insight	Patient Competency Rating Scale-Relative (PCRS-R)	Proxy report	Bédard et al. (20)	o	nr
Emotional Symptoms					
Emotional Status	Symptom Check List (SCL-90-R)	Self-report	Bédard et al. (70)	=	nr
			Bédard et al. (64)	±	nr
			Bédard et al. (20)	+	nr
			Bédard et al. (71)	=	sm
Depression	Patient Health Questionnaire-9 (PHQ-9)	Self-report	Bédard et al. (71)	=	sm
			Bédard et al. (20)	+	lg
	Center for Epidemiological Studies Depression Scale (CES-D)	Self-report	Kristofersson (22)	=	nr
			Bay et al. (60)	±	sm
	Beck Depression Inventory (BDI-II)	Self-report	Polich et al. (63)	+	nr
			Bédard et al. (64)	±	nr
			Bédard et al. (71)	+	med
			Bédard et al. (20)	+	med
			Bédard et al. (70)	+	med
Anxiety	State Trait Anxiety Inventory (STAI)	Self-report	Kristofersson (22)	=	nr
	Beck Anxiety Inventory (BAI)	Self-report	Polich et al. (63)	+	nr
Anxiety & Depression	Hospital Anxiety and Depression Scale (HADS)	Self-report	McMillan et al. (59)	=	nr
			Bédard et al. (20)	+	lg
	Comprehensive Psychopathological Rating Scale (CPRS)	Self-report	Johansson et al. (49)	+	nr
			Johansson et al. (66)	±	nr

Domain	Measurement Tools	Technique	Citation	Signif. Improve	Effect Size
PTSD	PTSD Checklist- Civilian version	Self-report	Cole et al. (69)	+	lg
Coping					
General Coping	Negative Affect Repair Questionnaire	Self-report	Mitchell et al. (58)	±	v sm
Emotional Regulation	Difficulties in Emotion Regulation Scale (DERS; primary)	Self-report	Azulay et al. (19)	+	lg
Mindfulness	Mindful Attention Awareness Scale (MAAS)	Self-report	Cikajlo et al. (72)	o	nr
			Azulay et al. (62)	+	nr
			Canade (73)	+	med
			Kubiesa (75)	+	sm
			McHugh & Wood (66)	o	nr
	Freiburg Mindfulness Inventory (FMI)	Self-report	Canadé (74)	+	lg
			Azulay et al. (19)	+	lg
	Cognitive and Affective Mindfulness Scale-Revised (CAMS-R)	Self-report	Polich et al. (64)	=	nr
	Philadelphia Mindfulness Scale (PHLMS)	Self-report	Bédard et al. (72)	±	sm
	Toronto Mindfulness Scale (TMS)	Self-report	Bédard et al. (72)	±	sm
Self-Efficacy	Perceived Self-Efficacy Scale	Self-report	Azulay et al. (63)	+	sm/md
			Azulay et al. (19)	+	lg
	Mindfulness-based Self-Efficacy Scale Revised (MSES-R)	Self-report	Canade (74)	±	med
	The Self-Efficacy Questionnaire for TBI (SEQ)	Self-report	Polich et al. (64)	=	nr
	Self-Efficacy Questionnaire for Children (SEQ-C)	Self-report	Paniccia et al. (62)	o	nr
Self-compassion	Self-Compassion Scale (SCS)	Self-report	Johansson et al. (67)	±	nr
Pain Interference	The Brief Pain Inventory (BPI-II)	Self-report	Nassif et al. (18)	+	nr
	Defense and Veterans Pain Rating Scale (DVPRS-II)	Self-report	Nassif et al. (18)	=	nr
Stress Response					
	Perceived Stress Scale – 14 (PSS-14)	Self-report	Kubiesa (75)	=	sm
			Bédard et al. (71)	+	v sm
			Bay et al. (61)	±	sm
	Muse - Time in “calm state”	Biomarker	Polich et al. (64)	=	nr
	Astrand’s Test (Maximal Oxygen Uptake)	Biomarker	Lilliecrutz et al. (23)	+	nr
General Health and QoL					
Health & Wellness	EuroQoL5D (EQ5D) Estimated Health State	Self-report	Lilliecrutz et al. (23)	=	nr
	General Health Questionnaire	Self-report	McMillan et al. (60)	=	nr
	Short Form Health Questionnaire (SF-36)	Self-report	Kristofferson (22)	−	nr
			Bédard et al. (65)	±	nr
			Bédard et al. (20)	±	nr
			Bédard et al. (71)	±	sm
	Multidimensional Health Locus of Control Scale (MHLC)	Self-report	Bédard et al. (65)	=	nr
			Bédard et al. (71)	=	nr

Domain	Measurement Tools	Technique	Citation	Signif. Improve	Effect Size
	Global Severity Index (GSI)	Self-report	Bédard et al. (71)	+	v sm
	Positive Symptom Distress Index (PSDI)	Self-report	Bédard et al. (71)	+	sm
QoL	Satisfaction with Life Scale (SWLS)	Self-report	Cikajlo et al. (73)	o	nr
	Health-related Quality of Life (HRQoL (EQ-5D)	Self-report	Lilliecrutz et al. (23)	=	nr
	Perceived Quality of Life Scale (PQoL)	Self-report	Azulay et al. (63)	+	med
			Azulay et al. (19)	+	med
			Canade (74)	=	lg
	Quality-of-Life After Brain Injury Instrument (QOLIBRI)	Self-report	Donnelly et al. (76)	+	nr
			Donnelly et al. (77)	+	nr
	World Health Organization Quality of Life short form (WHOQOL-BREF)	Self-report	Shirvani et al. (69)	+	nr
Symptoms & Function	Mixed Methods Questionnaire	Self-report	Combs et al. (21)	±	nr
Community Integration & Participation	Community Integration Questionnaire (CIQ)	Self-report	Bédard et al. (65)	=	nr
			Bédard et al. (71)	=	v sm
	Mayo Portland Adaptability Inventory-4 (MPAI-4)	Self-report	Bédard et al. (20)	=	nr
	Children's Assessment of Participation & Enjoyment (CAPE)	Self-report	Paniccia et al. (62)	=	nr
	Godin Leisure-Time Exercise Questionnaire (GLTE)	Self-report	Paniccia et al. (62)	±	nr
Participant's Experiences in Mindfulness Based Intervention					
	Focus group	Qualitative	Niraj et al. (78)	q	
			Kristofersson et al. (79)	q	
	Interview	Qualitative	Combs et al. (21)	q	
			Donnelly et al. (76)	q	
			Donnelly et al. (80)	q	
			Kristofersson (22)	q	
			Cole et al. (70)	q	
	Written comments/open text	Qualitative	Donnelly et al. (77)	q	
	Program Satisfaction Questionnaire	Self-report	Donnelly et al. (76)	o	nr
			Cole et al. (70)	o	nr
Other					
	Misconduct charges and negative file notes	Behavioral observation	Mitchell et al. (59)	=	nr
	Medication use (pain, anxiety, and depression-related)	Behavioral observation	Bédard et al. (71)	=	sm/md
	Buss–Perry Aggression Questionnaire (BPAQ)	Self-report	Shirvani et al. (69)	+	nr
	Head Tracking	Behavioral observation	Cikajlo et al. (73)	o	nr
	Canadian Occupational Performance Measure (COPM)	Self report (with assist)	Lilliecrutz et al. (23)	=	nr
	Adapted Beliefs about Yoga Scale (BAYS)	Self-report	Combs et al. (21)	=	nr

Domain	Measurement Tools	Technique	Citation	Signif. Improve	Effect Size
	Over-Selectivity Task	Performance	McHugh & Wood et al. (66)	+	nr
	Heart Rate Variability	Biomarker	Paniccia et al. (62)	o	nr
			Kubiesa et al. (75)	=	nr

+ statistically significant improvement, $p < 0.05$ or CI does not include 0

− worsened

= no significant change/no difference between groups

± statistically significant improvement for some subtests of the measure, but not all

o not reported

q results described in qualitative data

Effect sizes

Cohen's d: < .2 = very small "v sm", .2–.4 = small "sm", .4–.5 = small/medium "sm/md", .5–.7. = medium "med", .7–.8 = medium/large "md/lg", >.8 = large "lrg"

Pearson's r: < .1 = very small "v sm", .1–.3 = small "sm", .3–.5 = medium "med", > .5 = large "lg"

η^2: 0.01 = small; 0.06 = medium; 0.14 = large

Table 3:

Summary of Qualitative Results

Citation	Summary of Findings
Cole et al. (70)	Improved well-being, mindfulness skills, interpersonal skills, acceptance, and awareness of medical and psychiatric conditions, such as thoughts related to previous traumas and physical pain, and decreased stress reactivity.
Combs et al. (21)	Participation in the group was positively associated with individuals' self-reported belief about the benefit of mindfulness in the areas of overall health, physical health, mood, focus, and self-awareness.
Donnelly et al. (76)	Myriad psychological and physical benefits including improvements in overall wellbeing, sleep quality, emotional state, and concentration.
Donnelly et al. (81)	Belonging, sustaining community connection, physical health, self-regulation, self-efficacy, and resilience.
Donnelly et al. (77)	Perceived improvements in quality of life, positive affect, resilience, and cognition.
Kristofersson (22)	Subjective reports of positive effects of the intervention on quality of life, mood, impulsivity, anxiety, and personal relationships.
Kristofersson et al. (79)	General consensus of the benefits of the MBI and that it fitted well with the site's rehabilitation curriculum. Helped managed anxiety, relaxing.
Niraj et al. (78)	Four themes provided in-depth information about participants' lived experiences of mindfulness training and being in the group; "Developmental learning process", "Group as a supportive environment for learning", "Increased awareness" and "Benefits of mindfulness". Three subthemes within benefits were identified including improvement in sleep and pain, memory and concentration, and emotional wellbeing.

Analysis of themes in was focused on "benefits/outcomes" (themes related to program satisfaction and feedback were omitted)