MINDFULNESS-BASED INTERVENTION RECOMMENDATIONS FOR ATHLETES EXPERIENCING MILD TRAUMATIC BRAIN INJURY- A NARRATIVE SYNTHESIS REVIEW

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ABSTRACT

THESIS: Mindfulness-Based Intervention Recommendations for Athletes Experiencing Mild Traumatic Brain Injury - A Narrative Synthesis Review

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Research shows that the interventions for the cognitive, affective, somatic, and sleep dysregulation symptoms of mild traumatic brain injury have varying significance and low effect sizes. Recently, mindfulness-based interventions (MBI) have been considered for patients across many different clinical populations, including sport-related mild traumatic brain injury (mTBI). Additionally, athletes who have had previous mindfulness training through sport psychology performance interventions may benefit the most from mindfulness-based interventions for injury. Therefore, this narrative synthesis aims to summarize the current MBI literature surrounding the four main deficits of mTBI in college-aged individuals and provide recommendations to sport-psychology or -medicine practitioners. To accomplish this eight databased were searched for studies using MBIs to treat cognitive, affective, somatic, and sleep symptoms across different patient populations, with a mean age of 18-30 years. Results found common, significant, intervention themes for depressive, anxiety, and sleep symptomology. Interventions that emphasized open monitoring mindfulness-based interventions (MBIs) and emphasized detachment, acceptance or CBT showed significant improvements on depression symptoms. Focused attention, progressive muscle relaxation, or yoga MBIs showed the most significant improvements in anxiety symptoms. Mindful movement and focused attention MBIs were utilized in all three studies that significantly reduced sleep symptoms. No common themes were found for cognitive or somatic symptoms. This review recommends sport psychology and sports medicine practitioners take a symptoms-based response to mTBI treatment, emphasizing the most significant presenting symptom. MBIs can be used when treating athletes who mostly present with depression, anxiety, or sleepy dysregulation. However, standard practice is recommended for athletes presenting with either cognitive or somatic complaints.

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Chapter I

Introduction

Introduction

Traumatic brain injury (TBI) is defined as “an alteration in brain function, or other evidence of brain pathology, caused by an external force” (Menon et al., 2010;p. 1638) and is estimated to affect 57 million individuals worldwide each year, with 1.7-2.9 million in the United States alone (Blennow et al., 2016; CDC, 2021; Faul et al., 2010). Researchers have suggested that this annual number may be even larger since TBIs that occur in military populations or those treated in outpatient settings are typically not included in epidemiological statistics (Langlois et al., 2006). In the year 2000, the direct and indirect costs of TBI alone was estimated to be over 60 billion dollars in the United States (Finkelstein et al., 2006).

TBI is typically divided into two separate categories: mild traumatic brain injury (mTBI) and moderate-to-sever TBI. mTBIs are the most prevalent, accounting for 75-95% of all TBIs (CDC, 2003; Feigin et al., 2013) and are defined as “a complex pathophysiological process affecting the brain, induced by biomechanical forces” (McCrory et al., 2013;p. 256). Sport-related concussions are a common cause of mTBIs, and account for anywhere between 1.6-3.8 million cases each year in the United States (Harmon et al., 2013; Langlois et al., 2006; Leddy et al., 2012).

Symptoms commonly experienced by individuals with mTBI can be divided into four separate categories: cognitive, affective, somatic, and sleep dysregulation (Azouvi et al., 2017; Barman et al., 2016; Bramley et al., 2016; Polinder et al., 2018; Yeates et al., 2017). Cognitive symptoms present themselves as deficits in tasks such as attention, memory, and concentration

(Binder et al., 1997; Brooks et al., 1999; Cicerone & Azulay, 2002). Affective symptoms for mTBI are typically limited to depression and anxiety, however, other can also be present (Mainwaring et al., 2004; McCorkle et al., 2021). Somatic symptoms are generally limited to different severities of headaches (Baandrup & Jensen, 2005; Defrin, 2014), and the research surrounding sleepy dysregulation after mTBI is starting to be expanded upon (Wickwire et al., 2016).

Most individuals start to recovery from their mTBI within weeks post-injury (Cole & Bailie, 2015). However, literature disagrees on when to deem an individual to be fully recovered. For example, one study by Rabinowitz et al. (2015) found that individuals typically recovery within three months, while other studies find that a typical recovery can last six to twelve months (Barker-Collo et al., 2015; Nelson et al., 2019; Stulemeijer et al., 2006). Therefore, mTBI interventions are useful for the longer recoveries. Non-surgical interventions for mTBI are wide ranging and can include rest, education and reassurance, cognitive rehab, cognitive behavioral therapy (CBT), pharmacological treatment, and mindfulness-based interventions (Borg et al., 2004; Lumba-Brown et al., 2018; Sullivan et al., 2020; Teo et al., 2020; Williams & Evans, 2003).

The effectiveness of mTBI symptom interventions can vary greatly from study to study (Borg et al., 2004; Prince & Bruhns, 2017; Teo et al., 2020). One meta-analysis found that no intervention produced significant results in reducing the post concussive symptoms at 3-6 months post-injury (Teo et al., 2020). However, when these researchers examined the pooled functional outcomes, they observed a small overall effect size. The World Health Organization task force on mTBI found slightly different results when examining the literature (Borg et al., 2004). This task force found that education and reassurance showed a significant reduction in post concussive symptoms, but the effect size was also small (Borg et al., 2004). There are multiple hypotheses on why the literature has not come to a consensus regarding the optimal treatment for mTBI. Teo et al. (2020) state that there is a lack of consistent outcome measure used in mTBI intervention. Additionally, inconsistency between fewer outcome measure may not produce a consensus due to the heavy reliance on an individual's subjective experience, rather than rigorous biological or cognitive measures (Prince & Bruhns, 2017). Lastly, there is currently a lack of non-surgical interventions being explored for mTBIs (Borg et al., 2004).

Mindfulness-based interventions (MBIs) have recently been explored within the mTBI population (Acabchuk et al., 2021; Johansson et al., 2012; Kenuk & Porter, 2017; Shirvani et al., 2021) and focus on fostering an individual's self-regulation of attention in a non-judgmental manner (Bishop et al., 2004). The most common MBIs are mindfulness-based stress reduction (Kabat-Zinn & Hanh, 2009), yoga (Breedvelt et al., 2019), and mindfulness-based cognitive therapy (Bédard et al., 2014; Bédard et al., 2012). There are two theoretical justifications for the use of MBIs for treating mTBI symptomology. The first is that MBIs target deficits commonly seen after mTBI such as concentration, attention, and dysregulated emotional processing (Link et al., 2016). The second is how meditation can impact the default mode network (DMN). MBI research has found that these specific interventions can help with the regulation of the DMN (Boccia et al., 2015; Fox et al., 2014), a network of the brain that plays a significant role in disorders such as schizophrenia, depression, and anxiety (Coutinho et al., 2016; Whitfield-Gabrieli & Ford, 2012).

Athletes with mTBIs (concussions) may be in a position to benefit the most from MBIs. When individuals complete MBIs, trait mindfulness (how prone one is to be mindful everyday) is seen to increase (Carmody et al., 2008; Shahar et al., 2010; Shapiro et al., 2008). Additionally, those with higher pre-intervention trait mindfulness exhibited larger increases in subjective well-being, empathy, and hope, as well as larger decreases in stress than those with lower trait mindfulness up to one-year post-intervention (Shapiro et al., 2008). The Mindfulness-Acceptance-Commitment model (MAC) model is a mindfulness-based sport performance intervention that has been used with athletes for over two decades (Gardner, 2016; Gardner & Moore, 2017). Therefore, athletes who have experience with MBIs through the MAC model, may experience more benefits when using MBIs for mTBI recovery. Secondly, many positive sport- and performance-related outcomes measures have been improved through the implementation of MBI in sport psychology research (Bailey et al., 2018; De Petrillo et al., 2009; Pineau et al., 2014). For example, studies have shown that MBIs for sport performance can increase flow, attention, and affect (Bailey et al., 2018; Pineau et al., 2014), while also reducing stress (Bailey et al., 2018).

Purpose of the Study

The purpose of this systematic literature review was to analyze the trends and intervention strategies for each of the symptoms involved with mTBIs, specifically targeting college-aged student athletes. Additionally, this review intends to provide practitioners a summary of the state of MBIs across fields of medicine to stimulate future research about short-term injury recovery in sport. The information gathered through this review can be used to make protocol recommendations when treating college-aged student athletes who have experienced mTBI, focusing on a brief recovery window.

Research Questions

1. Based on a systematic review of the literature on mindfulness-based interventions (MBIs) for short-term symptoms of mild traumatic brain injury (mTBI), what is the current state of research and where can the research be expended upon?
2. Based on those findings, develop recommendations for practitioners interested in utilizing MBIs for college-aged athletes with mTBIs?

Definition of Terms

1. Athlete is defined as an individual who is training to improve their performance, actively competes in sport competitions, registered to a team, and where sport training and competition is a major activity in the individual's life (Araújo & Scharhag, 2016).
2. Mild Traumatic brain injury is defined as "a complex pathophysiological process affecting the brain, induced by biomechanical forces" (McCrory et al., 2013;p. 256).
3. Mindfulness is defined as involving "the self-regulation of attention so that it is maintained on immediate experience, thereby allowing for increased recognition of mental events in the present moment" (Bishop et al., 2004;p. 232) and "adopting a particular orientation toward one's experiences in the present moment, an orientation that is characterized by curiosity, openness, and acceptance" (Bishop et al., 2004;p. 233).
4. Mindfulness-based intervention is defined as an intervention that focus on fostering an individual's self-regulation of attention in a non-judgmental manner (Bishop et al., 2004).

Delimitations

1. Data bases limited to APA PsychINFO, CINAHL, ERIC EBSCOHost, MEDLINE, PubMed, Science Direct, Sport Discus, Sports Medicine & Education Index, and Web of Science.

2. Studies limited to peer-reviewed articles and doctoral dissertations published in the last 20 years in English.
3. Article selection criteria: 1) use short-term MBIs (lasting no more than 2 months); 2) include participant population with a mean age of 18-30 years old; 3) include a control group; and 4) target one of the four symptoms common to mTBI (i.e., decreased attention memory, and concentration; increased levels of depression and anxiety; pain, specifically headaches; and sleep dysregulation).

Assumptions

1. It was assumed that the selected journal for the initial search represents a comprehensive view of the literature.
2. It was assumed that the studies included in this narrative synthesis are reported accurately and with statistical honesty.
3. It was assumed that studies that did not include a specific age range, but general description of the study sample were within the inclusion criteria for mean age of the study sample.

Limitations

1. Note all included studies included effect size.
2. The quality of intervention descriptions varied from study to study.
3. Only 3 studies evaluating sleep were included in this review.

Significance of the Study

Research has shown that, despite a spike in popularity, MBI research for athletes with mTBI is still in its infancy. This narrative synthesis may help expand the literature by providing recommendations for college-aged athletes who are experiencing the common symptoms of mild traumatic brain injury. Additionally, a unique aspect of this review is how it examines and summarizes the literature unique to each symptom instead of solely the concussion literature of this age range. Sport psychologists and medical professionals may also benefit from the results of this review due to MBIs being found as cost-effective and the high prevalence of mindfulness-based applications, programs, and intervention plans available to download.

Chapter II

Review of Literature

Traumatic brain injury (TBI) is defined as “an alteration in brain function, or other evidence of brain pathology, caused by an external force” (Menon et al., 2010;p. 1638). Each part of the definition can be broken down further. For example, “an alteration in brain function” can be defined by the following signs: (1) a loss or decrease in level of consciousness for any period of time; (2) loss of memory of event preceding or following injury; (3) neurological deficits such as weakness, balance issues, vision changes, sensory loss, etc.; or (4) an alteration in mental functioning at the time of injury such as confusion, disorientation, etc (Menon et al., 2010). “Or other evidence of brain pathology” may include visual, neuroradiologic, or laboratory confirmation of the brain damage (Menon et al., 2010). Lastly, “caused by an external force” could include: (1) head being stuck or striking an object; (2) the brain experiencing acceleration/deceleration without direct external trauma to the head; (3) brain penetration by a foreign body; or (4) blast/explosion forces (Menon et al., 2010).

Traumatic brain injury affects an estimated 57 million people worldwide each year, with 1.7-2.9 million in the United States alone (Blennow et al., 2016; CDC, 2021; Faul et al., 2010). However, the prevalence of TBIs in the United States may be underestimated because TBIs experienced in the military and in outpatient settings are typically not included in these statistics (Langlois et al., 2006). The most recent report detailing the epidemiology of TBIs in the United States was released in 2021 with data from 2016-2017 (CDC, 2021). The data from the CDC showed that the number of TBI-related hospitalizations decreased from 227,000 in 2016 to 224,000 in 2017. Children 0-17 years of age represented roughly 8.6% of all hospitalizations due to TBI in 2016 and 7.8% in 2017. Rates of TBI-related hospitalizations in 2016-2017 were highest in adults aged ≥75 years, individuals aged 65-74 years, and those aged 55-64; their rates per 100,000 were 313.4 in 2016 and 320.8 in 2017; 104.8 in 2016 and 102.7 in 2017; and 67.7 in 2016 and 67.5 in 2017, respectively. Approximately 600,00 TBI-related deaths occurred in 2016, with that number increasing to over 61,000 in 2017. Children 0-17 years of age accounted for 4.5% of all the TBI-related deaths. The costs, both direct and indirect, due to TBI has estimated to total over 60 billion dollars in the United States (Finkelstein et al., 2006).

From vehicular accidents (Lowenstein, 2009; Maas et al., 2008) to unintentional falls (CDC, 2021), there are a wide range of events that can lead to a TBI-related hospitalization. Unintentional falls totaled 49% of all TBI-related hospitalizations in 2017 and vehicular accidents totaled 25% (CDC, 2021). Other significant causes of TBI-related injury and hospitalizations are sports and military service (Haring et al., 2015; Helmick et al., 2015). An estimated 500,000 sport-related TBI emergency department visits in the United States occurred between the years of 2006-2011 (Haring et al., 2015). Additionally, over 300,000 military service members have experienced a combat-related event that has caused a TBI since 2000 (Helmick et al., 2015).

Males have a significantly higher age-adjusted rates of the major mechanisms of injury that led to TBI-related hospitalizations compared to females (CDC, 2021). For example, in 2017 males had at higher rates of unintentional falls, more than twofold rates of motor vehicle crashes, unintentionally being struck by or against an object, and intentional self-harm, and a more than fourfold rate of assault than females. This risk factor is also seen in TBI-related deaths, as males have higher age-adjusted rates per 100,000 in the age rages of ≥75 years, 65-74 years, and 55-64 years.

TBI Categories

TBI can be reduced into three categories: mild, moderate, and severe, largely based on criteria such as structural imaging, loss of consciousness, alternation in consciousness/mental state, posttraumatic amnesia, and Glasgow Coma Scale rating (STATEMENTS, 2009). The Glasgow Coma Scale (GCS) is the most widely used assessment of TBI severity in clinical settings. The GCS scores range from 0-15 with scores of 13-15 indicating mild traumatic brain injury, scores of 9-12 indicating moderate traumatic brain injury, and scores of <9 indicating a severe traumatic brain injury (Cullum & Munro, 2019; STATEMENTS, 2009). While the GCS has been a leading assessment in acute brain injury populations for the past 40 years, it is recommended that it be used in tandem with other assessments in a multivariate model (Teasdale et al., 2014).

Mild Traumatic Brain Injury

Mild traumatic brain injury (mTBI), also called concussion, is defined as "a complex pathophysiological process affecting the brain, induced by biomechanical forces" (McCrory et al., 2013;p. 256). The estimated global prevalence of mTBI is 55.9 million each year (Dewan et al., 2018), and according to epidemiological studies, mTBIs are estimated to account for 75-95% of all TBIs (CDC, 2003; Feigin et al., 2013). This wide estimated range is due to the number of individuals who do not seek medical attention for their injuries (de Koning et al., 2017). Sport-related concussions has been stated to be a public health problem with roughly 1.6-3.8 million occurring each year in the United States (Harmon et al., 2013; Langlois et al., 2006; Leddy et al., 2012). The high prevalence and symptomology of mTBI shows that mTBI is not a "mild" injury in the slightest (McMahon et al., 2014).

One unique aspect of mTBI is the phenomena known as persistent post-concussion syndrome (PPCS). Persistent post-concussion syndrome is sometimes called post-concussion syndrome, but this term is also used to describe the symptoms immediately following injury. Therefore, this review will use the term persistent post-concussion syndrome. This phenomena occurs when individuals do not fully recovery and continue to experience their symptoms of mTBI months, or even years, after their injury (Binder, 1986; Mooney & Speed, 2001; Rutherford et al., 1979; Silverberg & Iverson, 2011). One study that found extreme results showed that a minority of individuals were still experiencing symptoms four years post-injury and required yearly interventions to help reduce their PPCS (Theadom et al., 2018). While self-reported concussions are not typically associated with PPCS, those who are exposed to frequent, long-term sport induced head impacts have a "modest, but statistically robust," detriment of inhibitory control, specifically with cognitive functioning abilities (Stafford et al., 2020). Persisting cognitive problem, specifically two years post-injury, are associated with lower level of education and to pre-injury cognitive deficits, and lower participation due to PPCS (in life, sports, etc.) is associated with slower inhibition speed, impaired visuospatial and verbal working memory (Lambregts et al., 2018).

Moderate-to-Severe TBI

Moderate-to-severe TBI is much less prevalent than mTBI, accounting for roughly 5-25% of all TBIs (CDC, 2003; Feigin et al., 2013). The two most common causes of moderate-to-severe TBI are vehicular accident and falling (Andriessen et al., 2011; McArthur et al., 2004). Dying from a moderate-to-severe TBI is a realistic probability compared to those with mTBI, with epidemiological studies finding rates as high as 30-44% (Andriessen et al., 2011; McArthur et al., 2004). For those who survive, the symptomology and recovery processes of moderate-to-severe TBI differs from mTBI. All three categories of TBI are associated with an increased risk of psychiatric illness following the injury; however, the clinically significant chance of psychiatric disturbance is 49% for those in moderate-to-severe TBI populations and 34% in mTBI populations (Fann et al., 2004). Additionally, individuals with moderate to severe TBI have a higher risk of psychiatric illness after the initial injury, while individuals who have experienced mTBI have a higher risk of persistent psychiatric illness (Fann et al., 2004). The neuropsychiatric symptoms for populations with moderate to severe TBI are wide ranging and typically include: apathy, irritability, dysphoria/symptoms of depression, disinhibition, eating disturbances, and agitation (Ciurli et al., 2011). Unlike mTBIs and PPCS, long term deficits are commonly found in individuals with moderate-to-severe TBI, with individuals of severe TBI sometimes requiring professional assistance for years post-injury to maintain psychological quality of life (Hoofien et al., 2001). Gender differences also appear to be present in moderate-to-severe TBI, with males experiencing a decreased ability to set realistic goals, experiencing restlessness, and higher sensitivities to noise, and women experiencing more issues in daily functioning, lack of initiative, and headaches

mTBI Symptoms

Overview

Symptoms commonly experienced by individuals with mTBI can be divided into four separate categories: cognitive, affective, somatic, and sleep dysregulation (Azouvi et al., 2017; Barman et al., 2016; Bramley et al., 2016; Polinder et al., 2018; Yeates et al., 2017). Cognitive symptoms present themselves as deficits in tasks such as attention, memory, and concentration (Binder et al., 1997; Brooks et al., 1999; Cicerone & Azulay, 2002). Affective symptoms for mTBI are typically limited to depression and anxiety, however, other can also be present (Mainwaring et al., 2004; McCorkle et al., 2021). Somatic symptoms are generally limited to different severities of headaches (Baandrup & Jensen, 2005; Defrin, 2014), and the research surrounding sleepy dysregulation after mTBI is starting to be expanded upon (Wickwire et al., 2016).

There are many risk factors that can impact how severe symptoms are presented, such as previous TBIs, sex, mental factors (stress, anxiety, and expectations), and social factors (Gunstad & Suhr, 2002; Polinder et al., 2018; Ponsford et al., 2000; Whittaker et al., 2007). For example, one study found that individuals who had a history of head injury were highly distressed for a significantly longer amount of time compared to those without a history of brain injury (Ponsford et al., 2000). Additionally, two studies found that when an individual perceives their injury to be something that will negativley impact their lives, are more likley to experience PPCS (Gunstad & Suhr, 2002; Whittaker et al., 2007). It is also important for clinicians to note that the symptoms may manifest themselves differently depending on the population being studied. For example, when athletes experience a mTBI (concussion), they appear to be stunned, confused about or forget what they are doing, uncoordinated movement on the field, reduced reaction time, or display great uncertainty (Kontos et al., 2004). Where the brain sustained the injury can also affect which types of symptoms an individual may experience (Kontos et al., 2004). For example, a blow to the frontal lobe is more likely to result in a change in personality or mood or confusion and executive functioning, with a lower chance of loss of consciousness, whereas a blow to the temporal lobe is more likley to result in confusion and memory disturbance compared to loss of consciousness (Kontos et al., 2004). A blow to the back of the head is likley to result in somatic symptoms such as dizziness, sensitivity to light and noise, with the highest change of loss of consciousness due to it being closer to deeper brain structures (Kontos et al., 2004).

Cognitive Symptoms

The cognitive deficits commonly observed by individuals with mTBI are a reduction in speed of information processing, attentional and concentration issues, reduction in memory, and issues involving executive functioning (Binder et al., 1997; Brooks et al., 1999; Cicerone & Azulay, 2002; Dikmen et al., 1986; Frencham et al., 2005; Leininger et al., 1990; Levin et al., 1987; McAllister & Arciniegas, 2002; McAllister et al., 1999; McAllister et al., 2001; McDonald et al., 2002; Raskin et al., 1998; Schretlen & Shapiro, 2003; Zakzanis et al., 1999). These deficits are seen immediately after injury, with sustained attention being the cognitive ability that takes the longest to recover (Kwok et al., 2008). As discussed above, cognitive symptoms contribute to a large portion of PPCS symptoms (Lambregts et al., 2018; Stafford et al., 2020). In order to optimally treat and track an individual's cognitive symptom recovery, neuropsychological assessments should be used (Miotto et al., 2010). One of the most effective methods of assessing cognitive impairments and an individual's cognitive recovery is through the use of functional neuroimaging methods such as the fMRI (Wylie et al., 2015). The benefits of fMRIs come from the method being a non-invasive way of assessing neuronal circuity while also able to examine gray matter and cortical structures (Mayer et al., 2015).

Memory and executive functioning issues are seen when individuals have legions to their frontal or temporal lobes (Miotto et al., 2010), regions responsible for these different tasks (Bigler, 2008; Ghajar & Ivry, 2008). Specifically, legions to the left frontal lobes are associated with lower recognition, delayed recall, and general executive function. Right and left temporal legions are associated with cognitive functioning, and right and left frontal temporal legions are associated with deficits in verbal fluency, naming, and information processing (Miotto et al., 2010). Deficits in neuropsychological attention processes are multifaceted, explaining the varied symptoms and severity (Gunstad et al., 2006). Symptomology may differ depending on the functional capability of the sensory selective attention, response selection or control, focus or capacity, and sustained attention processes.

Affective Symptoms

The affective symptoms commonly observed after experiencing mTBI are depression, anxiety, and fear/post-traumatic stress disorder (PTSD; Mainwaring et al., 2004; McCorkle et al., 2021). The prevalence rates of affective symptoms vary slightly in individuals who experience a mTBI (Hoge et al., 2008; Rapoport et al., 2003; Scholten et al., 2016). Depression has been found to be in 15.3% of mTBI cases (Rapoport et al., 2003) and multiple anxiety symptoms and disorders have been found in 21% of mTBI cases (Scholten et al., 2016). PTSD is strongly associated with mTBI in military populations with 43.9% of individuals experiencing loss of consciousness and 27.3% of individuals experiencing an altered mental state that meets the criteria for PTSD (Hoge et al., 2008). Athletes have been found to self-report PTDS-like symptoms in the earlier stages of recovery post-injury. The specific PTSD symptoms observed are general sleep difficulty, avoidance of similar situation, the inability to avoid thinking about the injury, feelings detached, flashbacks, and nightmares (Brassil & Salvatore, 2018).

Affective symptoms are often found to be comorbid, with anxiety being associated the most with other mood symptoms. While there is a strong link between anxiety and depression following mTBI (Barker-Collo et al., 2018), the presence and severity of anxiety is also found to be significantly related to other affective symptoms (Baldassarre et al., 2015). When an individual recovering from mTBI has high levels of anxiety, their ability to deal with stress can be diminished and lead to an exaggerate fear response (Maeng & Milad, 2015). Additionally, some researchers hypothesize that anxiety may be related to self-reports of irritability, however a direct one-to-one link has yet to be confirmed. Depression and fear may also be comorbid symptoms. One study found that fear expression was linked to the presence and severity of depressive symptoms (Gao et al., 2015). While these studies illustrate that affective symptoms may act as a negative feedback loop in some situations, a more optimistic view may see that decreasing the severity of one symptoms may have a positive universal impact on the patient.

A popular explanation for the presence of these affective symptoms, particularly depressive symptoms, is through connectivity changes between and within brain regions responsible for emotional processing (Hamilton et al., 2015; McCuddy et al., 2018). In mTBI populations, there is typically reduced connectivity between emotional processing regions that is associated with acute mood disturbance and an increased connectivity between the default mode network (DMN) and regions of the brain responsible for attention (McCuddy et al., 2018). The link between affective symptoms and reduced connectivity in emotional processing regions is commonly seen and follows logic, however the increased DMN connectivity as a compensation mechanism may be unique to mTBI (McCuddy et al., 2018). In patients with major depressive disorder, DMN connectivity is associated with clinically elevated levels of depression (Hamilton et al., 2015). Some researchers claim that this difference is not surprising due to the length of time depressive symptoms persist in these two scenarios (McCuddy et al., 2018).

Somatic Symptoms

Somatic symptoms are the most prominent symptoms individuals experience immediately after injury. Headaches are the most common somatic symptom (Gladstone, 2009) and is experienced by 83-86% of individuals post-injury (Bramley et al., 2015; Guskiewicz et al., 2000). A headache that develops within 7 day of trauma or injury is defined as posttraumatic headache (Society, 2004). Typically, individuals experiencing these headaches report them as tension or migraine-like headaches (Baandrup & Jensen, 2005; Defrin, 2014). The majority of these headaches are tension-type headaches at 75% of cases, with 21% being migraine-like, and 4% being unclassifiable (Haas, 1996). Research as sown that females are more likley to report headaches and have a significantly longer recovery compared to men (Bramley et al., 2016). The other somatic symptoms come as vestibular and oculomotor impairment in 60% of individuals following mTBI (Mucha et al., 2014). These include fatigue, dizziness, nausea, and blurred or double vision (Babcock et al., 2013).

Sleep Dysregulation

Sleep dysregulation may be the most important, yet under emphasized symptom following mTBI. The most common disturbances seen in individuals after experiencing a mTBI are insomnia (delayed sleep onset and increased awakenings), an increased need of sleep, excessive daytime sleepiness, and reduced sleep efficiency (Ouellet et al., 2015; Parcell et al., 2008). The rates of clinical insomnia in populations with mTBI can be as high as 69.2% (Mollayeva et al., 2016), a rate three times higher than what is observed in normal populations (Ohayon, 1997). One meta-analysis found that, across off levels of TBI, the average rate of sleep disorders is 25-29% (Mathias & Alvaro, 2012). This is just one study out of the growing body of literature finding that sleep dysregulation is more strongly associated in mTBI compared to moderate-to-severe TBI (Orff et al., 2009). Sleep dysregulation is often viewed as a comorbidity following mTBI, however researchers have been urged to take these symptoms more seriously due to their high prevalence and intensity (Wickwire et al., 2016).

While anxiety appears to be the center of most comorbidities in affective symptoms, sleep quality, even sleep quality pre-injury, may be the largest predictor of recovery and symptoms severity across all categories of symptoms (Mollayeva et al., 2016; Theadom et al., 2015). One study examining pre-injury predictors of overall recovery found that poor sleep quality significantly predicted poorer outcomes in overall cognition, productivity, social integration, anxiety, depression, and daytime sleepiness at one-year post-injury (Theadom et al., 2015). Post-injury sleep quality also impacts overall symptomology of mTBI. The link between post-injury sleep and symptoms of depression, anxiety, and cognitive impairments is well studied (Fichtenberg et al., 2000; Ouellet et al., 2015; Wiseman-Hakes et al., 2013). One study found that sleep quality explained 30% of the variance in depression (Mollayeva et al., 2016).

The reason sleep is a pivotal factor in severity and prevalence of symptoms is the role of sleep in memory and emotional processing/consolidation. Most mTBI sleep studies investigate how rapid eye movement (REM) sleep impacts emotional consolidation, and a link between the two have been established (Repantis et al., 2020; Tempesta et al., 2018). Patients with mTBI have less REM sleep, longer REM latency, and more sleep complaints, leading to poor emotional outcomes (Mantua et al., 2017). Poor emotional outcomes can result in modulated emotional reactivity, emotional memory formation, empathic behavior, fear conditioning, threat generalization and extinction memory (Tempesta et al., 2018).

The importance of sleep is present beyond mTBI, as it plays a major role in the majority of psychological disorders. The association between sleep and depression is commonly seen in normal populations (Antypa et al., 2016; Riemann et al., 2020). For example, one longitudinal study with following 5,481 patients found that sleep quality was significantly associated with remission of depressive symptoms (Schennach et al., 2019). Sleep quality is also a predictor of anxiety being present in individuals with PTSD, with one studying finding no relationship between PTSD and anxiety in individuals with good sleep quality (Mantua et al., 2018).

Symptom Recovery

Literature surrounding the recovery and normalization of symptoms in individuals following mTBI is highly variable. While symptom recovery is has been found to start a few days post-injury and normalize in the following weeks or months (Cole & Bailie, 2015), few studies agree on when to deem an individual as fully recovered. Some studies find that the majority of individuals recovery within the first three months (Rabinowitz et al., 2015), however the majority of studies find that most people recovery between six- and twelve-months post-injury (Barker-Collo et al., 2015; Nelson et al., 2019; Stulemeijer et al., 2006). There are also a number of studies that find many individuals suffer from mTBI-induced symptoms after one-year post-injury (Nelson et al., 2019). One study in particular found that 41% of people still experienced sleep difficulties one year after their mTBI (Theadom et al., 2015). The reasoning behind this variability is not often brought up in the literature. These disparities may be due to the methods of assessing post-concussive symptoms. If studies elected to assess different symptoms using different evaluations, instead of conducting general assessment, the recovery timeline and estimations may become clearer. For example, sustained attention has been found to normalize slower than information processing speed and verbal recognition/fluency (Kwok et al., 2008). Another way to evaluate symptomology without relying of self-reported measures is through the use of assessments that measure brain activity and connection. These assessments can be used to see how quickly certain brain regions are normalizing (Bharath et al., 2015).

The athlete population is different compared to general populations with mTBI as they have been seen to recovery more quickly (Kara et al., 2020). Studies have found that athletes return to play within four to ten days post-injury (Benson et al., 2011; Browne & Lam, 2006; Makdissi et al., 2010). It should be noted that these studies use return to play as their indicator of recovery. This data, while accurate, may be misleading as athletes may be pressured into returning to play before they are fully recovered. This is exemplified by a study that reported 8% of athletes returned to play in the same game where they experienced their mTBI (Benson et al., 2011). A two-year longitudinal study by Kara et al. (2020), might have more accurate results, showing that out of 594 participants, 77% of athletes recovered from their symptoms within the first month post-injury. Even with consistently observed reduced recovery time, variability between athletes is still present. For example, one study found that recovery rates in athletes were between 9 and 142 days (Hutchison et al., 2017). One factor that may increase symptomology, specifically mood symptoms, is an athletes reaction to being taken out of their sport. Negative cognitive appraisal may impact the severity of their symptoms.

Intervention

Management paths for mTBI can be divided into two categories: non-surgical and surgical treatment. Surgical management is rarely seen and mostly used with individuals experiencing intracranial hematoma and brain swelling (Levin & Diaz-Arrastia, 2015). The most effective way of assessing the patient for hematoma and brain swelling is by a CT scan (Levin & Diaz-Arrastia, 2015). Due to surgical treatments being used in a minority of cases, this review will solely discuss the non-surgical interventions. The most commonly used non-surgical interventions are rest, education and reassurance, cognitive rehab, cognitive behavioral therapy (CBT), pharmacological treatment, and mindfulness-based interventions (Borg et al., 2004; Lumba-Brown et al., 2018; Sullivan et al., 2020; Teo et al., 2020; Williams & Evans, 2003).

The effectiveness of mTBI symptom interventions can vary greatly from study to study (Borg et al., 2004; Prince & Bruhns, 2017; Teo et al., 2020). One meta-analysis found that no intervention produced significant results in reducing the post concussive symptoms at 3-6 months post-injury (Teo et al., 2020). However, when these researchers examined the pooled functional outcomes, they observed a small overall effect size. The World Health Organization task force on mTBI found slightly different results when examining the literature. This task force found that education and reassurance showed a significant reduction in post concussive symptoms, but the effect size was also small (Borg et al., 2004). There are a few hypotheses on why there is no consensus regarding the optimal non-surgical interventions for reducing mTBI symptoms (Borg et al., 2004; Teo et al., 2020). Teo et al. (2020) state that studies are not consistently using the same outcome measures; the mix of outcomes based on symptoms reduction, functional outcomes, and health-related quality of life make it difficult to review and synthesis data from different studies. The lack of non-surgical interventions being explored in research is also a contributing factor (Borg et al., 2004). Lastly, inconsistency in results may be due to the subjectivity of some outcome measure and lack of suitable care managers, such as neuropsychologists and rehabilitation psychologist (Prince & Bruhns, 2017). One type of intervention that may have large effect sizes on reducing mTBI symptomology is having individuals participate in more than one intervention at a time during recovery. While most studies focus on one type of intervention, some researchers who have combined psychoeducation and cognitive remediation (Tiersky et al., 2005) and cognitive rehabilitation and CBT (Cooper et al., 2017) have found significant results in reducing symptoms.

Rest

Physical and cognitive rest are the most commonly known treatment plan for those experiencing symptoms following mTBI. It has been considered to be the best, immediate treatment for mTBI (Moser & Schatz, 2012) with many medical professionals “often” or “always” prescribing rest (Mannix et al., 2019). However, it is no longer the consensus of experts to rest until asymptomatic (Silverberg & Otamendi, 2019). The shift away from resting being the most optimal treatment intervention is due to the fact that there are no clear guidelines on what cognitive and physical rest entails (Carson et al., 2014; McLeod et al., 2017). For example, athletes have been found to be prescribed rest until a reduction of symptoms, instead of until they are asymptomatic (Levin & Diaz-Arrastia, 2015). Additionally, when compared to controls receiving no instruction to rest, some studies find that mandating rest produces no significant results on symptom reduction (Varner et al., 2017), suggesting there may be better options for treatment (Levin & Diaz-Arrastia, 2015).

The prescription of brief rest is being researched as a possible alternative to resting until asymptomatic, however, the results of single studies also vary on its effectivness (Brooks et al., 2016; Buckley et al., 2016; Taubman et al., 2016). While there is no definitive definition of brief rest, these studies typically prescribe the individual to rest a single day following their injury (Brooks et al., 2016; Buckley et al., 2016). One study found that immediate rest following TBI was more effective at reducing symptomology within the first 30 days post-injury compared to individuals who waited up to a week before resting (Taubman et al., 2016). However, Buckley et al. (2016) found that a single day of cognitive and physical rest prescribed immediately following a mTBI had no effect on reducing the recovery time of symptoms. These results are further supported by Brooks et al. (2016) who observed no significant differences in recovery time between individuals prescribed a single day of rest and individuals prescribed a day of cognitive exertion (taking cognitive tests during their emergency department visit). The most comprehensive studies on the effectiveness and optimal dosage of rest comes from two literature reviews (Schneider et al., 2017; Silverberg & Iverson, 2013). These two reviews of literature suggest that having a period of rest between 2-3 days after the injury, followed by gradual cognitive and physical exertion is the optimal prescription following mTBI (Schneider et al., 2017; Silverberg & Iverson, 2013). Another study suggests the amount of cognitive and physical exertion following the brief period of rest is highly individual and should not be self-determined (Wells et al., 2016). Typically, the exertion consists of a gradual increase in exertion based on individual tolerance in activities that are not prone to mTBIs (Silverberg & Iverson, 2013). Specific guidelines have not been implemented (Wells et al., 2016).

Education and Reassurance

A second intervention that is often implemented shortly after mTBI is a session of education and reassurance. This intervention consists of a medical professional providing reassuring educational information such as general reassurance, estimated recovery timeline, and teaching strategies for symptom management (Comper et al., 2005; Nygren-de Boussard et al., 2014). However, due to the lack of published research on the best practices of education and reassurance, there is no consensus or guidelines. Despite this, the current research regarding education and reassurance interventions following mTBI is in two areas: 1) brief vs. intensive sessions and 2) education and reassurance in addition to standard medical care (Comper et al., 2005).

Paniak et al. (1998) conducted a study and a one-year follow-up (Paniak et al., 2000) on the difference in symptom outcomes following a brief session of education and reassurance compared to a longer and more detailed session. The first study's results were taken at three months and showed no differences between groups on outcome measures of symptomology and functioning (Paniak et al., 1998). The one-year follow-up study also found that there were no differences between the two groups. Similar results from comparing the effects of brief vs. intensive reassurance and education on symptomology has been found in a study lasting 6 months (Ghaffar et al., 2006) and 12 months (Andersson et al., 2007). Some studies have found significant differences between brief vs. intensive rest, however, these were not randomly controlled trails (Gronwall, 1986; Minderhoud et al., 1980).

When education and reassurance is added to routine medical care, the individuals receiving both treatments have been observed to report less symptoms earlier in the recovery process (Bell et al., 2008; Mittenberg et al., 2001; Ponsford et al., 2002; Wade et al., 1998). One study found significant improvements in mTBI symptoms in affective and somatic symptoms (Mittenberg et al., 2001). Similar outcomes have been found from Bell et al. (2008), who found that telephone calls resulted in significant improvements in symptom outcomes and Ponsford et al. (2002), who observed improvements when using educational booklets as the intervention medium. Education and reassurance have also been shown to easily incorporate into other types of intervention strategies, with one study finding an intervention of CBT and education being more effective at reducing symptoms than supportive counseling alone (Bryant et al., 2003).

Cognitive Rehabilitation

Cognitive rehabilitation is an intervention that is used more often in treating moderate-to-severe TBI but is also being considered as a possible treatment method in cases of mTBI (Cicerone et al., 2011; Marklund et al., 2019). Cognitive rehabilitation consists of compensatory and restorative interventions that aim to improve cognitive functioning and address specific deficits (Cooper et al., 2015; Marklund et al., 2019). Compensatory cognitive rehabilitation aims to help individuals re-learn old and implement new patterns of behavior through external mechanisms and environmental support (Cooper et al., 2015). In short, compensatory cognitive rehabilitation help people adapt to their circumstances to improve functioning and quality of life. Restorative cognitive rehabilitation also aims to help individuals re-learn old behaviors, but its secondary focus is on reducing neurological deficits through training (Cooper et al., 2015).

Because compensatory and restorative cognitive rehabilitation are similar, many individuals benefit from interventions that incorporate both styles (Cooper et al., 2015; Marklund et al., 2019). In general, cognitive rehabilitation has been found to improve memory, reduce symptoms, and improve quality of life when used in populations with TBI (Caplan et al., 2015).

As seen with the previous treatments, there is no standard methodology or guidelines for cognitive rehabilitation for populations with mTBI because of the variety of different strategies and lack of strict methodology (Fetta et al., 2017; Marklund et al., 2019). Computer-based cognitive rehabilitation is one area in the research that has conflicting results about its effectivness as an intervention (Fetta et al., 2017; Sullivan et al., 2012). One study by Sullivan et al. (2012) found that computer-based cognitive rehabilitation was effective at reducing symptoms in a military population with mTBI. This study is contrary to a review of literature that found computer-based cognitive rehabilitation to not be an effective intervention for all types of TBI across multiple patient populations (Fetta et al., 2017). A slight variation to solo, computer-based cognitive rehabilitation that has observed to be effective is video cognitive rehabilitation completed on a computer (Cernich et al., 2010; Riegler et al., 2013). Two studies have shown that clients who complete remote cognitive rehabilitation while using a video camera to talk with a therapist see the same improvements as those who complete clinic-based cognitive rehabilitation (Cernich et al., 2010; Riegler et al., 2013). The study by Riegler et al. (2013) also found that home-based cognitive rehabilitation increased compliance in those who did not commit to their clinic-based rehabilitation.

The research on cognitive rehabilitation has been shown to be effective at reducing deficits in attention, executive function, memory, and learning in populations including all TBI severities (Cantor et al., 2014; Chen et al., 2011; Huckans et al., 2010; Nelson et al., 2013;

Novakovic-Agopian et al., 2011; Twamley et al., 2014). This is further supported by meta-analyses that show cognitive rehabilitations leading to global cognitive functioning benefits in TBI populations (Mathias & Wheaton, 2007; Rohling et al., 2009). However, when only looking at studies that involve treating mTBI populations, the results are inconclusive (Snell et al., 2009).

CBT

The growing literature surrounding supports the use of CBT for reducing the symptoms of mTBI (Ashman et al., 2014; Cooper et al., 2015). CBT has been found to be the most effective at reducing affective symptoms such as depression and anxiety (Ashman et al., 2014; King & Coates, 2021; Ponsford et al., 2016), even becoming the first line of treatment for athletes experiencing these deficits post-injury (Conder & Conder, 2015). Outside of the athlete population, CBT is often utilized in military populations with symptoms of mTBI and PTSD (Kelly et al., 2012). Additionally, some research has shown that an added benefit of CBT is a reduction in anxiety for athletes who were influenced and confused by the contrasting information that surrounds recovery (King & Coates, 2021).

Despite CBT having validity in the general population and being found to be five to six times more effective at treating mTBI symptoms compared to cognitive rehabilitation (Vanderploeg et al., 2019), researchers are still exploring different ways of making CBT most effective for mTBI populations. Currently, it is estimated that an individual needs to attend eight sessions of CBT in order to see a significant improvement in symptoms compared to individuals who only received standard hospital care (Fann et al., 2015). Research has also found that using CBT in addition to other interventions may improve results even more. Ouellet et al. (2015) found that when CBT and medication were used, there was an additional improvement in reducing sleep-wake disturbances throughout recovery.

A growing body of research is studying how CBT for insomnia (CBT-I) may be used in treating the sleep dysregulation seen after a mTBI. The rationale behind this approach is because CBT-I has been found to be effective in populations that have comorbid depression, anxiety, PTSD, and substance abuse disorder (Taylor & Pruiksma, 2014), and most of these symptoms have overlap with mTBI (Azouvi et al., 2017; Polinder et al., 2018; Yeates et al., 2017). Additionally, CBT-I has been found to be effective at improving the sleep quality in adult populations without a clinical sleeping disorder (Murawski et al., 2018). Most of the research on CBT-I for mTBI is theoretical, however, one study that tested CBT-I on three patients with different TBI severities found that CBT-I produced clinical significance for symptoms of depression and anxiety, but not insomnia (Lu et al., 2016). Dietch and Furst (2020) claimed that while CBT-I may be an effective intervention for those with mTBI, three problems may arise and should be addressed in research. The first problem is that symptoms of mTBI, namely attention, concentration, and mental fatigue, may hinder an individual's ability to implement behavioral changes at home. The second is that insomnia may be present due to a separate sleep disorder, which may not be affected by CBT-I. Finally, Dietch and Furst (2020) state that an individual with multiple TBIs may not react to CBT-I as one who only experienced a single instance of TBI.

Pharmacology

Pharmacological interventions have been used in some cases of mTBI, however, the literature surround its effectiveness is small (Feinberg et al., 2021). Many of the studies on pharmacological interventions are uncontrolled or anecdotal cases, rarely are there randomized control trials (Rao & Lyketsos, 2000). One systematic review echoed this point in saying that they found only a limited number of high-quality pharmacological interventions, none of which produced data significant enough to recommend medications as a primary treatment option (Feinberg et al., 2021). Feinberg et al. (2021) recommended that in order for this domain of research to meaningfully progress, there needs to be a standardized method of prescription and the bias from the pharmaceutical industry must be acknowledged and reduced.

Currently, anti-inflammatory medication and acetaminophen are the most commonly prescribed medication following TBI (Mannix et al., 2019). Due to the large number of medications prescribed, this review will briefly discuss the medications seen in more than one study. Two studies prescribed methylphenidate and found that it improved deficits in cognition and depression (Lee et al., 2005; McAllister et al., 2016). Three studies prescribed sertraline and found that the only symptom that saw a decrease in severity was depression (Fann et al., 2000, 2001; Lee et al., 2005). Two studies prescribed amitriptyline for pain reduction. Hurwitz et al. (2020) observed no differences in pain severity between the control and treatment groups. Kuczynski et al. (2013), however, observed that amitriptyline did help their treatment group experience reduced pain severity. Lastly, two studies that prescribed melatonin to improve sleep quality did not report any significant changes (Barlow et al., 2020; Kuczynski et al., 2013).

Mindfulness

Mindfulness-based interventions (MBIs) have recently been explored within the mTBI population (Acabchuk et al., 2021; Johansson et al., 2012; Kenuk & Porter, 2017; Shirvani et al., 2021). An MBI is an intervention that focuses on fostering an individual's self-regulation of attention in a non-judgmental manner (Bishop et al., 2004). The techniques and theories that researchers use to promote mindfulness originated in Buddhist spiritual practices (Hanh, 1976). The most commonly used MBI is mindfulness-based stress reduction (MBSR) and achieves these qualities through guided mindfulness meditation exercises (Kabat-Zinn & Hanh, 2009).

MBSR is widely used to treat chronic illness, emotional, and behavioral disorders (Bishop et al., 2004). Other MBIs include yoga (Breedvelt et al., 2019) and mindfulness-based cognitive therapy (Bédard et al., 2014; Bédard et al., 2012).

The theoretical basis that justifies MBIs for mTBI populations states that MBIs tend to target and improve many areas of the brain that are commonly damaged in a TBI (Link et al., 2016). Additionally, many individuals with mTBI state that their difficulties stem from concentration, attention, and dysregulated emotional processing, all of which are directly targeted in MBIs, specifically MBSR (Link et al., 2016). Another theoretical explanation of why MBIs may be an effective interventions has to do with how MBIs interact with the default mode network (DMN) (McCuddy et al., 2018; van der Horn et al., 2017). One study conducted by van der Horn et al. (2017) found that individuals who had more complaints regarding their post-injury symptoms had stronger connectivity in the posterior midline areas of the DMN than those who had less complaints post-injury. These findings are consistent with broader medical literature that has found an abnormal connectivity of the DMN plays a significant role in disorders such as schizophrenia, depression, and anxiety (Coutinho et al., 2016; Whitfield-Gabrieli & Ford, 2012). Research has shown that meditation and MBIs have positive impact on regulating the DMN, specifically the areas that include meta-awareness and self-referential processes (Boccia et al., 2015; Fox et al., 2014).

The research involving MBIs and mTBI has gone beyond the theoretical, with many studies showing clinical significance (Acabchuk et al., 2021; Kenuk & Porter, 2017). For example, one meta-analysis found that out of 88 outcomes measures across 16 different studies, MBIs had a significant and positive impact on 75% of outcomes (Kenuk & Porter, 2017). A second meta-analysis also found that MBIs and yoga meditation significantly improve mental health, quality of life, and cognitive performance for individuals who experienced a mTBI (Acabchuk et al., 2021). Single studies exploring the effects of MBSR have found significant results on improving mental fatigue (Johansson et al., 2012; Shirvani et al., 2021), quality of life (Bedard et al., 2003), and a decrease in aggression (Shirvani et al., 2021).

Lastly, while there are no strict guidelines or a consensus on which MBI is the most effective, many variations have shown the same significant results (Azulay et al., 2013; Bay & Chan, 2019; Bédard et al., 2014). For example, Azulay et al. (2013) conducted a pilot study that adapted MBSR to be tailored to mTBI populations and found significant improvements on outcomes of quality of life, perceived self-efficacy, working memory, and attention regulation. The specific adaptations made were an increased focus on attentional skills and an increased awareness of internal and external stimuli that yielded a strong change in acceptance (Azulay et al., 2013). Another study utilized mindfulness-based group therapy as the primary intervention for mTBI patients and found that over an 8-week study, individuals had significant improvements in levels of chronic stress and a decrease in symptomology compared to the control group (Bay & Chan, 2019). Mindfulness-based cognitive therapy has also shown significant results, with one 10-week study finding a medium effect size in reducing depressive symptoms for individuals with varying TBI severities (Bédard et al., 2014). Overall, the literature surrounding MBIs as an effective treatment for mTBI symptom reduction is promising and cost effective (Bay & Chan, 2019). Despite the wide variety of possible effective interventions, researchers suggest that stricter evaluations standards and more rigorous methodology be introduced in order to solidify MBIs as the front-line treatment options after mTBI (Ozen et al., 2016).

Mindfulness Research in Multiple Patient Populations

The research examining the benefits of MBIs extends beyond brain injury populations and has been studied in diabetic (Izgu et al., 2020), psychologically distressed (Edenfield & Saeed, 2012; Hofmann et al., 2010; Toneatto & Nguyen, 2007), older (Fiocco & Meisner, 2020), and even healthy (Nyklíček & Kuijpers, 2008) individuals. Similarly to mTBI populations, the MBI most commonly used is MBSR, with mindfulness-based cognitive therapy, meditation, and yoga also being implemented frequently (Bédard et al., 2014; Bédard et al., 2012; Breedvelt et al., 2019). The research conducted within these populations mostly focus on how MBIs impact overall quality of life and affective disorders/symptoms (Hilton et al., 2017; Lauche et al., 2019; Shapiro & Weisbaum, 2020); however, pain management (Hilton et al., 2017; Lauche et al., 2019), cognition (Gothe & McAuley, 2015), and more specifically, memory (Anālayo, 2018; Rosenstreich, 2014) have started to become topics of study. Longitudinal studies are more prevalent in these populations compared to mTBI populations and may be useful in expending our knowledge of what to expect moving forward with mindfulness research for mTBI. For example, research has shown that individuals who have long-term traditional meditation routines or who have completed mindfulness-based stress reduction interventions have structural and functional brain changes (Behan, 2020). Additionally, longitudinal research has shown that when individuals continue to observe significant benefits when they sustain their mindfulness practice years post-intervention, positing MBIs as a cost-effective treatment (Miller et al., 1995).

Quality of Life

The impact mindfulness has on quality of life is one area of research that has received attention within a number of different populations. Typically, research on MBIs for quality of life is conducted on patient populations with disabilities or those with medical problem. For example, MBIs have been used in Parkinson's populations (Son & Choi, 2018), individuals with diabetes (Izgu et al., 2020), and on individuals with gastroesophageal reflux disease (Chandran et al., 2019), all of which have found significant and positive results. Though clinical patient populations have been a primary focus of MBI quality of life research, other studies have been examining its effects on more general populations. Ducar et al. (2020) found that mindfulness meditation, alongside progressive muscle relaxation, can improve the quality of life for individuals with demanding jobs such as emergency medical technicians. Additionally, higher levels of trait mindfulness have been found to support and foster health attitudes towards aging in older populations (Fiocco & Meisner, 2020). The general, healthy, population can also benefit from mindfulness-based stress reduction, with one studying finding improvements in overall quality of life as a result (Nyklíček & Kuijpers, 2008).

Affective Symptoms

Quality of life assessments typically include evaluations of positive and negative affect (Nyklíček & Kuijpers, 2008). While no studies found in this literature review specifically examine which quality of life assessment factors are more influenced by MBIs, the affective influence of MBIs have been studies in many populations outside of traumatic brain injuries (Edenfield & Saeed, 2012; Hofmann et al., 2010; Toneatto & Nguyen, 2007). One meta-analysis involving over 1,000 patients in many different clinical populations found that MBIs had a moderate effect size on improving anxiety and other mood symptoms throughout the duration of the studies, and effect sizes of 0.95-0.97 were observed when the data set was limited to those with clinical anxiety and mood disorders (Hofmann et al., 2010). Similar results were found by Schreiner and Malcolm (2008) who found that individuals with severe affective symptoms benefitted the most from a MBI. Additionally, one study found that an MBI used in addition to standard medical care was effective at reducing depressive recurrences in individuals with more than two previous episodes of depression, while those with two or less episodes did not show any benefit in reduction.

While MBIs have been seen to be most effective for individuals struggling with clinical or severe affective symptoms, they also benefit those with milder symptoms (Edenfield & Saeed, 2012; Rod, 2015; Young & Baime, 2010; Young et al., 2009). In one study examining the effect of MBIs on individuals with chronic pain, the use of mindfulness meditations resulted in significant change in the levels of depressive and anxiety symptoms post-intervention (Rod, 2015). Additionally, a literature review conducted by Edenfield and Saeed (2012) found that, despite the methodological differences and limitations, MBIs have positive and significant effects of depression and anxiety across patient populations. Another affective outcome measure, distress, has also been the topic of some studies (Young & Baime, 2010; Young et al., 2009). These two studies found that MBSR can be an effective intervention in reducing levels of distress in older populations and in diabetic populations, with the study of older populations reporting a majority of patients reporting lower levels of distress after treatment (Young & Baime, 2010).

Duration of MBIs

Typically, MBIs are conducted for eight weeks (Bédard et al., 2012; Praissman, 2008). The specific instructions during these eight weeks, however, can vary from study to study. For example, one study by Bédard et al. (2012) only held one 90-minute sessions of mindfulness-based cognitive therapy each week, while another study had its participants attend a 2.5 hour session each with, with the other days of the week requiring a solo 45-minute mindfulness meditation session (Praissman, 2008). Additionally, some research has been conducted on brief MBIs, instructing participants to allocate 10 minutes a day for 5 days a week towards mindfulness meditation (Malinowski et al., 2017). Each of these methods have produced significant results (Bédard et al., 2012; Malinowski et al., 2017; Praissman, 2008).

MBIs in Athlete Populations

Trait Mindfulness in Athletes

Mindfulness-based strategies and interventions have been used in the field of sport psychology for over two decades and produced positive results (Gardner, 2016; Gardner & Moore, 2017). The Mindfulness-Acceptance-Commitment model (MAC) is the most used and researched MBI that consistently produces data showing that mindfulness can improve outcome measures in sport (Gardner & Moore, 2020). The foundations of the MAC model suggest that attitudes of non-judgement towards negative emotions will be more beneficial than attempting eliminate, change, or suppress these emotions through traditional CBT approaches (Gardner & Moore, 2004). Athletes who have previous experience with the MAC model or any other mindfulness-based intervention/practice may be in a unique position to benefit more from MBIs after mTBI. When individuals complete MBIs, trait mindfulness (how prone one is to be mindful everyday) is seen to increase (Carmody et al., 2008; Shahar et al., 2010; Shapiro et al., 2008). Additionally, those with higher pre-intervention trait mindfulness exhibited larger increases in subjective well-being, empathy, and hope, as well as larger decreases in stress than those with lower trait mindfulness up to one year post-intervention (Shapiro et al., 2011).

MBIs and Sport Performance

Many positive sport- and performance-related outcomes measures have been improved through the implementation of MBI in sport psychology research (Bailey et al., 2018; De Petrillo et al., 2009; Pineau et al., 2014). For example, De Petrillo et al. (2009) found that performance factors such as sport-related worries, standards of perfectionism, and parental criticism were observed to be positivley influenced in runners after undergoing Mindful Sport Performance Enhancement. Another study found that flow, attention, affect, and physiological factors were also outcome measures associated with mindfulness (Pineau et al., 2014). Sport and performance factors have also been seen to be directly influenced by the intensity of the intervention, with one study finding that the number of days in which an athlete practiced mindfulness was directly associated with larger improvements in perceived stress, positive and negative affect, mindfulness, flourishing, and self-compassion (Bailey et al., 2018).

Neuroscience Framework of Mindfulness

Despite the many observed benefits resulting from MBIs, the underlying neurological, psychological, and biological processes affected by mindfulness must be clarified and understood in order for stronger research to emerge from this field (Ainsworth et al., 2013; Vago & David, 2012). The Self-awareness, self-regulation, and self-transcendence (S-ART; Vago & David, 2012) framework of mindfulness attempts to encapsulate and explain how mindfulness can change brain functioning. Vago and David (2012) state that through experiencing negative life events, an individual's cognition, emotions, and self-perception can be dysfunctional and become negativley biased. Through a mindfulness practice that emphasizes self-awareness (meta-awareness of self), self-regulation (the ability to manage impulses and responses), and self-transcendence (developing positive relationships that are not driven to serve the self), these biases can be reduced (Vago & David, 2012). The S-ART framework is comprised of three self-processing networks: the enactive experiential self (EES), the experiential phenomenological self (EPS), and the narrative self (NS), and three styles of mindfulness meditation: focused attention (FA), open monitoring (OM), and ethical enhancement (EE) (Vago & David, 2012). This framework of mindfulness may be viable for explaining the benefits of MBIs for mTBI due to the brain regions and processes involved with the DMN and emotional regulation and processing being a focal point of both mTBI symptomology (Hamilton et al., 2015; McCuddy et al., 2018) and this framework (Vago & David, 2012).

Self-Processing Networks of the S-ART Framework

The three self-processing networks of the S-ART framework can be divided into two categories: self-specifying processing, which includes the EES and EPS, and a self-related process, the NS (Vago & David, 2012). These two categories are functionally distinct, with the self-specifying processing involving brain networks that are involved in external sensation-perception and attention (Vincent et al., 2008), while the self-related processes of the NS involve networks that are responsible for internal mental activity related to long-term memory and planning (Buckner & Carroll, 2007; Vincent et al., 2008). The foundations of these two networks are the dorsal attention system (DAS) and the hippocampal-cortical memory system (HCMS) (Vincent et al., 2008). The differences in these networks are highlighted when examining brain activity, as their regions are negativley correlated with each other (Fox et al., 2005).

Enactive Experiential Self

The EES network is involved with the processing of unconscious sensory and motor stimuli, such as movement from musculoskeletal feedback and sensations/perceptions from the internal milieu and visceral organs, and using this information to sub-consciously influence a specific stimulus response (Vago & David, 2012). Research has shown that repeated non-conscious associations between a person's body and their environment can condition thoughts and processes related to self-identification (Craig, 2009; Lenggenhager et al., 2009), and these self-specifying processes associated with the EES network are located in the spinothalamocortical regions (Vago & David, 2012). These specific regions have been found to be largely responsible for the monitoring, decoding, and categorizing interoceptive feedback sub-consciously (Craig, 2008; Damasio, 1999). The interoceptive feedback is then categorized hierarchically by emotional tone, with motivational, social, and emotional feelings being represented the strongest and more easily reached by an individual's conscious experience (Craig, 2004). A secondary function of the EES is its involvement in goal-directed action via the brain systems responsible for motor preparatory behavior, early perceptual processing, search, and detection (Vago & David, 2012). Repeated dysfunctional involvement in these tasks can create issues, as these processes condition emotional memory formation and expression over time (Vago & David, 2012). Lastly, sustained activation of the EES is associated with better concentration (Newberg et al., 2010) and lower depression scores (Farb et al., 2010).

Experiential Phenomenological Self

The EPS network is a self-as-subject awareness acting in the present moment without reflection (Tagini & Raffone, 2010). This network is able to access the contents of the EES with different degrees of ease, depending on the previously mentioned hierarchical categorization, and can modulate, control, or amplify them (Gallagher, 2000; Raffone & Pantani, 2010). However, the EPS may also be influenced by the categorization and emotional tone of the contents of the EES (Vago & David, 2012). Vago and David (2012) propose that the EPS is a form of higher awareness that is related to exteroceptive and interoceptive (meaning both inside and outside the body) experiences, including top-down attentional control and feelings of motivation, sociability, and emotion. The two main areas of the brain that comprise the EPS are the dorsolateral prefrontal cortex (DLPCF) and anterior cingulate cortex (ACC) and are responsible for vigilance and alertness (Posner & Rothbart, 2009; Raz & Buhle, 2006). Additionally, the anterior insular cortex (AIC) has a strong connection to the ACC and is thought to be responsible for the phenomenological experience that comes from consciousness which may provide improved self-regulation and autonomic control (Gilbert et al., 2010). The EPS has been studied in relation to MBIs and when comparing expert meditations to novices, with results finding higher gray matter concentration in regions associated with the EPS in experts compared to controls (Hölzel et al., 2008; Lazar et al., 2005).

Narrative Self

Where the EPS involves processes that have the self as a subject, the NS is a self-as-object awareness in the present moment that is reflective and in a narrative experience, comprised of an individual identity and experience across physical, social, and psychological domains (Craig, 2004; Damasio, 2012; Tagini & Raffone, 2010). The NS also a part of metacognitive knowledge, such as an individual knowing the level of their knowledge and knowing what learning strategies work best for them (Flavell, 1979). A common feature of the NS is the ability to have sustained reflection across time that leads to a stable sense of self (Vago & David, 2012). The ability for the NS to be central in reflective processes is due to its mediation by the hippocampal-cortical memory system (HCMS), which is known for including many processes of evaluation (Legrand, 2007; Legrand & Ruby, 2009). Many structures within the HCMS interact with the hippocampus, amygdala, thalamus, which makes the activation of the NS play a role in episodic memory formation (Peters et al., 2009; Spreng et al., 2009), the autobiographical self (Spreng et al., 2009; Zelazo et al., 2007), and appraisal and control mechanisms (Drevets et al., 2008; Roy et al., 2012). Despite the NS serving an important role, overactivation of the NS during activities that require high attention or concentration will cause a decrease in efficiency and can result in negative health outcomes if sustained for long periods of time (Grimm et al., 2009; Rimes & Watkins, 2005). Mindfulness research has support this by showing that those with meditation experience have lower activation of the NS and less mind wandering during tasks that require concentration and attention (Brewer, 1993; Farb et al., 2007; Ott et al., 2010).

Mindfulness Meditations in S-ART Framework

Focused Attention Meditation

Focused attention (FA) meditation involves the individual closely focusing on a single mental or sensory object, such as the feeling from a part of the body, a mantra, or the breath (Lutz, Slagter, et al., 2008; Vago & David, 2012). The purpose of this meditation is to have individuals notice their intrusive thoughts and return their focus on the initial subject of attention quickly and without any judgement (Lutz, Slagter, et al., 2008). The typical behaviors during FA meditation include monitoring attention, becoming aware of distractions, then disengagement and redirection of attention (Lutz, Slagter, et al., 2008). The key indicator of progress in FA meditation is the amount of effort required to hold an individual's attention on the initial object. One study found that experienced FA meditators with an average of 19,000 hours of practice demonstrated higher activity in the related brain regions compared to controls, whereas experienced meditators with an average of 44,000 hours of practice demonstrated lower activity, demonstrating more progress (Brefczynski-Lewis et al., 2007). Other data related to skill acquisition has shown similar results in the amount of time needed for mastery (Sakai, 2005). FA meditation is theorized to impact both the EES and EPS (Lutz, Slagter, et al., 2008; Vago & David, 2012). Studies have shown that FA attention can lead to the de-automatization of unconscious, perceptual stimuli (Bishop et al., 2004; Deikman, 1963) and that FA meditation has a significant impact on executive attention (Ainsworth et al., 2013). Additionally, some FA meditation behaviors involve the ACC and DLPFC (Carter et al., 1998; Ridderinkhof et al., 2004), with both regions being in the EPS network.

Open Monitoring Meditation

Open monitoring (OM) meditation, while sharing some similarities to FA meditation, is a practice that is opposite to that of FA meditation. OM meditation involved individuals focusing on a single object, as they would in FA meditation; however, individuals are then instructed to slowly disengage their attention until there is no target of focus and only monitor their internal and external experience (Vago & David, 2012). While in this state of monitoring, the practitioners are instructed to only recognize the emotional tone of the different stimuli ("good", "bad", "pleasant", or "unpleasant") and objects they are monitoring (Lutz, Slagter, et al., 2008). The difference between novice and experienced OM meditators is that novices will tend to continuously engage and disengage with objects, whereas experienced meditations will be in a constant state of non-engaged monitoring (Lutz, Slagter, et al., 2008). Research suggests that OM meditation may influence both the EPS and NS networks. For example, the practice itself of awareness in the present moment is the exact function of many of the regions in the EPS, particularly emotional processing (Lutz, Slagter, et al., 2008). This is further supported by neuroimaging studies that show increased activity in the amygdala, ventrolateral prefrontal cortex, and ventromedial prefrontal cortex during the process of verbally labeling affective stimuli (Lieberman et al., 2007; Ridderinkhof et al., 2004). Additionally, it is theorized that OM meditation will improve excessive elaboration on the part of the practitioner (Bishop et al., 2004), a key feature of the NS network.

Ethical Enhancement Meditation

The third type of meditation in the S-ART framework is ethical enhancement (EE), sometimes called loving kindness meditation (Vago & David, 2012). This type of meditation instructs the practitioners to start off by expressing feelings of loving-kindness to four people, themselves, someone neutral, a friend, and a difficult person, before expanding these feelings to everyone (Lee et al., 2012; Vago & David, 2012). The only restriction on the subject of loving-kindness is that it should not be an intimate partner or someone who is deceased (Vago & David, 2012).

Due to the lack of research surrounding EE meditation, there is a gap in the literature surrounding the neurological processes involved over time (Lee et al., 2012). However, preliminary research may indicate that EE meditation may impact all three networks in the S-ART framework (Halifax, 2012; Lee et al., 2012; Lutz, Brefczynski-Lewis, et al., 2008; Lutz et al., 2009). Regarding the attentional processes of the EES, EPS, and NS, Halifax (2012) states that EE meditation should activate the attentional processes of the brain due to actions required for meditation. However, a study by Lee et al. (2012) found that, unlike FA meditation, EE meditators showed no more significant activation of attentional neural regions during a cognitive test compared to controls, suggesting that EE meditation may not be associated with any change in attentional networks or regions. Through influencing affective processes, EE meditation may influence the EPS and NS (Cavanna & Trimble, 2006; Lee et al., 2012; Lutz, Brefczynski-Lewis, et al., 2008). For example, two studies have shown that the ACC, an important region in the EPS network, is more active when responding to emotional stimuli in experienced practitioners compared to novices (Lee et al., 2012; Lutz et al., 2009). These studies are also the basis on how EE meditation can influence the NS, with Cavanna and Trimble (2006) suggesting that the prefrontal cortex and ACC have a network connected by the precuneus that allows ACC activation to influence the episodic memory and self-referential processes of the NS.

Conclusion

mTBIs account for the majority of TBIs in the United States (CDC, 2003; Feigin et al., 2013). Overall, mTBI interventions have mixed significance and effect size (Borg et al., 2004; Prince & Bruhns, 2017; Teo et al., 2020). MBIs are starting to be studied as possible interventions for mTBI, after showing significance across multiple different patient populations in the domains of quality of life and affective symptomology (Edenfield & Saeed, 2012; Hofmann et al., 2010; Toneatto & Nguyen, 2007). Additionally, athletes with mTBI may be in a unique position to benefit more from MBIs compared to non-athletes if they have previous experience with mindfulness through sport performance interventions (Carmody et al., 2008; Shahar et al., 2010; Shapiro et al., 2008). This fact, alongside the S-ART framework of mindfulness, suggest that MBI have the potential to be an effective treatment for athletes with mTBI.

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Chapter III

Methodology

Data Collection

Article selection for this systematic literature review was conducted via database searches limited to peer-reviewed articles and doctoral dissertations published in the last 20 years in English. This decision was made to ensure the research material selected was the most reliable and relevant information on the topic. The databases included: APA PsychINFO, CINAHL, ERIC EBSCOHost, MEDLINE, PubMed, Science Direct, Sport Discus, Sports Medicine & Education Index, and Web of Science. These databases were selected as they provided the researcher with the most access to research conducted across multiple fields of psychology and medicine, a critical aspect of this systematic literature review. The initial database search included the terms “mindfulness-based intervention,” “short-term,” “cognitive deficits,” “affect deficits,” “somatic deficits,” and “sleep dysregulation,” all connected by the Boolean operator *AND*. In addition to these terms, more terms were included using the Boolean operator *OR*: “MBI,” “cognitive symptoms,” “affect symptoms,” “emotional deficits,” “emotional symptoms,” “physical deficits,” “physical symptoms,” and “sleep symptoms.” The same search string was used in all databases to ensure consistency and reach all potential papers before the preliminary screening.

Once the initial search was completed, the researcher conducted a preliminary screening using titles and abstracts of each study. Research material that progressed through preliminary screening then went through a second screening where the researcher read the entire article to ensure that it met the inclusion and exclusion criteria: 1) used short-term MBIs (lasting no more than 2 months); 2) included participant population with a mean age between 18-30 years old; 3) included a control group; and 4) targeted one of the four symptoms common to mTBI (i.e., decreased attention memory, and concentration; increased levels of depression and anxiety; pain, specifically headaches; and sleep dysregulation). The specific type of MBI was not an inclusion or exclusion criteria in order to keep this review broad in scope.

Data Analysis

A systematic literature review, which is “a systematic, explicit, and reproducible method for identifying, evaluating and synthesizing the existing body of completed and recorded work produced by researchers, scholars and practitioners,” was conducted to answer the research questions (Fink, 2009, p. 3). Specifically, analysis of the data followed the guidance of Popay et al. (2006) on conducting a narrative synthesis due to the heterogeneity between the studies included in the review. When the methodology and patient populations differ widely between included studies, it is hard to conduct robust statistical analysis and therefore a narrative synthesis is a better method of analysis (Popay et al., 2006). Specifically, a narrative synthesis refers to an approach to the review and synthesis of findings from studies that relies primarily on the use of words and text to summarize and explain the findings (Popay et al., 2006). The tools used in this narrative synthesis included coding, textual descriptions of each article, grouping and tabulation, and content analysis.

Each article was coded by MBI type, sample size and demographics, intervention description, duration and frequency, symptoms treated, and intervention efficacy (see Appendix). Intervention efficacy was further detailed into information around significance and effect size. After coding was completed, the researcher wrote a textual description of each article, based on the coded information, and included other information deemed relevant to the review. Each textual description included the same essential information included in order to make grouping and contrasting articles as systematic as possible (Popay et al., 2006).

The researcher then grouped each article into clusters based on symptoms treated and tabulated the results. Articles were not limited to one cluster, but rather all that apply. After each article was assigned to the relevant clusters, the relationships and common themes between articles in each of these groups were analyzed through content analysis. The process of content analysis allowed the researcher to highlight common themes and data from individual studies that could then be used to create treatment recommendations for the specific cluster being analyzed. Content analysis considered information relevant to each of the codes given to the article (MBI type, sample demographics, intervention description, duration and frequency, and intervention efficacy).

Once each symptom cluster had treatment recommendations, the final phase of analysis was conducted. This phase involved a second instance of content analysis and comparisons between each of the cluster's recommendations. The researcher then aimed to use the extracted information to recommend treatment options for individuals who have experienced a mTBI. During the construction of the full injury treatment recommendations, the researcher considered factors unique to recovering athletes in this age range, such as other responsibilities an individual will be obligated to complete and if the MBI intervention will have a negative impact on that athlete's return to play. An example of this would be eliminating short-term, but time-intensive interventions (multiple hours a day) that may negatively impact the athlete's ability to attend class or do homework.

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Chapter IV

Manuscript

Mindfulness-Based Intervention Recommendations for Athletes Experiencing Mild Traumatic Brain Injury – A Narrative Synthesis Review

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Target Journal: *Mindfulness*

Abstract

Objective: In this narrative synthesis, researchers summarized the current MBI literature surrounding the four main deficits of mTBI in college-aged individuals (negative affect, cognitive dysfunction, somatic symptomology, and sleep dysregulation) and provide recommendations to sport psychology and sports medicine practitioners. **Methods:** Eight databased were searched for studies that were using MBIs to treat affective, cognitive, somatic, and sleep symptoms across many different patient populations, with a mean age of 18-30 years. Included studies were coded by MBI type, intervention duration and frequency, sample demographics, and grouped on symptom category. Content analysis was performed to identify common themes between significant findings. **Results:** Common themes were identified in the literature on depressive, anxiety, and sleep symptomology. Interventions that emphasized open monitoring mindfulness-based interventions (MBIs) and emphasized detachment, acceptance or CBT showed significant improvements on depression symptoms. Focused attention, progressive muscle relaxation, or yoga MBIs showed the most significant improvements in anxiety symptoms. Mindful movement and focused attention MBIs were utilized in all three studies that significantly reduced sleep symptoms. No common themes were found for cognitive or somatic symptoms. **Conclusion:** This review recommends sport psychology and sports medicine practitioners take a symptoms-based response to mTBI treatment, emphasizing the most significant presenting symptom. MBIs can be used when treating athletes who mostly present with depression, anxiety, or sleepy dysregulation. However, standard practice is recommended for athletes presenting with either cognitive or somatic complaints.

KEYWORDS: Mild Traumatic Brain Injury, College Athletes, Mindfulness, Mindfulness-based Intervention, Concussion

Introduction

Traumatic brain injury (TBI) is defined as "an alteration in brain function, or other evidence of brain pathology, caused by an external force" (Menon et al., 2010; p. 1638) and is estimated to affect 57 million individuals worldwide each year, with 1.7-2.9 million in the United States alone (Blennow et al., 2016; CDC, 2021; Faul et al., 2010). Researchers have suggested that this annual number may be even larger since TBIs that occur in military populations or those treated in outpatient settings are typically not included in epidemiological statistics (Langlois et al., 2006). In the year 2000, the direct and indirect costs of TBI alone was estimated to be over 60 billion dollars in the United States (Finkelstein et al., 2006). TBI is typically divided into two separate categories: mild traumatic brain injury (mTBI) and moderate-to-sever TBI. mTBIs are the most prevalent, accounting for 75-95% of all TBIs (CDC, 2003; Feigin et al., 2013) and are defined as "a complex pathophysiological process affecting the brain, induced by biomechanical forces" (McCrory et al., 2013; p. 256). Sport-related concussions are a common cause of mTBIs, and account for anywhere between 1.6-3.8 million cases each year in the United States (Harmon et al., 2013; Langlois et al., 2006; Leddy et al., 2012).

Symptoms commonly experienced by individuals with mTBI can be divided into four separate categories: cognitive, affective, somatic, and sleep dysregulation (Azouvi et al., 2017; Barman et al., 2016; Bramley et al., 2016; Polinder et al., 2018; Yeates et al., 2017). Cognitive symptoms present themselves as deficits in tasks such as attention, memory, and concentration (Binder et al., 1997; Brooks et al., 1999; Cicerone & Azulay, 2002). Affective symptoms for mTBI are typically limited to depression and anxiety, however, others can also be present (Mainwaring et al., 2004; McCorkle et al., 2021). Somatic symptoms are generally limited to different severities of headaches (Baandrup & Jensen, 2005; Defrin, 2014), and the research surrounding sleepy dysregulation after mTBI is starting to be expanded upon (Wickwire et al., 2016).

Non-surgical interventions for mTBI are wide ranging and can include rest, education and reassurance, cognitive rehab, cognitive behavioral therapy (CBT), pharmacological treatment, and mindfulness-based interventions (Borg et al., 2004; Lumba-Brown et al., 2018; Sullivan et al., 2020; Teo et al., 2020; Williams & Evans, 2003). However, many meta-analyses do not find many non-surgical interventions to be effective against the symptoms of mTBI (e.g., Borg et al., 2004; Prince & Bruhns, 2017; Teo et al., 2020). One meta-analysis found that no intervention produced significant results in reducing the post-concussive symptoms at 3-6 months post-injury (Teo et al., 2020). However, when these researchers examined the pooled functional outcomes, they observed a small overall effect size. The World Health Organization task force on mTBI found slightly different results when examining the literature (Borg et al., 2004). This task force found that education and reassurance showed a significant reduction in post-concussive symptoms, but the effect size was also small (Borg et al., 2004). There are multiple hypotheses on why the literature has not come to a consensus regarding the optimal treatment for mTBI. Teo et al. (2020) state that there is a lack of consistent outcome measures used in mTBI intervention. Additionally, inconsistency between fewer outcome measures may not produce a consensus due to the heavy reliance on an individual’s subjective experience, rather than rigorous biological or cognitive measures (Prince & Bruhns, 2017). Lastly, there is currently a lack of non-surgical interventions being explored for mTBIs (Borg et al., 2004).

Mindfulness activities focus on fostering and individual’s self-regulation of attention in a non-judgmental manner (Bishop et al., 2004). The most common MBIs are mindfulness-based stress reduction (Kabat-Zinn & Hanh, 2009), yoga (Breedvelt et al., 2019), and mindfulness-based cognitive therapy (Bédard et al., 2014; Bédard et al., 2012). In recent years, more researcher has utilized mindfulness-based interventions (MBIs) to treat mTBI (Acabchuk et al., 2021; Johansson et al., 2012; Kenuk & Porter, 2017; Shirvani et al., 2021). Two theoretical justifications exist for the use of MBIs for treating mTBI symptomology. The first is that MBIs target deficits commonly seen after mTBI such as concentration, attention, and dysregulated emotional processing (Link et al., 2016). The second is how meditation can impact the default mode network (DMN). MBI research has found that these specific interventions can help with the regulation of the DMN (Boccia et al., 2015; Fox et al., 2014), a network of the brain that plays a significant role in disorders such as schizophrenia, depression, and anxiety (Coutinho et al., 2016; Whitfield-Gabrieli & Ford, 2012).

The use of MBIs specifically for mTBI is a relatively new topic. However, MBIs have been utilized and studied independently for the individual symptoms that are commonly present in mTBIs. For example, many studies have found a variety of MBIs to be effective in treating symptoms of depression and anxiety when examined individually (Braun et al., 2020; Fu et al., 2022; Gu et al., 2018). Additionally, researchers have proposed theoretical explanations regarding how different types of MBIs impact various brain networks and regions. One example is the S-ART framework of mindfulness from Vago and David (2012) that details how different MBIs impact and regulate neural networks of the brain associated with some of the main symptoms of mTBI. Analyzing both the results from clinical studies and their theoretical mechanisms of action is important when testing out novel interventions. Thus, the purpose of this narrative synthesis is to summarize the current MBI literature surrounding the main categories of symptoms, cognitive, affective, somatic, and sleep dysregulation, of mTBI in college-aged individuals and provide methodological recommendations to sport psychology and sports medicine practitioners. This review aims to stimulate new research and interventions to help college-aged athletes who have experienced mTBI recover more quickly and effectively.

Method

Data Collection

Article selection for this systematic literature review was conducted via database searches limited to peer-reviewed articles and doctoral dissertations published in the last 20 years in English. This decision was made to ensure the research material selected was the most reliable and relevant information on the topic. The databases included: APA PsychINFO, CINAHL, ERIC EBSCOHost, MEDLINE, PubMed, Science Direct, Sport Discus, Sports Medicine & Education Index, and Web of Science. These databases were selected as they provided the researcher with the most access to research conducted across multiple fields of psychology and medicine, a critical aspect of this systematic literature review. The initial database search included the terms "mindfulness-based intervention," "short-term," "cognitive deficits," "affect deficits," "somatic deficits," and "sleep dysregulation," all connected by the Boolean operator *AND*. In addition to these terms, more terms were included using the Boolean operator *OR*: "MBI," "cognitive symptoms," "affect symptoms," "emotional deficits," "emotional symptoms," "physical deficits," "physical symptoms," and "sleep symptoms." The same search string was used in all databases to ensure consistency and reach all potential papers before the preliminary screening.

Once the initial search was completed, the researcher conducted a preliminary screening using the titles and abstracts of each study. Research material that progressed through preliminary screening then went through a second screening where the researcher read the entire article to ensure that it met the inclusion and exclusion criteria: 1) used short-term MBIs (lasting no more than 2 months); 2) included participant population with a mean age between 18-30 years old; 3) included a control group; and 4) targeted one of the four symptoms common to mTBI (i.e., decreased attention memory, and concentration; increased levels of depression and anxiety; pain, specifically headaches; and sleep dysregulation). The specific type of MBI was not an inclusion or exclusion criteria to keep this review broad in scope.

Data Analysis

A systematic literature review, which is “a systematic, explicit, and reproducible method for identifying, evaluating and synthesizing the existing body of completed and recorded work produced by researchers, scholars, and practitioners,” was conducted to answer the research questions (Fink, 2010, p. 3). Specifically, the analysis of the data followed the guidance of Popay et al. (2006) on conducting a narrative synthesis due to the heterogeneity between the studies included in the review. When the methodology and patient populations differ widely between included studies, it is hard to conduct robust statistical analysis and therefore a narrative synthesis is a better method of analysis (Popay et al., 2006). Specifically, a narrative synthesis refers to an approach to the review and synthesis of findings from studies that relies primarily on the use of words and text to summarize and explain the findings (Popay et al., 2006). The tools used in this narrative synthesis included coding, textual descriptions of each article, grouping and tabulation, and content analysis.

Each article was coded by MBI type, sample size and demographics, intervention description, duration and frequency, symptoms treated, and intervention efficacy. Intervention efficacy was further detailed into information around significance and effect size. After coding was completed, the researcher wrote a textual description of each article, based on the coded information, and included other information deemed relevant to the review. Each textual description included the same essential information included to make grouping and contrasting articles as systematic as possible (Popay et al., 2006).

The researcher then grouped each article into clusters based on the symptoms treated and tabulated the results. Articles were not limited to one cluster, but rather all that apply. After each article was assigned to the relevant clusters, the relationships, and common themes between articles in each of these groups were analyzed through content analysis. The process of content analysis allowed the researcher to highlight common themes and data from individual studies that could then be used to create treatment recommendations for the specific cluster being analyzed. The content analysis considered information relevant to each of the codes given to the article (MBI type, sample demographics, intervention description, duration and frequency, and intervention efficacy).

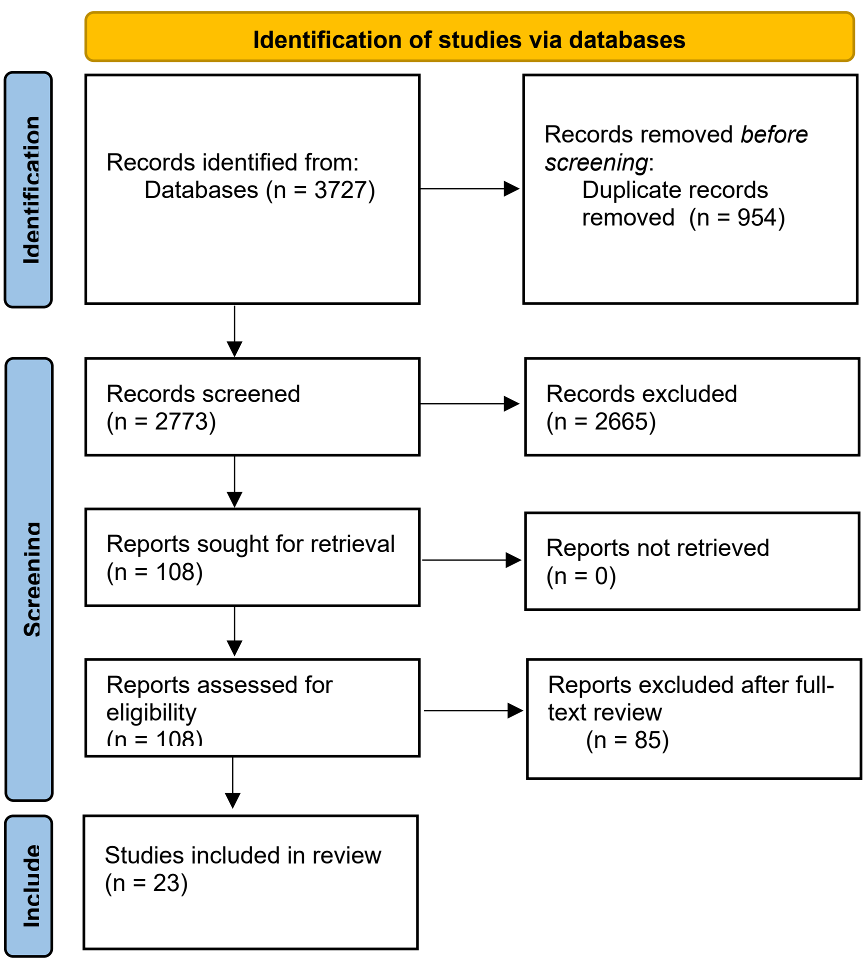
Once each symptom cluster had treatment recommendations, the final phase of analysis was conducted. This phase involved a second instance of content analysis and comparisons between each of the cluster's recommendations. The researcher then aimed to use the extracted information to recommend treatment options for individuals who have experienced an mTBI. During the construction of the full injury treatment recommendations, the researcher considered factors unique to recovering athletes in this age range, such as other responsibilities an individual will be obligated to complete and if the MBI intervention will have a negative impact on that athlete's return to play. An example of this would be eliminating short-term, but time-intensive interventions (multiple hours a day) that may negatively impact the athlete's ability to attend class or do homework.

Results

Database Search

The initial database search of all eight databases yielded 3,727 results, with 2,773 after deduplication (see Figure 1). The process of screening titles and abstracts to find relevant articles and studies eliminated an additional 2,665 articles from consideration. Eighty-five articles were excluded after conducting a full article screening of the remaining 108 articles. Twenty-three articles were included for analysis in this review. Each of the articles that passed a full text screening were included for analysis. This decision was made due to the limited number of studies included in each of the 5 symptom categories. Since the analysis focused on common themes presented in the literature and focused on aspects of MBIs not commonly evaluated, it was important to have as many studies as possible included within the categories.

Figure 5.1. PRISMA Flow Chart for Database Searching



Coding

Coding was completed for mindfulness-based intervention (MBI) type, sample size & demographics, intervention description (i.e., intervention method and tools), duration & frequency, symptoms treated (i.e., depression, anxiety, somatic, cognitive dysfunction, and sleep dysfunction/dysregulation), and intervention efficacy. The coding categories most utilized within the analysis include MBI type, intervention duration & frequency, and symptoms treated. Intervention efficacy coding was only completed for articles that included effect size. Studies with multiple interventions or specific modifications to manualized interventions received multiple codes within the MBI type category, which allowed the researcher to get a better understanding of the mechanisms behind each intervention and more specific comparisons between interventions during the conceptual modeling process. For example, Hunt et al. (2018) conducted an intervention consisting of multiple intervention groups, each performing different mindfulness practices. Therefore, this article was coded by yoga, mindfulness-based stress reduction (MBSR), or MB-Other.

To properly compare and analyze different MBI types, it is important to discuss the mechanisms used within each intervention. For example, there are different types of mindfulness practices and strategies; two studies that may be coded as mindfulness meditation could use drastically different mindfulness practices within those meditations. Therefore, this review provides details about the mechanisms utilized in each intervention, namely focused attention, open monitoring, or loving-kindness. Focused attention (FA) meditation involves the practitioner focusing their attention on an object or sensation in a sustained fashion, and open monitoring (OM) meditation involves expanding one's awareness to both the contents of experience and mental processes in the present moment without selectively attuning to them (Yordanova et al., 2020). Loving-kindness (LK) meditation is intended to reduce the negative effect of the practitioner by instructing them to focus on and wish for the well-being and happiness of themselves and all others equally (Yordanova et al., 2020).

Results are categorized by symptom: depression, anxiety, somatic, cognitive, and sleep symptomology; each with a common intervention theme found to be associated with the most significant reduction of symptomology. Additionally, treatment recommendations based on those findings are detailed in the discussion section along with other topics that require further explanation.

Depressive Symptomology

Analysis of the 12 depression studies (see Table 1) found a common intervention theme that produced significant results. Five of the 12 studies found that significant reductions in depression occurred when interventions included OM meditation and emphasized CBT, detachment, or acceptance. This intervention combination was found to produce significant results regardless of intervention duration, intervention frequency, or sample demographics. OM meditation was utilized within different MBI types, highlighting the fact that the mechanisms behind each intervention are more important than the specific intervention type itself.

Table 1

Depression Symptomology

Author	MBI Type	MBI Duration	MBI Mechanisms
Al-Refae et al., 2021*	Self-Compassion	30 Days	LK | OM
Asl & Barahmand, 2014*	MBCT	8 Weeks	OM
Braun et al., 2020	MBSR (Modified)	8 Weeks	FA | LK
Devillers-Reolon et al., 2022*	Mindful Meditation	17 Days	FA | OM

Fu et al., 2022	MBSR (Modified)	8 Weeks	FA | OM
Gu et al., 2018	MBCT	6 Weeks	FA
Hunt et al., 2018	MBSR | Yoga | MB-Other	4 Weeks	FA | OM
Keng et al., 2015*	MB-Other	4 Weeks	OM
Parcover et al., 2018*	ACT (Modified)	3 Weeks	FA | OM
Ritvo et al., 2021	MB-Other	8 Weeks	-
Walsh et al., 2016	Body Scan | Mindful Meditation | Yoga	4 Weeks	FA
Wu et al., 2019	Mindful Meditation	1 Week	FA

** - Significant Results; MBCT – Mindfulness-based Cognitive Therapy; MBSR – Mindfulness-based Stress Reduction; ACT – Acceptance & Commitment Therapy; FA- Focused Attention; OM- Open Monitoring; LK- Loving Kindness*

The combination of OM meditation with an emphasis on CBT, detachment, or acceptance was found to be effective across different intervention durations ranging from 17 days (Devillers-Reolon et al., 2022), 3 weeks (Parcover et al., 2018), 4 weeks (Al-Refae et al., 2021; Keng et al., 2015), to 8 weeks (Asl & Barahmand, 2014). Six other studies conducted MBIs without the use of OM meditation and some form of CBT/detachment/acceptance and failed to produce significant reductions in depressive symptomology (Braun et al., 2020; Fu et al., 2022; Gu et al., 2018; Hunt et al., 2018; Ritvo et al., 2021; Walsh et al., 2016).

Additionally, this review found no evidence that an MBI without OM meditation and some form of CBT would eventually become effective at reducing depressive symptoms by simply extending the frequency and intensity of the intervention. For example, one study by Gu et al. (2018) consisted of a 6-week MBI with participants being instructed to practice for 30minutes daily (unspecified guided meditation) and attend weekly, 1-hour sessions focused on ADHD symptomology. Furthermore, one study with an 8-week MBI that consisted of (1) 12 educational and mindfulness video modules, (2) 3 anonymous peer-to-peer discussions, and (3) 1 anonymous, group-based, professionally guided, 20-minute videoconference also found no significant reduction in depressive symptoms when compared to the control (Ritvo et al., 2021). When compared to the weekly frequency of effective interventions utilizing OM meditation and emphasizing CBT/detachment/acceptance, these two studies provide evidence that the type of intervention strategies used is more significant in reducing depressive symptomology than MBI duration and frequency.

Participant demographics are also important to consider when evaluating the effectiveness of MBI interventions related to depressive symptoms. The majority of studies measuring depression consisted of non-clinical participant samples. However, two studies analyzed specific patient populations (Asl & Barahmand, 2014; Walsh et al., 2016): drug-dependent males with depressive symptoms and mild-to-moderately depressed females, respectively. Asl and Barahmand (2014) utilized OM meditation, CBT, and emphasized detachment and acceptance, whereas Walsh et al. (2016) utilized body scan techniques, sitting meditation, and yoga. Only Asl and Barahmand found a significant improvement in depressive symptoms, showing that the common theme of OM/CBT/detachment/acceptance can possibly be effective in both clinical and non-clinical samples. However, the duration of these studies differed drastically, with Asl and Barahmand's (2014) study lasting twice that of Walsh et al. (2016), so conclusions about the effectiveness of OM in clinical populations should be drawn cautiously.

Anxiety Symptomology

Sixteen studies surrounding anxiety symptoms were included in this review (see Table 2). Analysis of these studies also demonstrated a theme around the mechanism used within each intervention instead of MBI type, duration, or frequency. Eight of the 10 studies with significant reductions in anxiety utilized FA meditation as a major mechanic of their intervention. The other two significant studies utilized progressive muscle relaxation (PMR); a very similar technique that may provide the practitioners the same benefit as FA meditation.

Table 2

Anxiety Symptomology

Author	MBI Type	MBI Duration	MBI Mechanisms
Al-Refae et al., 2021	Self-Compassion	30 Days	LK | OM
Beerse et al., 2020*	MB-Art | Yoga	5 Weeks	FA
Bellosta-Batalla et al., 2020*	Mindful Meditation	1 Day	FA
Dehghan-nayeri & Adib-Hajbaghery, 2011*	PMR	8 Weeks	-
Devillers-Reolon et al., 2022*	Mindful Meditation	17 Days	FA | OM
Fu et al., 2022	MBSR (Modified)	8 Weeks	FA | OM
Gu et al., 2018*	MBCT	6 Weeks	FA
Hunt et al., 2018*	MBSR | Yoga | MB-Other	4 Weeks	FA | OM
Keng et al., 2015*	MB-Other	4 Weeks	OM
Parcover et al., 2018*	ACT (Modified)	3 Weeks	FA | OM
Ritvo et al., 2021	MB-Other	8 Weeks	-
Smith & Norman, 2017	Deep Breathing | PMR	1 Day	-
Stefan et al., 2018*	MBSR (Modified)	6 Weeks	FA | OM
Weis et al., 2021*	Koru Mindfulness	4 Weeks	FA |

Wu et al., 2019	Mindful Meditation	1 Week	FA

** - Significant Results; MBCT – Mindfulness-based Cognitive Therapy; MBSR – Mindfulness-based Stress Reduction; ACT – Acceptance & Commitment Therapy; PMR- Progressive Muscle Relaxation; FA- Focused Attention; OM- Open Monitoring; LK- Loving Kindness*

Similar to the results found in the depression literature, FA appears to consistently produce significant results regardless of duration. For example, the inclusion of FA meditation has been effective during interventions lasting 1 day (Bellosta-Batalla et al., 2020), 17 days (Devillers-Reolon et al., 2022), 3 weeks (Parcover et al., 2018), 4 weeks (Hunt et al., 2018; Weis et al., 2021), 5 weeks (Beerse et al., 2020), and 6 weeks (Gu et al. 2018; Stefan et al., 2018). Two other studies utilized non-FA interventions lasting the same duration and did not find significant results (Al-Refae et al., 2021; Smith & Norman, 2017). Additionally, Ritvo et al. (2021) conducted a non-FA intervention that lasted longer than any other study within the anxiety literature (i.e., 8 weeks) and did not find significant results. Therefore, this review finds that a common intervention theme of FA is the most effective way of treating symptoms of anxiety. Additionally, the analysis found that FA meditation can be incorporated into different intervention types, as none of the significant studies followed the same intervention protocols, emphasizing FA meditation differently. For example, two studies that both utilized FA meditation across a 6-week intervention with different strategies (MBSR and MBCT), found significant reductions in anxiety (Gu et al. 2018; Stefan et al., 2018). One of these studies found that a 6-week intervention consisting of daily and weekly sessions with FA meditation, OM meditation, and body scanning activities were effective at reducing levels of anxiety in the intervention group compared to the control (Stefan et al., 2018). Gu et al. (2018) found significant results by utilizing daily FA meditations alongside weekly mindfulness-based cognitive therapy. One study even found significant reductions in anxiety through FA emphasized MB-art therapy (Beerse et al., 2020). This intervention involved both yoga and clay modeling with a particular focus on the current task at hand, instructing practitioners to recenter their focus if it waivered.

Despite these findings, four studies in this review do not align with this common intervention theme. Two of these studies included FA meditations within their intervention but found no significant reductions in anxiety (Fu et al., 2022; Wu et al., 2019), possibly due to their range of intervention mechanisms and methodology. The intervention utilized by Fu et al. (2022) consisted of 8 weekly sessions with only two of the eight weeks emphasizing practices based in FA meditation. The other non-significant study compared the intervention group to an active control group, rather than a true control that completed an emotional regulation education course (Wu et al., 2019). These two exceptions to the common theme raise interesting questions that the data from this review could not answer. The results from Fu et al. (2022) imply that there may be a minimum amount of FA meditation needed for an intervention to work, despite a one-day intervention consisting of FA meditation finding significance (Bellosta-Batalla et al., 2020). The results from Wu et al. (2019) show that emotional regulation education may be as effective as FA meditation. However, the inclusion criteria in this review does not allow for further exploration on this topic.

The other two studies addressing anxiety symptoms that did not align with the common theme found significant results by instructing participants to complete daily PMR sessions (Dehghan-nayeri & Adib-Hajbaghery, 2011; Keng et al., 2015). The practice of PMR involves focusing full attention and awareness on one part of the body at a time, similar to the practice of FA meditation. The difference between these two practices, however, is that PMR involves changing focus to a new part of the body periodically. The similar mechanisms between PMR and FA meditation may be enough to benefit the practitioners in the same way. The study by

Dehghan-nayeri and Adib-Hajbaghery (2011) lasted eight weeks and consisted of one 30-minute psychoeducation session within small groups followed by daily PMR practice for 15-20 minutes. Keng et al. (2015) utilized an intervention over four weeks that consisted of psychoeducation, PRM, and OM-emphasized meditation. Despite the similarities between intervention mechanisms, a one-day intervention utilizing PMR before a cold pressor task did not find significant reductions in anxiety symptoms (Smith & Norman, 2017).

While no studies in this review consisted of clinical participant samples for anxiety, results from two studies (i.e., Devillers-Reolon et al., 2022; Stefan et al., 2018) may imply that this common theme may also be effective at treating this population. Devillers-Reolon et al. (2022) conducted a secondary analysis that showed participants with a higher baseline of anxiety symptomology benefited significantly more than those with a lower baseline. The participant sample for Stefan et al. (2018) consisted of individuals at-risk for social anxiety disorder. These results provide a foundation for future studies to explore FA-meditation as a possible effective intervention for clinical anxiety populations.

Somatic Symptomology

No clear common intervention theme was found within the literature using MBIs to reduce somatic symptoms. Of the five studies included within this category (see Table 3), three found a significant, positive effect on symptomology (Askari et al., 2018; Benvenutti et al., 2017; Davies et al., 2021). However, unlike the other symptom categories, there were no major similarities between the intervention duration, frequency, or mechanisms utilized within each intervention. Askari et al. (2018) implemented an 8-week intervention utilizing MBCT that emphasized OM, detachment, and acceptance. Benvenutti et al. (2017) conducted the intervention over a single session of hatha yoga and used blood pressure, heart rate, and salivary cortisol for analysis. Finally, Davies et al. (2021) implemented a 1-week intervention that utilized FA mindfulness over 6 sessions. Additionally, Davies et al., (2021) found that a sham mindfulness intervention group performed equally to a true mindfulness group over an intervention duration of one week. The limited literature on MBIs for somatic symptoms within the target population prevents this review from finding common intervention themes to treat these symptoms.

Table 3

Somatic Symptomology

Author	MBI Type	MBI Duration	MBI Mechanisms
Askari et al., 2018*	MBCT	8 Weeks	OM
Benvenutti et al., 2017*	Yoga	1 Day	FA
Davies et al., 2021*	Mindful Meditation	1 Week	FA | OM
Karing & Beelmann, 2021	MBSR (Modified)	6 Weeks	FA
Smith & Norman, 2017	Deep Breathing | PMR	1 Day	-

** - Significant Results; MBCT – Mindfulness-based Cognitive Therapy; MBSR – Mindfulness-based Stress Reduction; PMR-Progressive Muscle Relaxation; FA- Focused Attention; OM- Open Monitoring; LK- Loving Kindness*

Cognitive Symptomology

Similarly, the analysis of the literature surrounding the use of MBIs for cognitive symptomology found no common theme. Of the five studies included within this category (see Table 4), two found a significant, positive effect on cognitive abilities (Gu et al., 2018; Weis et al., 2021). Gu et al., (2018) conducted a 6-week intervention based on MBCT that emphasized FA and included ADHD psychoeducation while Weis et al., (2021) conducted a 4-week intervention utilizing body scanning, mindful movement, FA, and LK. Four of the five studies included outcome measures related to attentional tasks or scales with the remaining study utilizing a Trail-Making-Test as its cognitive outcome measure. Additionally, none of the studies utilized the same instrument to measure the cognitive ability of its participants. This variability between measures and the wide number of abilities within cognitive symptomology prevented this review from finding a common intervention theme in regard to duration, frequency, mechanisms within each intervention, or specific attentional or cognitive abilities.

Table 4

Cognitive Symptomatology

Author	MBI Type	MBI Duration	MBI Mechanisms
Braun et al., 2020	MBSR (Modified)	8 Weeks	FA | LK
Devillers-Reolon et al., 2022	Mindful Meditation	17 Days	FA | OM
Gu et al., 2018*	MBCT	6 Weeks	FA
Karing & Beelmann, 2021	MBSR (Modified)	6 Weeks	FA
Weis et al., 2021*	Koru Mindfulness	4 Weeks	FA |

** - Significant Results; MBCT – Mindfulness-based Cognitive Therapy; MBSR – Mindfulness-based Stress Reduction; FA-Focused Attention; OM- Open Monitoring; LK- Loving Kindness*

Sleep Symptomology

Three studies included in this review examined the impact MBIs had on sleep dysregulation (see Table 5). Each of these studies found significant improvements in sleep quality and utilized mindful movement or activities, alongside FA within their interventions. For example, Fu et al., (2022) utilized an MBI based on MBSR over the course of 8 weeks. Many different MBI techniques were included across eight weekly sessions such as OM, FA, PMR, and mindful movement/activities (e.g., mindful walking or eating); themes of acceptance and awareness were emphasized throughout the intervention. Gray et al., (2018) and Weis et al., (2021) implemented a 4-week Koru Mindfulness intervention utilizing deep breathing techniques

(FA), imagery and mindful movement. In addition to the Koru Mindfulness sessions, Weis et al., (2021) instructed the participants to practice LK meditations daily. While each intervention included mindful movements/activities and FA meditation within their intervention procedure, this common theme is considered weaker than those found in the depression and anxiety literature due to the limited number of studies and a multitude of other mindfulness-based activities used within each intervention. Another explanation could be the increase in state-mindfulness levels due to the intervention as an explanation of the significant findings.

Table 5

Sleep Symptomology

Author	MBI Type	MBI Duration	MBI Mechanisms
Fu et al., 2022*	MBSR (Modified)	8 Weeks	FA | OM
Gray et al., 2018*	Koru Mindfulness	4 Weeks	FA
Weis et al., 2021*	Koru Mindfulness	4 Weeks	FA

** - Significant Results; MBSR – Mindfulness-based Stress Reduction; FA- Focused Attention; OM- Open Monitoring; LK- Loving Kindness*

Discussion

Sport-related concussions are one of the most common causes of mTBI and account for roughly 1.6-3.8 million cases each year in the United States (Harmon et al., 2013; Langlois et al., 2006; Leddy et al., 2012). The implementation and evolution of the results found in this narrative synthesis into standard concussion treatment has the potential to reduce this number and improve the recovery of other patient populations suffering from mTBI. Additionally, athletes who have worked with a sport psychologist may have previous mindfulness experience through sport performance interventions, possibly increasing the rate at which they can correctly perform the tools used in MBI for injury recovery. If an athlete has higher trait mindfulness due to past MBI exposure, short-term interventions on athletes may be able to predict how a longer intervention may impact patient populations with lower trait mindfulness. The results of this review are not found from a sample of athletes. However, the implementation of these recommendations to an athlete sample may provide further insight into the treatment of mTBI through the use of MBIs.

When making methodological recommendations for an MBI intended to target major symptom categories associated with mTBIs experienced by college-aged athletes, this review found specific intervention mechanisms are most effective. More specifically, open monitoring and compassion, detachment, or acceptance interventions for depression, focused attention interventions for anxiety, and focused attention and mindful movements or activities for sleep dysregulation. Additionally, if the athlete presents with symptoms of cognitive dysfunction or somatic complaints, the results of this review lead the authors to recommend standard care over mindfulness-based interventions due to the lack of central intervention themes. Sports medicine and sport psychology practitioners are advised to create an intervention based on one of these methodological interventions, targeting the most prominent symptom category the athlete is experiencing.

The results of this review can be viewed through, and are supported by, some theoretical explanations of how MBIs lead to reduce symptoms support the findings of this review. However, it should be noted that no explanation has received a consensus from the scientific community. For example, one meta-analysis found strong evidence of MBIs impacting cognitive and emotional reactivity, ruminating negative thoughts, and self-compassion (Gu et al., 2015). Chiesa et al. (2014) found that enhanced positive emotion regulation, an increase in self-compassion, and decreased rumination and avoidance learned through MBIs were associated with clinical benefits in stress, depression, and anxiety. The findings regarding emotional reactivity and regulation increased self-compassion, and a decrease in ruminating negative thoughts are shared between these explanations and reductions seen in depression and anxiety in this review. However, the impact on cognitive reactivity seen in the explanation proposed by Gu et al., (2015), particularly relating to performance on cognitive tasks, was not found in this review. Additionally, neither theoretical explanation supports how this review found reductions in sleep dysregulation.

Interestingly, the self-awareness, self-regulation, and self-transcendence (S-ART; Vago & David, 2012) framework of mindfulness attempts to explain how MBIs interact with different neurological networks to change brain functioning. The findings from this review are most clear when viewed from this model, as this model specifically references focused attention, open monitoring, and ethical enhancement (read: loving kindness) meditation. The S-ART Model proposes that focused attention meditation impacts two networks they call the enactive experiential self (EES) and experiential phenomenological self (EPS). In short, the EES is responsible for processing of sensory and motor stimuli and hierarchically organizing those sensations by emotional tone, with motivational, social, and emotional feelings being represented the strongest and more easily reached by an individual's conscious experience (Craig, 2004; Vago & David, 2012). The EPS is proposed to access the contents of the EES with different degrees of ease, depending on the previously mentioned hierarchical categorization, and can modulate, control, or amplify them (Gallagher, 2000; Raffone & Pantani, 2010). Taken together, these networks impacted by FA highlights why this review found reductions in anxiety with the use of FA. Depending on the emotional coding and hierarchical ranking of stimuli within the EES, then accessed by the EPS, utilizing FA to train the practitioners mind to disengage from the negatively coded emotions and sensations may be linked to a reduction in anxiety.

Additionally, the S-ART Model proposes that OM meditation impacts the EPS as well as another network called the narrative self (NS). The NS differs from the EPS as it is reflective and can understand the self as an object over time. It is also comprised of individual identity and experience across physical, social, and psychological domains (Craig, 2004; Damasio, 2012; Tagini & Raffone, 2010). In short, the NS is comprised of many different brain regions that are responsible for reflection. OM interacts with the NS by regulating its activity. For example, an overactive NS can lead to increased rumination about the self. In the case of depressed individuals, an overactive NS would lead to negative outcomes and increased depressive symptoms. Therefore, the use of OM to treat depression is supported through this model.

The broader literature supports the presence of the exceptions found regarding the use of PMR to treat anxiety alongside MBIs. However, this review still recommends FA over PMR for treating symptoms of anxiety for two reasons: FA interventions are more commonly implemented for anxiety compared to PMR and FA may have more positive impacts on the athlete outside of a reduction of symptoms. Research on the use of PMR compared to MBIs has found that MBIs may provide a buffering effect against future emotional problems in the future. For example, one study found that both PMR and a MBI decreased worry, trait anxiety, depressive symptoms, and health complaints in each intervention group; However, emotional comprehension was found to be higher in the MBI group (Delgado, 2010). Another study found similar results between the use of PMR or MBIs for distress. Jain et al., (2007) found that interventions decreased distress and increased positive mood states over time. In addition to these results, the MBI group also reduced ruminative thoughts and behaviors.

The recommendations from this review have been made to specifically target an athlete’s most prominent presenting symptom from their mTBI. While there is some overlap between symptom treatment recommendations, this review does not allow for recommendations for an intervention aimed at reducing all possible symptoms of mTBI. There are two main reasons for this decision. Firstly, this review did not find intervention themes that were significant in reducing cognitive dysregulation and somatic complaints. Second, while not a result of this review, interventions included within this review typically did not find significance when they included more than two to three intervention tools. Thus, at this point, the recommendation would be to select an intervention based on the main or target symptom.

These results highlight how mTBI interventions, particularly for college-age athletes, may be improved to consistently produce significant clinical outcomes, despite not all mTBI symptom categories having a central intervention theme. Many meta-analysis have failed to find intervention strategies that consistently produce positive outcomes, including the use of MBIs. However, understanding and utilizing the methodological differences required for MBIs to consistently reduce each symptom category associated mTBI may be a steppingstone toward a consistent reduction of symptomology in future research on MBIs. Many sports medicine and sport psychology practitioners work with athletes who are constantly at risk of a sport-related mTBI. College athletics may provide many opportunities for MBI research that will progress the literature surrounding mTBI treatment and could have effects on many different patient populations as well.

Limitations

Evaluation of the summary and treatment recommendations within this review should take into account some methodological limitations. Firstly, many studies did not include effect sizes in their results; the recommendations were based on common themes included in significant studies. This review was not able to compare the significant results and themes found against one another. Second, this review relied on the descriptions of each intervention given in each study. Potential methodological themes may have been missed. Third, the strict inclusion criteria used during data collection led to some symptom categories having only a few studies included.

Future Research

Future research has many possible avenues to expand on within the use of MBI for mTBI. Firstly, there is a limited number of MBI studies that have found significant reductions of cognitive and somatic symptoms in college-aged individuals with mTBI. Future research could be aimed at finding theoretical hypotheses or conducting clinical trials on what type of MBI, if any, could be effective at reducing these symptom categories. Additionally, this review did not find common themes for intervention duration and frequency. Meta-analyses encompassing a larger age range may be able to find common themes for short-term MBIs. Third, future research should include all mTBI symptom categories in their outcome measures. Many reviews included in this review had only a few of the common mTBI symptoms in their outcome measures. In order to find interventions that can treat each symptom category for mTBIs, individual studies should conduct pre- and post-measures of each symptom. Lastly, the findings of this review should be tested on college-aged athletes who have experienced mTBI. These findings may translate to similar clinical outcomes. However, the continuation and evolution of these recommendations require clinical studies to progress.

Conclusion

When treating athletes who have experienced mTBI, this review recommends OM and compassion, detachment, or acceptance to reduce depression, focused attention for anxiety, and focused attention and mindful movements or activities for sleep dysregulation. The results specific to the recommendations for depression and anxiety are consistent and supported by the S-ART framework proposed by Vago and David, (2012) that states FA helps reduce anxiety by impacting the brains networks known as the EES and EPS. Additionally, OM helps reduce depression by impacting the EPS and regulating the NS netwoks. However, this theoretical explanation does not detail how this review found a common MBI theme for sleep dysregulation. Despite these prominent themes, this review does not make reccomendations on creating interventions that aim to reduce all symptoms categories that may present in an athlete who experienced mTBI. No common intervention themes were found for cognitive dysregulation or somatic complaints, and this review recommends standard practice interventions when treating athletes who present with these specific symptoms after mTBI.

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Appendix A

Author	Symptoms Treated	MBI Type	Sample Size	Mean Age	Intervention Description	I-Duration	I-Frequency	I-Efficacy
Al-Refae et al., 2021	Depression; Anxiety	Self-Compassion	165	25.24	The intervention group was tasked with completing one mindfulness meditation (focusing on self-compassion) from the app Serene once a day and to include cognitive restructuring tasks (based-on CBT) as needed for 30 days. The specific mindfulness meditation selected each by each individual in the intervention group was of their choice.	30-Days	Daily (Individual, 10-15 min)	Data analysis revealed a significant decrease in depression (p < .05, d= -.43), but no significant decrease in anxiety (p > 0.05, d = −0.15).
Askari et al., 2018	Somatic	MBCT	40	21.53	The intervention consisted of 8 weekly sessions of MBCT that followed the standard protocol of 1- Attentional control that is maintaining a moment-by-moment awareness, 2- How to disengage from judgmental and evaluative language by processing and moving to an experiential attention of the present moment and, 3- How to disengage from negative thoughts and emotions and physical sensations.	8-Weeks	Weekly (Group)	The mean score of physical symptoms significantly reduced in the intervention group compared with the control group just after the completion (P < 0.001), and one month after the intervention (P < 0.001).
Asl & Barahmand, 2014	Depression	MBCT	35	29.5	The intervention used in this study was MBCT where individuals were trained "to gain an ability to realign themselves away from their thoughts and feelings and focus instead on the changes occurring in their body and mind. Clients were encouraged to adopt a new way of being and relating to their thoughts and feelings, while placing little emphasis on altering or challenging specific cognitions."	8-Weeks	Weekly (Group, 2 hrs)	The intervention consisted of 8 weekly 2-hour sessions. Post analysis found that there was a significant decrease in levels of depression in the intervention group vs control (p < .000).
Beerse et al., 2020	Anxiety	MB-Art; Yoga	115	19.7	The intervention used a mix of yoga clay modeling and audio clips centered on concepts of mindfulness. Main concept included was focused attention	5-Weeks	Bi-Weekly (Online, 10-15 minutes)	Analysis showed that the intervention group had a significant decrease in levels of anxiety (p = .000) when compared to control.
Bellosta-Batalla et al., 2020	Anxiety	Mindful Meditation	68	24	On one day a psychoeducation session and 2 guided meditations were performed. The purpose of these meditations was to direct one's attention to breathing and physical sensations, trying not to identify with the mental events that arose during this process. The psychoeducation session included basic instruction were explained (pay attention to the content of the consciousness), as well as the attitudes that accompany the practice (curiosity, openness, acceptance and kindness	1-Day	3 activities (Group, 10-15 min each)	Analysis showed that the intervention group had a significant decrease in state anxiety (d = −.54, p = .007) compared to the control.
Benvenutti et al., 2017	Somatic	Yoga	24	22.9	After the stress task was completed, the participant either completed the hatha yoga session or watched a video for 30 minutes (control). The hatha yoga consisted of holding positions, focused breathing, and meditation.	1-Day	30-min (Group)	Analysis of the data showed that the intervention group had significantly lower levels of somatic stress (p< .001) following the stress task and intervention compared to the control.

Braun et al., 2020	Cognitive; Depression	MBSR (Modified)	48	25.96	The intervention was constructed from MBSR and a MBSR manual adapted for physicians. The intervention consisted of a weekly 2-hour session for 8 weeks. Each session started with 45-60 minutes of discussion on relevant topics then a brief meditation practice of focused attention or loving-kindness. The remainder of the session time was spent practicing hatha yoga (35–40 min), deep breathing (during movement practice), relaxation (10 min), and seated meditation (5–22 min).	8-Weeks	Weekly (Group, 2 hrs)	Analysis showed no significant effects on either depressive symptoms or TMT performance.
Davies et al., 2021	Somatic	Mindful Meditation	93	21.39	Both active intervention consisted of 6 x 20-minute mindfulness session (real and sham-mindfulness) over the course of one week with an acute pain test being conducted at baseline and at the end of the week. This focused-attention practice builds a foundation for more advanced meta-cognitive practices by training two core cognitive/meta-cognitive processes: a) building attentional stability by anchoring attention on present-moment bodily experience and b) building mindful meta-awareness by observing and accepting experiences non-reactively and nonjudgmentally.	1-Week	6-Times (20 min, Individual)	Analysis showed that both the mindfulness and sham-mindfulness intervention groups increased pain tolerance when compared to the control ($p< .009$ & $p< .012$ respectively), with no differences found between the two intervention groups.
Dehghan-nayeri & Adib-Hajbaghery, 2011	Anxiety	PMR	200	N/A	The intervention consisted of one small group (n= 5-8) 30-minute psychoeducation session regarding the benefits of relaxation techniques and instructing the participants to practice relaxation techniques daily for 15-20 minutes for a total of 8-weeks.	8-Weeks	Daily (15-20 min, Individual)	The mean difference was found to be significantly increased in the intervention compared to the control after the intervention ($p < .000$).
Devillers-Reolon et al., 2022	Depresssion; Anxiety; Cognitive	Mindful Meditation	76	22.23	The intervention consisted of daily guided meditation sessions delivered virtually that lasted 10-20 minutes for 17 days. The guided meditations emphasized focused attention breathing techniques and addressed the consciousness of breathing, the development of positive emotions, and the development of acceptance. The relevant outcome measures for this review include anxiety, depression and attentional abilities.	17-Days	Daily (10-20 min, Individual)	Analysis found a significant reduction in levels of anxiety in the intervention group when compared to control ($p= .002$). An additional analysis of anxiety levels, differentiating between high and low baseline anxiety levels found that the intervention has a significantly strong decrease in anxiety for the high-baseline group compared to the low-baseline group ($p< .001$). Similar results were found in the analysis of depression with a significantly positive effect on reducing depression symptoms in the intervention group when controlling for baseline differences vs the control and comparing high-baseline depression with low-baseline depression ($p= .025$ & $p= .005$
Fu et al., 2022	Depression; Anxiety; Sleep	MBSR (Modified)	45	23	The intervention consisted of varying mindfulness techniques including psyched (at the start), focused attention, open monitoring, mindful walking, and body scan activities. There was a total of 8 weekly sessions each lasting an average of 120 minutes. The goal of the intervention was to improve sleep quality and reduce anxiety and depressive symptoms among university students by practicing mindfulness, which means that they would learn to pay attention to what is happening in the present moment with an attitude of acceptance.	8-Weeks	Weekly (120 min, Group)	Data collection occurred at baseline, post-intervention, and 1-month follow-up. Analysis showed a significant, postive effect of group and time on sleep quality ($p= .012$), but no significant main effect. Additionally, no significant differences were observed in depressive or anxiety symptomology.

Gray et al., (2018)	Sleep	Koru Mindfulness	36	N/A	The intervention consisted of 4 weekly sessions lasting about 75 minutes each and included varying activities such as belly breathing, dynamic breathing, counting breaths, the "S.T.O.P." check-in practice (a teaching acronym that stands for Stop, Take a breath, Observe, and Proceed), guided imagery, Gatha practice, mindful walking, and mindful eating. Daily practice was encouraged but not required.	4-Weeks	Weekly (75 min, Group)	Analysis found significant improvements in sleep quality for the intervention group compared to control (p< .05).
Gu et al., 2018	Depression; Anxiety; Cognitive	MBCT	54	20.29	The intervention was conducted on a weekly basis for 6 weeks, lasting about 60 minutes each session. Additionally, participants in the MBCT group were instructed to follow guided practices for 30-minutes each day and were given psychoeducation materials on ADHD. This MBCT was done individually instead of in a group setting.	6-Weeks	Daily (30 min, Individual) & Weekly (60 min, Individual)	Analysis showed that there was no significant improvement in levels of depression, but there were significant improvements in levels of anxiety (p= .019). As for symptoms of ADHD, analysis showed that both inattentive and hyperactivity/impulsivity symptoms were significantly lower in the intervention group (p= .003 & p= .004, respectively).
Hunt et al., 2018	Depression; Anxiety	Yoga; MBSR; MB-Other	119	N/A	Participants randomized into one of five groups: meditation (MBSR: FA & OM, but no movement), yoga, combined meditation and yoga, therapy dog, or control group. Sessions for each active intervention group were held once over the course of 4 weeks.	4-Weeks	Weekly	Analysis showed that there were no significant changes in depression levels for any intervention group compared to control. However, levels of anxiety were found to be significantly reduced compared to control in the meditation, yoga and combined groups at the end of the 4-weeks (all p< .05).
Karing & Beelmann, 2021	Cognitive; Somatic	MBSR (Modified)	71	22.68	The intervention lasted 6 weeks and consisted of one 90-minute session and five 30-minute sessions as a group. The intervention was based on MBSR and the exercises included: awareness of breathing and body scan meditation (week 1), awareness of breathing and body (week 2), mindful eating week3), walking meditation (week4), sitting meditation (week 5), and mindful hatha yoga (week 6). Participants were measured at baseline, post-intervention, and at a 2.5-month follow-up.	6-Weeks	Weekly (Group, 90-min & 30 min)	There were no significant effects found on either of these outcome measures during analysis.
Keng et al., 2015	Depression; Anxiety	MB-Other	139	22.4	The MBI integrated both qualities of mindfulness training and cognitive behavioral therapy and lasted 4 weeks. Exercises emphasized in the intervention included body scans, mindful breathing, and psychoeducation (CBT). Daily practice was encouraged but not required.	4-Weeks	Weekly (Group, 3 hrs)	Analysis revealed a significant reduction in both symptoms (depression p< .000; anxiety p= .020).
Parcover et al., 2018	Depression; Anxiety	ACT (Modifiled)	271	19	The MBI consisted of 3 weekly group sessions that focused on teaching the participants about breath work, nonjudgmental observation of thoughts, and values-focused behavior (ACT based).	3-Weeks	Weekly (Group)	Analysis of the data show a significant time x group interaction for reducing symptoms of both depression (p < .001) and anxiety (p < .001).

Ritvo et al., 2021	Depression; Anxiety	MB-Other	154	23.1	The intervention in this study was called The Mindfulness Virtual Community and was based on principles of mindfulness and CBT. The intervention lasted 8-weeks and included (1) 12 educational and mindfulness video modules, (2) 3 anonymous peer-to-peer discussions, and (3) 1 anonymous, group-based, professionally guided, 20-minute videoconferences.	8-Weeks	Varied	Analysis showed no significant differences between the intervention and control group.
Smith & Norman, 2017	Somatic; Anxiety	PMR; Deep Breathing	53	20	Participants were randomized into one of three groups: deep breathing (n= 17), progressive muscle relaxation (n= 21), or control (n= 15). Each intervention only lasted 10-minutes and was completed before a cold pressor pain task.	1-Day	Once	Analysis of the pre and post tests found no significant main or interaction effects for the intervention groups.
Stefan et al., 2018	Anxiety	MBSR (Modified)	46	18.92	The MBSR format used in this study differed from the original manual in a few ways: (1) it includes six training sessions with an additional two optional sessions, with the latter lessons being recommended for delivery by trainers with more extensive experience in teaching MBSR, (2) it has shorter training sessions lasting between 1.5–2 h, (3) contains less teaching focused on yoga type exercises, and (4) does not include the all-day retreat focused on meditation. The intervention group had additional homework assignments that included: (1) educational material related to meditation, (2) formal practice of mindfulness meditation for an average of 30 min/day, and (3) informal mindfulness practice in day-to-day activities.	6-Weeks	Daily (30 min); Weekly (1.5-2 hr)	Analysis found a significant group x time interaction on decreasing levels of anxiety in the intervention group vs control ($p < .001$).
Walsh et al., 2016	Depression	Body Scan; Mindful meditation; Yoga	64	19.13	The mindfulness-based intervention lasted 4-weeks and included weekly group sessions with 35 minutes of practice and 15 minutes of discussion. The first week was focused on body scanning techniques, the second and third week focused on sitting meditations, and the final week was yoga.	4-Weeks	Weekly (Group, 50 min)	Analysis showed no significant differences in the reduction of depressive symptoms in the intervention group vs control after 4-weeks.
Weis et al., (2021)	Sleep; Anxiety; Cognitive	Koru Mindfulness	N/A	N/A	KM is a 4-week intervention with weekly, 75-minute group sessions. Each session consists of a brief centering activity to focus attention, an introduction of a new mindfulness skill and meditation practice. Topics include (a) diaphragmatic and dynamic breathing and body scan meditation; (b) walking meditation and the use of gathas during meditation; (c) guided imagery and acceptance of negative thoughts; and (d) mindful eating and acceptance of negative feelings. Weekly readings supplement each session and intervention participants were encouraged to participate in daily meditations each day for 10-minutes.	4-Weeks	Weekly (Group, 75 min) Daily (10 min, Individual)	Analysis showed that the intervention group had significant improvements in sleep latency ($p < .025 \mid \eta^2 = .12$), sleep quality ($p < .005 \mid \eta^2 = 16$), and anxiety ($p < .015 \mid \eta^2 = 13$). However, sleep duration saw no significant differences. Cognitive improvements were detectability ($p < .007$) omission ($p < .018$) and commission ($p < .004$) (all attentional tasks).
Wu et al., 2019	Mindful Meditation	Depression; Anxiety	46	21.64	Participants were randomly allocated to the brief mindfulness meditation (BMM) group (n = 23) or the emotional regulation education (ERE) control group (n = 23). The intervention was based on the core concepts of mindfulness and breath meditation.	1-Week	Daily (Group, 15 min) 1-time PsychEd (Group, 30 min)	No significant differences were found in analysis.