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A Pilot Study Examining the Effect of Mindfulness-Based Stress Reduction on Symptoms of Chronic Mild Traumatic Brain Injury/Postconcussive Syndrome

Joanne Azulay, PhD; Colette M. Smart, PhD; Tasha Mott, PhD; Keith D. Cicerone, PhD

Objective: To evaluate the effectiveness of the mindfulness-based stress reduction (MBSR) program tailored to individuals with mild traumatic brain injury (mTBI). **Design:** A convenience sample recruited from clinical referrals over a 2-year period completed outcome measures pre- and posttreatment intervention. **Setting:** Post–acute brain injury rehabilitation center within a suburban medical facility. **Participants:** Twenty-two individuals with mTBI and a time postinjury more than 7 months. Eleven participants were men and 11 were women, ranging in age from 18 to 62 years. **Intervention:** A 10-week group (with weekly 2-hour sessions) modeled after the MBSR program of Kabat-Zinn, but with modifications designed to facilitate implementation in a population of individuals with brain injury. (The treatment involved enhancement of attentional skills, in addition to increased awareness of internal and external experiences associated with the perspective change of acceptance and nonjudgmental attitude regarding those experiences). **Main Outcome Measures:** Perceived Quality of Life Scale, Perceived Self-Efficacy Scale, and the Neurobehavioral Symptom Inventory. Secondary measures included neuropsychological tests, a self-report problem-solving inventory, and a self-report measure of mindfulness. **Results:** Clinically meaningful improvements were noted on measures of quality of life (Cohen $d = 0.43$) and perceived self-efficacy (Cohen $d = 0.50$) with smaller but still significant effects on measures of central executive aspects of working memory and regulation of attention. **Conclusion:** The MBSR program can be adapted for participants with mTBI. Improved performance on measures associated with improved quality of life and self-efficacy may be related to treatment directed at improving awareness and acceptance, thereby minimizing the catastrophic assessment of symptoms associated with mTBI and chronic disability. Additional research on the comparative effectiveness of the MBSR program for people with mTBI is warranted. **Key words:** *mild traumatic brain injury*, *mindfulness*, *quality of life*, *rehabilitation*, *self-efficacy*

TRAUMATIC BRAIN INJURY (TBI) is a major cause of disability and mortality in the United States. Such injuries can lead to significant cognitive and neurobehavioral symptoms that can affect interpersonal and occupational function. The Centers for Disease Control and Prevention currently estimates that 1.7 million people sustain a TBI annually[2] and direct and indirect costs of TBI in 2000, for example, totaled 60 billion dollars in the United States.[3] A total of 5.3 million Americans, approximately 2% of the population, have long-term or even lifelong need for assistance in daily activities as a result of sustaining a TBI.[4] Of individuals sustaining TBI, approximately 75% of those involve concussions or some other form of injury that would be designated as mild.[5] A number of studies outline the acute symptoms usually associated with mild traumatic brain injury (mTBI).[6–8] Typically, mTBI sequelae include cognitive impairment and neurologically based personality changes, with poor emotional adjustment and alterations to one's self-concept.[9–11] For most individuals, the cognitive residual of mTBI have largely dissipated by 3 months postinjury.[12,13] There is, however, a subset of individuals who demonstrate incomplete recoveries and continue to experience persistent symptoms months and even years after their initial injury.[14–16] Clinical and research findings suggest 4 main symptom constellations comprising the clinical presentation of chronic mTBI/postconcussive syndrome: (1) cognitive symptoms, including reduced attention, mental control, executive dysfunction, and recall deficits secondary to reduced attention; (2) physical symptoms, such as headache, sensory changes, and

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cognitive/physical fatigue; (3) psychiatric sequelae, including depression, anxiety, and posttraumatic stress disorder; and (4) emotional dysregulation.[17,18]

Although many patients with mTBI have fairly rapid symptom resolution, a significant "miserable minority"[19] of patients experience chronic symptoms that present unique therapeutic challenges as compared with individuals with more severe injuries.[9] Unfortunately, although there has been much discussion and great controversy surrounding the mere existence of a "post-concussive syndrome," comparatively less attention has been paid to development of effective treatments for affected individuals.[19,20]

Mild TBI patients differ in presentation from the more moderate-to-severe injuries with regard to the lack of correlation between the subjective response to their symptoms and the assessable neurologic and neuropsychological deficits.[21] Belanger and colleagues[21] found that the significant emotional distress caused by mTBI contributed to the differences found between mTBIs and more severe injuries. In fact, key features associated with mTBI are the increased endorsements of symptoms[22] and reduced self-efficacy[23] as compared with more severe injuries; often resulting in an inflated and often debilitating emotional response to potentially milder symptoms. Although the constellation of symptoms lack specificity, the etiologic mechanism remains controversial.[24] The emotional distress, rumination, and ability to limit and control the attention to distressful thoughts may be the key to effective treatment with this population. With a paucity of treatment options available to date, treatments used in this population are often taken from samples of individuals with more moderate to severe brain injury, with questionable results.[25,26] Snell and colleagues in 2009[27] systematically reviewed the treatment literature specific to mTBI and found that robust evidence of effective treatments was scarce. They noted supportive evidence for educational interventions but questioned whether the typical intervention of brain injury education applied in the very acute-stage post-mTBI holds any validity in the chronic population. As such, there would seem to be a strong need to implement and assess the impact of treatments tailored specifically to the chronic mTBI symptom constellation, with a particular focus on emotional reactivity to symptoms and controlling the attention focus away from ruminating thoughts and negative evaluation, which, may in turn, positively increase self-efficacy and life satisfaction.

The mindfulness-based-stress reduction (MBSR) program is a group-based intervention that was developed by Jon Kabat-Zinn in 1979.[28] Initially designed for patients with chronic pain, it has now been widely implemented in a variety of medical and psychiatric populations such as those with chronic fatigue, pain, psoriasis, anxiety, and cancer.[29–35] The practice of mindfulness involves learning attention control and cultivating moment-to-moment awareness of thoughts, feelings, and bodily sensations. This is accomplished through a series of mind-body practices that include a "body scan" (ie, somatically focused mindfulness practice), walking meditation, sitting meditation, and yoga. Mindfulness training encourages each participant to become more attuned to his or her own inner resources. This focus may, therefore, enhance self-efficacy and reduce the self-perception of helplessness in the face of residual symptoms. There is no emphasis on productivity and the associated concepts are often synonymous with rehabilitation, such as improving, changing, stopping, or progressing behaviors. Rather, the emphasis is on first recognizing one's emotional and somatic experience and then cultivating acceptance toward it rather than judging it or acting impulsively from a place of emotional reactivity. Theoretically, as patients improve their awareness to their thoughts and bodily sensations, their overall ability to monitor and cope with stress improves. Subsequently, their belief in their ability to manage their symptoms also improves, as their locus of control is reoriented from an external to internal focus. Equally, the process of becoming aware of wayward thoughts and practicing and maintaining control of attention focus may, therefore, improve overall mental control and subsequently ones ability to learn new information. Thus, the ability of MBSR to influence cognitive, emotional, and somatic symptoms makes it very relevant to an mTBI population.

Recent review studies suggest that mindfulness training can result in not only statistically significant but also clinically meaningful outcomes. A 2004 meta-analysis by Grossman and colleagues[36] examined the impact of MBSR on a variety of health samples, such as cancer, pain, heart disease, and psychiatric illness and found moderate ($d = 0.5$) effect sizes. Hoffman and colleagues,[37] who focused specifically on individuals with primary psychiatric illnesses such as depression and anxiety, found similar results in a recent meta-analysis. Clinical research, to date, has focused less on the impact of mindfulness training on cognitive functions such as attention, and as such no meta-analytic studies in this context are available. More information on this topic is available from studies examining healthy novice and expert practitioners of mindfulness. An increasing body of literature demonstrates structural and functional neuroplasticity in circuits related to self-directed attention and emotion regulation arising from both short- and long-term meditation practices,[38,39] although methodologic consistencies across such studies continue to cause undue influence in the interpretation of associated findings.[40] Given that attention is one set of cognitive functions shown to be amenable

to cognitive rehabilitation,[41] one might then extrapolate that mindfulness training could impact attention in individuals for whom this ability is impaired. Chamber and colleagues[42] demonstrated positive changes in both sustained attention and executive function of working memory with a healthy population. Furthermore, there is evidence to support the notion of enhanced attention functioning through mindfulness, positively impacting memory specificity, which, in turn, is related to social problem solving and skills associated with generating solutions to similar events.[40]

To date, there are few studies exploring the use of mindfulness training for people with brain injury. McMillan and colleagues[43] attempted to implement a brief mindfulness intervention with a sample of individuals with TBI of mixed severity. They failed to obtain significant effects on several aspects of attention, stating that "brief exposure to mindfulness meditation cannot be recommended as a treatment technique for traumatic brain injury cases." More encouraging findings have emerged from the work of Bédard and coworkers,[44] who examined the impact of a mindfulness intervention on quality of life within a mild-to-moderate TBI sample. Ten participants who had already completed traditional rehabilitation were consecutively enrolled in a 12-week manualized group treatment based on a combination of Kabat-Zinn's program and Kolb's experiential learning cycle. Compared with 3 treatment dropouts used as controls, the intervention group showed a statistically and clinically significant improvement on the Mental Health subscale of the 36-Item Short Form Health Survey. Depression scores within the subscale also approached significance, reflecting changes in mood regulation.[44]

In sum, there exists a significant minority of individuals with mTBI who experience chronic deficits of sufficient magnitude to impact cognitive and emotional functioning, for whom few if any empirically supported, theoretically driven interventions exist. Mindfulness-based interventions (particularly MBSR) have been shown to improve emotional functioning in various medical and psychiatric populations, but they have yet to be implemented and evaluated in a systematic way within the chronic mTBI population. The aims of this study were (1) to determine whether traditional MBSR could be tailored for clinical use with patients with persisting symptoms after mTBI and (2) to determine the effects of treatment on self-reported postconcussive symptoms, psychological functioning (self-efficacy and life satisfaction), and neuropsychological functioning (attention, memory, and problem solving). We hypothesized that a meditation-based stress reduction program, delivered in a group format would result in an increase in self-efficacy and perceived quality of life and a decrease in severity of neurobehavioral symptoms. We also hypothesized that there would be an improvement in social problem solving secondary to reduced emotional reactivity along with objective improvements in attention and new learning secondary to training in attentional focus.

METHODS

Participants, Recruitment, and Eligibility

The study was conducted in a post–acute brain injury rehabilitation center within a suburban rehabilitation hospital. A convenience sample of 22 participants was recruited from clinical referrals over the course of 2 years. The study was reviewed and approved by the Solaris Health System institutional review board. Inclusion criteria were as follows: (1) 18 to 62 years of age; (2) TBI that meets American Congress of Rehabilitation Medicine criteria for mTBI[45]; (3) at least 3 months postinjury; (4) being medically stable; (5) having sufficient language functioning to participate in a treatment conducted in English; (6) willingness and ability to participate in and travel to a 10-week treatment with agreement to daily homework assignments; and (7) average memory functioning to be able to benefit from a progression of treatment (as measured by total learning trials on the California Verbal Learning Test-II[46] within 1.5 standard deviations of the mean). Specific exclusion criteria included (1) active substance abuse and (2) an acquired brain injury of nontraumatic origin (eg, stroke and encephalitis).

Design

People with mTBI who were participating, or had previously participated, in a post–acute brain injury rehabilitation program were referred for the study by their treating clinicians. Each potential participant was initially assessed for eligibility by one of the investigators on this study. Those who met inclusion criteria and gave their written informed consent completed neuropsychological measures of attention and new learning in addition to a number of self-report measures 1 to 2 weeks before beginning the 10-week treatment program. All measures were administered again within 2 weeks of completion of the program. Treatment dropouts were incorporated through an intent-to-treat analysis. A total of 5 groups were run over a 2-year period with 4 to 6 mTBI individuals per group. The groups generally ran consecutively with breaks during the holiday season secondary to the need for consistent attendance

Outcome Measurement

Perceived quality of life scale

The PQOL scale was initially developed as a cognitive appraisal of patient's life satisfaction after intensive medical care.[47] The modified PQOL scale has been used

with adults with chronic neurologic disability including stroke and TBI.[48] The PQOL scale measures the degree to which the individual is satisfied with his or her functioning on a 10-point scale ranging from *extremely dissatisfied* to *extremely satisfied*.

Perceived self-efficacy scale

Perceived Self-Efficacy Scale for the management of symptoms was adopted from a measure developed for people with chronic disability[49] and modified specifically for use with TBI.[49] Each item is preceded by the question "How confident are you that you can . . . " with responses on a 1- to 10-point Likert scale from *not at all confident* to *totally confident*. We used the total Perceived Self-Efficacy Scale score and examined effect sizes for subscales assessing self-efficacy for the management of cognitive, emotional, and social problems.

Neurobehavioral symptom inventory

The Neurobehavioral Symptom Inventory (NSI) is a self-report rating scale of 22 symptoms that are characteristic of postconcussion syndrome.[50] Participants are asked to rate each symptom according to how much the symptom has disturbed them in the past 2 weeks, using a 5-point rating scale from 0 (*none*) to 4 (*very severe*). The NSI has been shown to reflect cognitive, affective, and somatic/sensory clusters of symptoms.[17,50] In this study, we analyzed the total score and also examined effect sizes for each of the symptom clusters.

Neuropsychological measures

A brief neuropsychological battery was administered to assess the central executive aspects of attention and the ability to acquire new information. These measures were chosen on the basis of the cognitive deficits typically associated with mTBI as well as the literature regarding positive cognitive changes associated with mindfulness in a healthy population. The central executive aspects of attention were assessed with the Continuous Performance Test of Attention[50] and the Paced Auditory Serial Addition Test (PASAT).[51] The Continuous Performance Test of Attention is an auditory continuous performance test with 5 conditions reflecting varied processing loads and conditions and has previously been described in more detail.[50] The raw scores were based on the total number of errors, which were corrected for age and education. The Paced Auditory Serial Addition Test is another measure of auditory processing speed and working memory. Verbal learning and memory were assessed with the total score from the learning trials on the California Verbal Learning Test-II, Alternate Form,[46] with the assumption that improved attention functioning may lead to improved recall.

Social problem-solving inventory–revised short form

A self-report measure of problem solving (Social Problem-Solving Inventory–Revised Short Form)[52] was administered to assess changes in problem-solving orientation and problem-solving skills. This measure looks at problem-solving awareness and style with statements such as "I am too impulsive when making decisions," that are measured from 0 (*not at all like me*) to 5 (*extremely true of me*). Raw scores from the Positive Problem Orientation and Negative Problem Orientation subscales were combined to form a single measure, with higher scores indicating more positive problem-solving orientation. Problem-solving skills were assessed with raw scores obtained on the short form Social Problem-Solving Inventory.

The mindful attention awareness scale

We also assessed participants' self-reported levels of mindfulness using the Mindful Attention Awareness Scale,[53] with items such as "I find it difficult to stay focused on the present" which are measured from *almost always* to *almost never*.

Intervention

The intervention consisted of a 10-week group (one 2-hour session per week) modeled after Kabat-Zinn's MBSR program, but modified to accommodate the needs of a population of individuals with brain injury. Although we considered providing an individual modality of treatment, we opted to maintain a group format to remain consistent with Kabat-Zinn's MBSR program. The modifications were made to specifically meet cognitive challenges such as reduced recall, disorganization, poor topic maintenance, and attention dysregulation. We expanded the number of treatment sessions from 8 to 10 and reduced group sizes to an average of 6 rather than 25 to allow for the increased time patients required for us to explain concepts, repeat procedures, reinforce learning process, and process their experiences with the practice. We also provided an increased amount of modeling of more sophisticated techniques, such as using mindfulness for exploration of emotional and physical pain, as brain injury–related problems with abstract reasoning sometimes makes these concepts more difficult to grasp and apply. To address memory problems, in addition to repetition of procedures and ideas, we provided all assignments in writing each week along with homework log to write in the amount of time practiced and observations regarding experiences. This tailored treatment was then manualized to ensure treatment consistency across groups and leaders. Each group was run by 2 leaders, all of whom were neuropsychologists with training in MBSR (J.A., C.M.S., or T.M.). For each

group, of the 2 leaders, one specialized in brain injury rehabilitation and the other had been actively practicing and teaching meditation for more than 10 years.

RESULTS

Demographics

Table 1 provides the full demographics of the sample. In summary, the sample comprised 50% women, 68.2% white, with a mean age of 48.9 years (SD = 8.3). More than half of the participants were married (54.5%), and 68% had more than a high school education (mean: 14.5 years, SD = 2.5). Religious affiliation was designated as Catholic or some other form of Christian in the vast majority of the group (91%). Most participants (80%) had time postinjury of more than 12 months and none were earlier than 7 months. Most listed their employment status as disabled at the time of treatment (68.2%). All of the participants had received some form of concurrent rehabilitation during their participation in the study, with the majority (81.8%) receiving limited (individual neuropsychology only) treatment through a neuropsychology clinic. Mean treatment prior to participation in the study was 9.1 months (SD = 4.8).

TABLE 1 *Demographics of the sample*

Demographics	Frequency	Valid percent
Gender		
Men	11	50.0
Women	11	50.0
Ethnicity		
African American/black	2	9.1
Asian Pacific Islander	1	4.5
White	15	68.2
Hispanic/Latino	4	18.2
Marital status		
Never married	4	18.2
Married	12	54.5
Divorced	6	27.3
Level of education		
<12 y	1	4.5
12-16 y	18	81.9
>16 y	3	13.6
Religious/spiritual affiliation		
Agnostic	1	4.5
Catholic	13	59.1
Jewish	1	4.5
Other Christian	7	31.7
Time postinjury		
7-12 mo	4	20.0
13-36 mo	15	75.0
>36 mo	1	5.0
Current Employment Status		
Disabled	15	68.2
Full-time	6	27.3
Seeking employment	1	4.5
Current treatment status		
Standard cognitive rehabilitation[a]	4	18.2
Neuropsychology clinic[b]	18	81.8

[a]Patients receiving more than 3 disciplines such as ot, pt, and neuropsychology treatment.

[b]Patients receiving less than 3 treatments such as neuropsychology and pt only.

Self-report and neuropsychological measures

Paired sample *t* tests were used to ascertain significant changes in those variables from pre- to posttest intervention. Results are presented in Table 2. To avoid the possibility of spurious findings due to type I error, the Sidak correction for multiple comparisons was applied to the 5 self-report measures and the 3 neuropsychological tests. To maintain α at .05, this required an adjustment to $P < .01$ for both the self-report measures and the neuropsychological tests. We generally used total scale scores for the outcome measures for statistical analysis of significance. For the neuropsychological measures, we considered a patient to make clinically meaningful change when the test score moved from an impaired to normal range. In keeping with the study objectives, we also examined the effect sizes for subscales of the various outcome measures.

Significant pre/posttest changes were observed on the Perceived Self-Efficacy Scale and PQOL scales, with evidence of moderate effect sizes (Table 2). Improvements in perceived self-efficacy were most apparent for the management of cognitive ($d = 0.55$) and emotional symptoms ($d = 0.56$). Participants also showed a reduction in symptoms on the NSI although this did not reach significance. The overall NSI showed a small-to-moderate effect size (0.32). Reduction in self-reported symptoms on the NSI was most apparent for cognitive symptoms ($d = 0.36$) and emotional symptoms ($d = 0.38$) and was less evident for somatic/sensory symptoms ($d = 0.22$).

Both measures of attention showed significant improvements from baseline to postintervention, while new learning remained unchanged. We observed small effect sizes on the Continuous Performance Test of Attention ($d = 0.31$) and Paced Auditory Serial Addition Test (0.32).

Standard scores were obtained for these individuals on the basis of relative age and education-corrected normative data. Of the 21 individuals with pre/posttest data, one-third of these ($n = 7$) showed clinically significant change from a lower functioning category (eg, impaired) to a higher functioning category (eg, average) on either or both of the attention measures. The mean level of education for individuals showing clinically significant change (15.3 years) was not different from that of the sample as a whole. There was no statistically

TABLE 2 *Pre/postintervention changes in self-report and neuropsychological measures*

Variable	*M* (SD)	*t* (*df*)	*P*	Cohen *d*
NSI				
Pre	44.5 (15.3)			
Post	39.9 (13.5)			
Difference	4.6 (11.3)	–1.90 (21)	.07	0.32
MAAS				
Pre	48.1 (14.8)			
Post	53.0 (10.7)			
Difference	4.9 (14.9)	1.41 (17)	.18	
PSES				
Pre	51.9 (24.6)			
Post	64.9 (27.2)			
Difference	13.0 (16.3)	3.76 (21)	.001	0.50
PQOL				
Pre	40.5 (19.9)			
Post	49.1 (20.1)			
Difference	8.6 (12.0)	3.37 (21)	.003	0.43
SPSI				
Problem orientation				
Pre	19.6 (8.6)			
Post	22.2 (7.1)			
Difference	2.6 (mmm)	–2.49 (21)	.021	0.33
Rational problem solving				
Pre	8.7 (4.0)			
Post	9.7 (3.9)			
Difference	1.0	11.51 (21)	.134	0.25
CPT-A				
Pre	20.0 (14.7)			
Post	15.4 (15.1)			
Difference	4.6 (7.9)	–2.64 (20)	.01	0.31
PASAT				
Pre	92.4 (34.0)			
Post	103.9 (37.7)			
Difference	11.5 (14.3)	3.69 (20)	.001	0.32
CVLT-II				
Pre	46.6 (9.7)			
Post	48.4 (11.5)			
Difference	1.8 (5.0)	1.66 (20)	.11	0.02

Abbreviations: CPT-A, Continuous Performance Test of Attention; CVLT-II, California Verbal Learning Test, Second Edition-Alternate Form, Trials 1-5; MAAS, Mindful Attention & Awareness Scale; NSI, Neurobehavioral Symptom Inventory; PASAT, Paced Auditory Serial Addition Test; PQOL, Perceived Quality of Life Scale; PSES, Perceived Self-Efficacy Scale; SPSI, Social Problem-Solving Inventory-Revised, Short-Form.

significant effect on verbal learning and memory. There was no statistically significant effect on verbal learning and memory, with minimal clinical effect.

Participants exhibited more positive problem-solving orientation after the intervention, but no significant improvement in self-reported problem-solving skills

DISCUSSION

This study represents a systematic attempt to deliver an MBSR program to a cohort of individuals with PCS following mTBI. Although a large number of studies demonstrate the impact of mindfulness-based interventions in a variety of medical populations, comparatively fewer studies focus on implementation of mindfulness practice in a sample of participants with brain injury. This study provides encouraging results regarding the application of MBSR in a chronic mTBI population. This finding is particularly pertinent given the widespread acceptance and interest in alternative and complementary interventions such as meditation among individuals recovering from TBI.[54] In fact, despite the less than typical treatment, when asked for posttreatment feedback, patients were very positive and consistently reported benefits that impacted many areas of their life; even those initially more skeptical. They often spoke of the

treatment as being "life changing." Many of their comments throughout the study were used to shape the final treatment product.

More specifically, in this study, we were able to demonstrate that MBSR can be implemented in a sample of participants with mild brain injury with specific elements of the program tailored for this population. Most notably, clinically significant improvements were noted in participants' perceived self-efficacy, particularly for the management of emotional and cognitive symptoms. Consistent with these findings, participants reported more positive problem-solving orientation after the intervention. These changes in perceived self-efficacy and problem orientation may underlie the improvements in global life satisfaction that also accompanied the intervention. These findings are consistent with the findings of Bédard et al[44,55] regarding the impact of mindfulness training on mTBI. The moderate effect sizes we observed are also consistent with recent meta-analyses regarding the impact of mindfulness training on psychological variables in nonneurologic samples.[36,37]

Despite positive changes in participants' self-efficacy for management of cognitive and emotional symptoms associated with the intervention, we did not observe a significant reduction in neurobehavioral symptoms. This may reflect participants' improved ability to tolerate and manage the disruptive effects of cognitive and emotional symptoms, with less change in self-reported symptom severity per se. However, the reduction in cognitive and emotional symptom severity did show a modest clinical effect, and it is possible that improvements in self-reported symptoms would be more evident with a larger sample of participants. The relationship among symptom severity, self-efficacy for symptom management, and life satisfaction after mTBI requires further investigation.

We obtained small but significant effects of mindfulness training on the central executive aspect of attention, commensurate with a recent meta-analytic review regarding the impact of traditional cognitive rehabilitation on attention.[41] As noted, few studies have been conducted that examine the use of mindfulness as a treatment for impaired attention in clinical samples. Of the limited research available, our study is consistent with recent work showing improvement in both executive control and self-reported cognitive and emotional functioning in both adolescents and adults with attention deficit/hyperactivity disorder following traditional MBSR training[43] failed to find a significant effect of mindfulness training on attention functions. However, the delivery of the treatment did not follow the standard MBSR format, was primarily self-administered at home via audio recording, and was of shorter duration than typical mindfulness training, and as such may have been of insufficient "dose" to produce clinically meaningful benefit. Our results are also consistent with the demonstrated effects of integrative meditation, including mindfulness training, on the efficiency of the executive attention network related to self-regulation in nonneurologic participants, with no change on the orienting or alerting aspects of attention.[57] Tang and Posner[58] have suggested that attention state training (meditation and mindfulness training) and direct attention training may both produce brain changes in the connectivity between anterior cingulate and lateral prefrontal cortex and lead to improvements in attention and self-regulation. Novakovic-Agopian et al[59] have recently shown that goal-oriented attention training that included MBSR resulted in significant improvements on neuropsychological tests of attention and executive functioning. This evidence suggests that future research might examine the neural and behavioral similarities (and differences) between direct attention training and attention state training and that MBSR training may be an effective aspect of training attention regulation and executive functioning.[58] The extent to which improvements in the ability to regulate attention are related to positive changes in mood, mental fatigue, and emotional regulation also merits consideration. As hypothesized by Chiesa et al,[40] it may well be that the enhanced ability to self-regulate emotions as well as control and direct attention decrease rumination and effect an improved experience of self-efficacy with an internalized sense of locus of control.

Although a large number of studies demonstrate the impact of mindfulness-based interventions in a variety of medical populations, comparatively fewer studies focus on implementation of mindfulness practice in a sample of participants with brain injury. This study provides encouraging results regarding the application of MBSR in a chronic mTBI population. This finding is particularly pertinent given the widespread acceptance and interest in alternative and complementary interventions such as meditation among individuals recovering from TBI.[54]

This study has several limitations. All of the participants were receiving concurrent rehabilitation, so that it is impossible to isolate the effects of MBSR. Future research should address the comparative effectiveness of MBSR using adequate controls. The ability to detect improvements on certain measures may have been limited by the relatively small sample size. It will also be important to examine the effects of MBSR using specific measures of emotional regulation and mental health in future studies. The further addition of a control group, and randomization to treatment conditions, may also enhance the strength of the design and further elucidate the effects of mindfulness training in chronic mTBI.

CONCLUSIONS

This study represents one of the few systematic efforts to evaluate the impact of MBSR in a TBI population, and possibly the first specifically tailored to the chronic mTBI population. Given the prevalence of mTBI and its costs to the individual and society at large, we hope that this study will stimulate further efforts to develop empirically supported interventions for this population, including the use of mindfulness-based interventions.

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