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Review

Integrating Mindfulness and Physical Exercises for Medical Students: A Systematic Review

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Abstract:

***Background*:** The purpose of this systematic review was to appraise the empirical evidence pertaining to medical students and the integration of mindfulness and physical exercise regimens.

***Methods*:** A systematic review was undertaken. Five databases were used to survey the salient literature.

***Results*:** The initial search identified 353 potentially relevant articles of which 17 articles were considered for the final review. The findings indicated that the research was mainly conducted in the USA with some research originating from Europe, Canada, Jamaica, and India. In addition, a range of research designs were applied to measure or discuss the efficacy of the integrated intervention. Four key categories captured the essence of the results of our review, namely: (1) quality of evidence and research methods; (2) types of interventions; (3) measurement protocols; and (4) benefits of integrating mindfulness and physical exercises.

***Conclusions*:** This systematic review demonstrated that when mindfulness and physical exercises are integrated there are likely to be positive health outcomes for medical students. In the studies that yielded the highest level of evidence it was clear that this combination enhanced mental health, and reduced stress levels amongst students, and the benefits may assist with interpersonal development, such as greater empathetic levels and improved interpersonal responsivity.

Keywords

Mindfulness; physical exercise; medical students; wellbeing

1. Introduction

Mindfulness is a well-established philosophy and practice that has been described by the Mental Health Foundation of New Zealand as a state of mind which involves "paying attention to what is presently occurring, with kindness and curiosity"[1]. Brown and Ryan [2] have also characterised the meditation practice of mindfulness as a "state of being attentive to and aware of what is taking place in the present". Monitoring and paying attention to thoughts in the mind and sensations in the body combined with genuine awareness of surrounding influences in the environment are part of the skill to be developed [3].

Mindfulness meditation practices can be undertaken to achieve a more insightful state throughout the day, and mindfulness courses have been shown to enhance wellbeing [4]. Such courses are usually structured and delivered over a prescribed number of weeks (e.g., 8-weeks) [4]. They consist of weekly face-to-face group meetings plus home practice. The two courses most commonly cited and researched are Mindfulness Based Stress Reduction (MBSR) and Mindfulness Based Cognitive Therapy (MBCT) [5].

MBSR was developed by Jon Kabat-Zinn and presents a secular approach to a long standing traditional Buddhist practice. The MBSR approach is therapeutic and educational and its aim is to promote awareness of the mind and body and has a pragmatic orientation that involves developing coping strategies for dealing with toxic stress. It has several components that can include a sitting meditation, a body scan, and hatha yoga [6]. MBCT came from the development of the MBSR system and combines the principles of cognitive therapy and mindfulness often to manage the state of depression. Typically a MBCT programme utilises a seated meditation and

develops awareness on mood changes, rumination, and negative thoughts [6]. MBCT is now included in the National Institute for Health and Care Excellence (NICE) guidelines in the United Kingdom as a depression relapse prevention programme [7].

Medical students are often cited as being at risk of burnout and other psychological conditions, such as anxiety, depression, and insomnia [8-12]. A recent meta-analysis of 77 studies concluded that depression affected almost one third of medical students [13]. Calls have been made for medical educators to address this issue, including during medical undergraduate training. Although the recent meta-analysis did conclude that medical students are at greater psychological risk than students from other courses, there were clearly benefits of mindfulness training for all health professional students. Even twenty years ago, it was known that mindfulness training reduced anxiety and increased empathy in medical students[4], which are also clearly core skills for a doctor[14]. Mindfulness training has, therefore, been applied to the medical education context [15-17]. In addition to its use as a therapeutic practice, the theory and application of mindfulness has been embedded in some medical curricula both formally and informally [18, 19].

What is less well-known is to what extent an integrative mind-body approach, which includes both mindfulness and physical exercise regimens, is taught or researched with medical students. Despite the commonly held belief that the mindfulness exercises are generally conducted whilst in a seated posture there is a well-established connection between mindfulness approaches and physical exercise [3]. Given the lauded benefits of mind-body strategies in promoting health and ameliorating ill-health [20, 21], we were interested to find out what methods were being researched and to see if these methods had proven to be effective for medical students.

This study preferentially employed a systematic review to determine the evidence, in both the quantitative and qualitative literature, regarding the use of mindfulness and physical exercises to enhance the wellbeing of medical students. Systematic reviews require the implementation of a detailed search strategy and aim to methodologically search relevant databases and determine the quality of evidence on a particular topic [22]. This review option was preferred to a narrative review that may have a selection bias or a meta-analysis which requires a focus on the quantitative evidence to determine a summary effect size [22].

The aim of this systematic review was to appraise the quality of research evidence regarding the use of both mindfulness and physical exercises to enhance the wellbeing of medical students [23, 24]. The research question was, “what is the quality of evidence establishing the efficacy for integrating mindfulness and physical exercise with respect to enhancing medical students’ wellbeing?”

2. Materials and Methods

As a systematic review, this manuscript did not require ethical approval as it contains no primary data.

2.1 Search Protocol

A literature search was conducted in five databases: the three Ovid databases Embase (1980-Present), Medline (1946-Present) and PsycINFO (1806-Present), as well as Scopus and all segments of the Cochrane Library. Three researchers (MH, TJP, JH) collaborated to identify search terms and develop search strategies that would be both sensitive enough to retrieve all relevant studies, as

well as studies specific to our research focus. The key concepts mindfulness/meditation, were combined with a range of exercise related terms and modalities. The keyword medic* was included to narrow the focus to medical students. Relevant subject headings specific to each database were combined with keywords to increase the scope of the searches, for example, see Table 1 for the medical subject headings and keywords used. Search strategies were checked several times initially by TJP, then by MH and JH. One of the database search strategies, PsycINFO, is illustrated in Table 2.

Table 1 Medline subject headings and keywords.

Medline subject headings (MeSH)	**Keywords**	
Mindfulness		
Mindfulness/ Meditation/	Mindful* Meditat*	
Exercise		
Mind-body therapies/ exp Exercise/ Yoga/ Tai Ji/	(Mind adj3 body) Exercis* Physical activit* Sport Sports Taiji Taijiquan Tai Chi T'aichi T'ai chi Walking	Swim* Running Jogging Baseball Basketball Football Judo Martial art* Soccer Tennis Weightlifting
Medical		
	Medic*	
Students		
Students/ exp Students, health occupations/	Student* Freshm?n Post graduate* Postgraduate* Graduate Sophmore	Intern Interns Trainee*

Table 2 The PsycINFO search strategy and terms used.

#	Searches	Results
1	exp EXERCISE/	23304
2	exp sports/	23398
3	exercis*.mp.	66604
4	(tai ji or taiji or taijiquan or tai chi or t'aichi or t'ai chi).mp.	525
5	yoga.mp.	2520
6	mind body therapy/	150

7	("mind and body" adj3 exercis*).mp.	51
8	(mind-body adj3 exercis*).mp.	53
9	(body-mind adj3 exercis*).mp.	9
10	("baseball" or "basketball" or "extreme sport*" or "football" or "judo" or "martial art*" or "soccer" or "swim*" or "tennis" or "weightlifting").mp.	20830
11	sports.mp.	26598
12	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11	107566
13	mindfulness/ or meditation/	10302
14	(mindful* or meditati*).mp.	18281
15	13 or 14	18281
16	medical students/	12542
17	postgraduate students/ and medic*.mp.	100
18	exp college students/ and medic*.mp.	2614
19	((freshm?n or student* or post graduate* or postgraduate* or graduate* or under grad* or undergrad* or freshman or sophomore or trainee* or intern or interns) adj3 medic*).mp.	20395
20	16 or 17 or 18 or 19	22150
21	12 and 15 and 20	21

2.2 Type of Participants

Participants for our study were defined as university students enrolled in a medicine programme.

2.3 Types of Interventions

Interventions had to include mindfulness or mind-body based exercises that also incorporated physical exercise.

2.4 Types of Outcome Measures

Outcome measures for our study were not defined ahead of time, but were identified as the outcomes reported in the included papers (outcomes being beneficial, harmful or uncertain). The final search strategies were run in all five databases and search results were imported and collated into EndNote, a reference management program [25]. The articles were then reviewed by two researchers (MH, TJP) and duplicates were removed. The resulting studies were screened systematically by TJP and MH, first by title and then by abstract. After screening, the full texts were reviewed together by two researchers (TJP & MH) using precise inclusion and exclusion criteria as listed below:

1. Studies must have included an empirical study or a critical review of the area.
2. Only journal articles and conference abstracts (with sufficient data) were considered for review.
3. Studies must have included students who were studying medicine at the time of the research in at least one of the intervention groups.

4. The intervention must have incorporated both mindfulness-based practices and physical exercise. Studies that only used either mindfulness-based practices or physical exercise were removed.

2.5 Data Analysis

Using the aforementioned criteria, articles were first identified, then screened for eligibility and finally inclusion was confirmed for the final review of the full text. This process was documented in a flow diagram (Figure 1) and a final list of eligible articles for review were summarised (Table 3), which is consistent with PRISMA guidelines [26].

A categorisation system of key study features was applied to this list of articles. This process was predominantly inductive relying on the generation of categories, which is a version of thematic analysis [27]. In the first review round, two authors (MH, TJP) familiarised themselves with the findings of the studies being reviewed noting down initial ideas. Next, all authors reviewed the essential features of the selected articles and confirmed the final categories that best represented the ideas and conclusions emerging from the articles. The categories were checked at different stages by all authors.

The quality of the evidence was analysed using several methods. First, a risk of bias analysis was conducted using the Cochrane risk of bias criteria for randomised or nonrandomised control studies (Table 4a) [28-31]. Second, the Newcastle-Ottawa Scale was used to assess the quality of nonrandomised cohort studies (Table 4b) [32]. Third, the Critical Appraisals Skills Programme (CASP) checklist was applied to qualitative and descriptive studies (Table 4c) [33]. Lastly, levels of evidence were applied to all studies according to predefined criteria (Tables 4a to 4c) [23, 24, 34]. To further maintain the integrity of the process, analysis procedures were discussed amongst all authors and several strategies were used to establish trustworthiness in the data analysis process [35].

3. Results

3.1 Search History and Results

The initial search results from the five databases yielded a total of 353 articles (Figure 1). Seventy six duplicates were identified and in the next step we conducted a review of 277 titles and abstracts based on inclusion and exclusion criteria. The subsequent quota of articles resulted in the exclusion of 250 articles. A list of 31 articles was identified as potentially relevant by two researchers (MH, TJP). This was reduced to a final list of 17 refereed sources after appraisal of the full text. Table 3 shows the final collated list of 17 articles included in the evidence review, showing key study features such as methods, research design, key findings and conclusions.

3.2 Summary of the Articles Included for Review

Table 3 shows the country of origin as well as overall sample size. Of the 17 articles, the majority were conducted in the USA (n=10, 59%) followed by India (n=3, 18%). One article was found to be published from Norway, one from Canada, one from Jamaica and one with students from Sweden and the Netherlands (n=4, 23%). The pooled medical student sample size was 1,307

plus 112 psychology and 47 nursing students. The psychology and nursing students were compared and contrasted with medical student groups in two separate studies [36, 37].

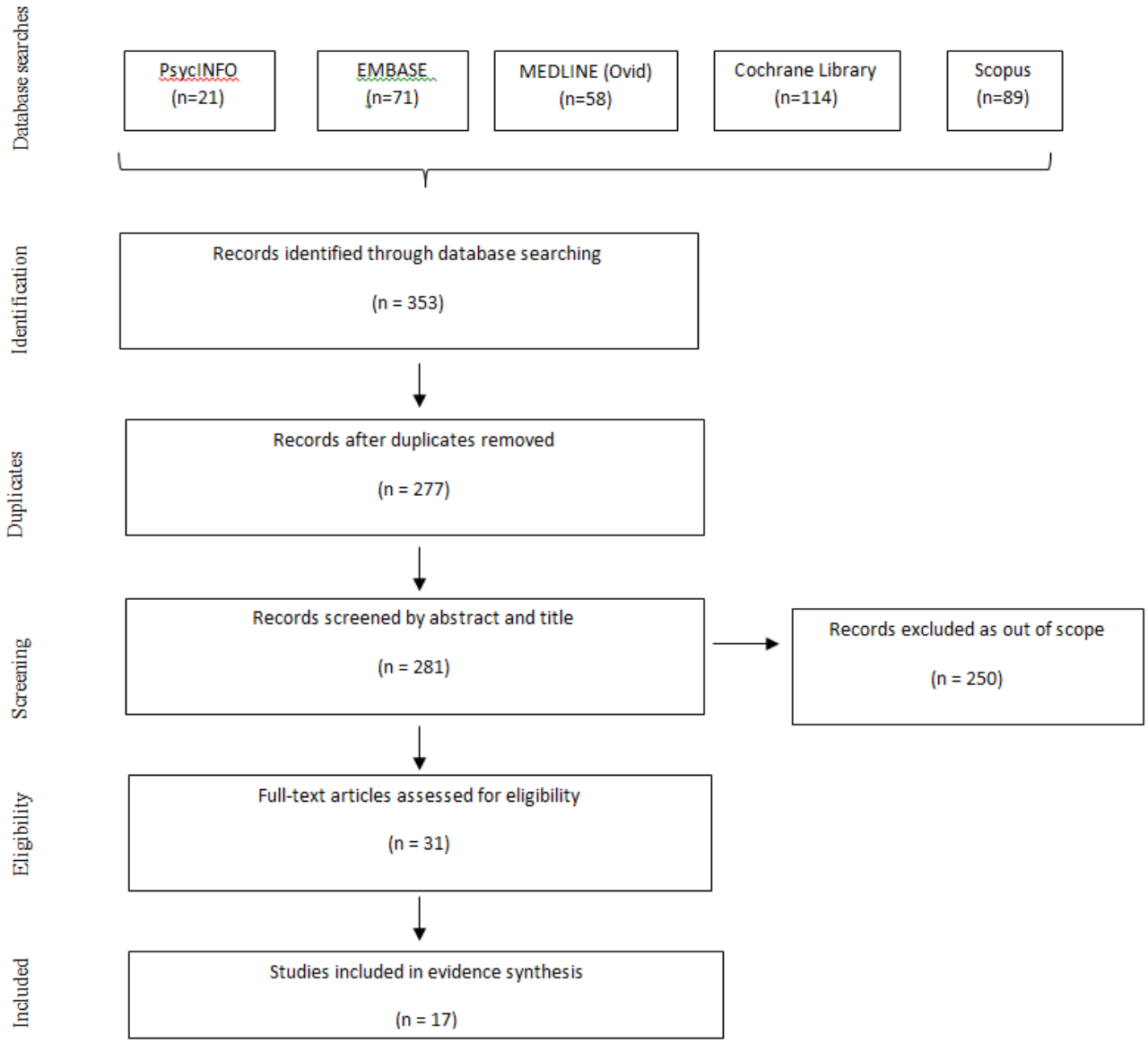

Figure 1 Search methodology flow diagram (exclusion and inclusion criteria are stated in section 2.4).

Table 3 Characteristics of the 17 studies (in alphabetical order) utilising both mindfulness meditation and exercise strategies.

#	Author	Methods				Research design	Key findings	Conclusion	Level of evidence
		Participants	Procedure	Instrument/s	Analysis of data				
1	Biswas (2010)	42 1st year medical students, Jawaharlal Nehru Medical College, India.	1 hour sessions a day over 4 weeks. Random selection in 3 yoga groups: (1) (n=12) Pranayama only; (2) Asanas only (n=13); and (3) Rajyoga meditation only (n=17).	Visual reaction time (VRT) and auditory reaction time (ART).	Paired samples t-test	Randomised cross-sectional survey	(1) Pranayam only: ART & VRT decreased; (2) Asanas only: VRT decreased; and (3) Rajyoga meditation only: VRT decreased.	Significant decrease in VRT shows that regular practice of yoga increases attention and concentration.	Ib
2	Bond, Mason, Lemaster, Shaw, Mullin, Holick & Saper (2013)	27 1st and 2nd year medical students, Boston University of Medicine, USA.	Taught breathing and meditation exercises and participated in hour-long yoga sessions. Also 30 mins lecture on neuroscience of yoga, relaxation, and breathing. Pre- and post-measures.	Empathy (Jefferson Scale of Physician Empathy), Perceived stress (Cohen's Perceived Stress Scale), Self-regulation (Self-Regulation	Change scores and Pair-wise t-test	Prospective matched cohort study.	Self-regulation and self-compassion significantly increased. Trend increases noted for empathy and perceived stress.	Increased self-regulation and self-compassion scores indicated benefits for students and potential for positive follow on effect for their future patients.	IIb

				Questionnaire), and Self-compassion (Self-Compassion Scale)					
3	Bughi, Sumcad, & Bughi (2006)	104 3rd & 4th year medical students, two Southern California Universities, USA.	A lecture on stress at end of rotation on review of the endocrinology of stress response. Change over a one month period was assessed. The behavioural therapy to manage stress utilised: (1) deep diaphragmatic breathing (yoga breathing); (2) self-control; and (3) walking meditation. Apply these methods into daily lives - 3 to 4 daily.	The General Well Being Scale	Repeated measures ANOVA	Prospective matched cohort study	Significant pre- and post-decrease in anxiety and increase in positive well-being. However, no changes were noted for depression, self-control, vitality and general health.	Short term interventions can have positive effects on students with respect to less anxiety and a greater sense of positive well-being.	IIb

4	Campos, Archibald, Burns, Koszycki, MacLean, Duschesne, & Gonsalves (2017)*	14 medical students during 3rd year family medicine rotation, the University of Ottawa, Canada.	A 3 hour mandatory workshop (mindfulness in clinical practice) was developed and included informal mindfulness practices (breathing, walking, eating, and listening awareness) as well as formal practice (sitting or lying).	Qualitative	Thematic content analysis	Interview	6 participants preferred informal mindfulness practices over formal practice due to time constraints. Participants reported reduced stress as main benefit.	The findings in this conference paper indicated generalised feeling of being less stressed after exposure to a system of mindfulness practices.	IV
5	De Vibe, Solhaug, Tyssen, Friborg, Rosenvinge, Sørlie, & Bjørndal, (2013)	112 psychology and 176 medical students, University of Oslo, Norway.	8 weekly session of 2.5 hours each plus a 7-hour session: (1) physical and mental exercises to increase participant mindfulness of experiences in the present moment, (2)	General Health Questionnaire, Maslach Burnout Inventory, Five Facet Mindfulness Questionnaire, students compliance, and attendance.	Multivariate statistics, e.g., MANCOVA & multilevel mixed linear regression	Randomised cross-sectional survey	Improvements were noted for women on mental distress, subjective well-being and student stress, but not for men. Women also showed a reduction in burnout. Improvements in mindfulness were indicated for the intervention group.	The results concur with other findings and suggest improved mind states as a result of mindfulness based intervention.	Ib

			didactic teaching on mindfulness, stress, stress management and mindful communication, and (3) a group process to facilitate reflections on practising mindfulness.				Improvements on mental distress and wellbeing were consistent across medicine and psychology groups.		
6	Dutton, Prashar, Romero, Talley, Amri, Haramati, & Harazduk (2012)*	59 1st year medical students, Georgetown University School of Medicine, USA.	Mind-Body Skills (MBMS) program involving teaching of self – awareness, relaxation, meditation, guided imagery, biofeedback, physical exercise, art music and movement.	Medical school faculty mind-body skills group questionnaire measures of depression and anxiety, physical health symptoms and mindfulness.	Repeated measures ANOVA	Prospective matched cohort study	Significant improvements depression, anxiety, and mindfulness skills. mindfulness skills predicted depression and anxiety.	The MBMS course can be used as an intervention for medical professionals to deal with stressful study and work environments.	IIb
7	Gordon (2014)	15 medical schools, USA.	Mind-Body Medicine (MBM) methods used in 15 medical schools	Qualitative	Descriptive analysis	Qualitative survey	Georgetown and University of Washington had well-established groups.	Mind-body skills including several forms of active meditation and	IV

			were appraised. Faculty were asked which MBM methods were being used, e.g., biofeedback, guided imagery, autogenics, meditation, genograms, art, journaling, and movement.				Reported benefits include: (1) safe place for sharing personal information, (2) reduction in problems related to depression, anxiety, insomnia and headache, (3) less competitive and more compassionate, (4) recommitment to medicine, 7and (5) increased self-care.	"mindful walking" enhance medical students' experiences and their mental health.	
8	Gupta, Jain, & Kumar (2016)	60 young obese (BMI>30) medical students, Saraswathi Institute of Medical Sciences, Hapur, India.	The students had their pulmonary function parameters recorded before and after 4 weeks practice of Raja Yoga.	Forced vital capacity (FVC), expiratory reserve volume (ERV), peak expiratory flow rate (PEFR) and maximum voluntary ventilation (MVV) were recorded using a computerized	Student's paired t-test	Prospective matched cohort study	After 4 weeks practice of Raja Yoga, significant increases were found in FVC, ERV and more significant increase in PEFR and MVV	Practicing Raja Yoga significantly improves the pulmonary functions in obese medical students.	IIb

				spirometer.					
9	Harwani, Motz., Graves, Amri, Harazduk, & Haramati (2013)	118 1st year medical students of Georgetown University School of Medicine, USA.	11-week course in mind-body medicine skills (e.g. mindfulness meditation, autogenic training, guided imagery, movement and writing exercises).	Perceived Stress Survey (PSS), Positive and Negative Affect Schedule PANAS, Interpersonal Reactivity Index (IRI), and Freiburg Mindfulness Inventory (FMI).	Pre- and post-univariate analysis	Prospective matched cohort study	A significant decline in PSS, negative affect (PANAS), and response to distress in others (IRI). FMI, positive affect (PANAS) and empathic concern (IRI) increased.	The 11-week mind-body program improved aspects of stress, affect regulation and coping with distress.	IIb
10	Kondam, Nagadeepa, Jagan, Jyothinath, Suresh, & Chandrasekhar (2016)	80 undergraduate medical students, MNR Medical College and Hospital, India.	Random assignment to 4 groups (1) control group with no yoga; (2) only pranayama or breathing exercise; (3) only suryanamaskar or yoga postures; or (4) both pranayama and suryanamaskar.	Addenbrooke's Cognitive Examination-Revised (ACE-R): measures attention and orientation, memory, fluency, language and visuo-spatial skills.	One-way ANOVA followed by paired t-tests (Dennett's test)	Prospective matched cohort study	Memory and visuospatial skills increased in groups 3 & 4. Greater attention, orientation, fluency and language in group 3 cf with groups 2 & 4.	Yoga intervention improved all measures of cognition (ACE-R). The combined groups showed greater improvement (some were trends only) than groups 2 & 3.	Ib

11	Motz, Graves, Gross, Saunders, Amri, Harazduk, & Haramati (2012)*	72 1st year medical students, Georgetown University School of Medicine, USA.	The Mind Body Medicine Skills (MBS) program - mindfulness meditation, autogenic training, guided imageries, movement, writing exercises, and group sharing.	Perceived Stress Scale (PSS), Freiberg Mindfulness Inventory (FMI), Positive and Negative Affect Scale (PANAS), Trait Meta Mood Scale, and the Interpersonal Reactivity Index.	Paired comparison and use of effect sizes	Prospective matched cohort study	Decline is perceived stress, increase in mindfulness, empathetic concern, and positive affect. Female students only decreased in negative affect and personal distress, and increased in attention to feelings and perspective taking.	Participation in a one-semester MBS course is effective in enhancing mindfulness and empathic concern, while reducing students' perceived stress.	IIb
12	Parshad, Richards, & Asnani (2011)	64 medical students, University of West Indies, Jamaica.	Six (6 weeks) yoga exercises: (1) Lecture and baseline measures; (2) Posture instructions; (3) Lotus posture instruction; (4) Breathings exercises; and (5) Dhyana or attention practice; and (6) Dhyana	Systolic and diastolic blood pressure, mean arterial blood pressure, heart rate, inter-beat interval, left ventricular ejection time, stroke volume, cardia output, total peripheral	Used t-tests but no mention of these being paired	Prospective non-matched cohort study	Increases in heart rate, stroke volume, cardiac output, total arterial compliance. Decreases in total peripheral resistance, inter beat interval, ascending arterial characteristic impedance. No differences observed in other measures, i.e. blood pressure.	Practice of yoga over 6 weeks has physiological benefits.	IIb

			and cardiovascular tests.	resistance, ascending aorta characteristic impedance, and total arterial compliance.					
13	Prasad, Varrey, & Sisti (2016)*	27 1st to 3rd year medical students, Cornell Medical College, USA.	Two 1 hour sessions per week of yoga & meditation for 6 weeks.	Perceived Stress Scale (PSS), and Self-Assessment Survey (measures happiness, peace, focus, endurance, positivity, personal satisfaction, self-confidence, patience and fatigue).	Paired t-tests and Wilcoxon signed-rank test	Prospective matched cohort study	Reductions in perceived stress. Improvement in feelings of peace, focus, endurance & fatigue. No significant changes in happiness, positivity, personal satisfaction, self-confidence or patience	Six weeks of yoga & meditation can have benefits in managing stress and promoting personal wellbeing.	IIb
14	Rosenzweig, Reibel, Greeson, Brainard, &	302 2nd year medical students, Jefferson	Mindfulness-based stress reduction (MBSR) - body scan, breath	Profile of Mood States (POMS) – six affective states	Repeated measure multivariate analysis of	Prospective matched cohort study	*MBSR group*: decreases in total mood disturbance, tension-anxiety, and confusion-	Efficacy of MBSR in prompting mood states is established.	IIa

	Hojat (2003)	Medical College, USA.	awareness, Hatha Yoga, eating meditation, walking meditation, and guided imagery. 140 in the MBSR group and 162 in a control group.	– (1) tension-anxiety, (2) depression dejection, (3) anger-hostility, (4) vigour-activity, (5) fatigue-inertia, and (6) confusion-bewilderment.	variance		bewilderment with increase in vigour-activity. *Control group*: elevated scores in tension and anxiety, fatigue inertia and total mood disturbance with decrease in vigour-activity.		
15	Shapiro, Schwartz, & Bonner, (1998)	35 premedical and 38 medical students, University of Arizona, USA.	The intervention group received an 8-week stress reduction and relaxation course based on the work of Kabat-Zinn: (1) sitting meditation, (2) body scan, and (3) hatha yoga.	Empathy Construct Rating Scale, Hopkins Symptoms Checklist, Depression scale, The State-Trait Anxiety Inventory, and Index of Core Spiritual Experiences.	A repeated measures MANCOVA and structural equation modelling	Randomised cross-sectional survey	The intervention had a positive effect on reducing self-reports of depression, and state and trait anxiety. It increased levels of empathy and spiritual experience. Compliance played an important part in outcome. A mediation effect was noted for stress and anxiety which led to greater compassion and empathy.	Efficacy of the stress reduction technique involving mindfulness, hatha yoga and other interventions was established.	Ib

16	Van Vliet, Jong & Jong (2017)	74 2nd year medical, Netherlands and 47 1st year nursing students, Sweden.	The Mind- body medicine course: breathing, meditation, guided imagery, biofeedback, art, yoga and tai chi, music, movement and writing.	Perceived Stress Scale (PSS), Dutch Groningen Reflection Ability Scale (GRAS), and Interpersonal Reactivity Index (IRI).	Comparative analysis: chi-square, t-test and ANOVA	Prospective, nonrandomized, controlled trial	Medical students: increase in empathic concern and fantasy with decrease in personal distress compared to controls. Nursing students: Decrease in perceived stress and decreased personal distress compared to controls.	Demonstration of long-term beneficial effects of the MBM course on perceived stress, distress and interpersonal reactivity skills.	IIa
17	Wolf, Randall, & Faucett (1990)	Available to all medical students, Louisiana State University, USA.	A full day of orientation: choice of aerobics, relaxation/ meditation, support groups, time management, and/or nutrition.	Lifestyle, nutrition, and wellness assessment	Descriptive analysis of choices within the programme	Narrative and descriptive analysis	Participation was voluntary. Aerobics and relaxation/meditation were the best attended. Improvement was found in 11 wellness dimensions.	Composite lifestyle and nutrition course proved to be somewhat effective.	IV

Note: (1)*denotes conference abstract or poster only; (2) ethnicity details provided if available.

3.3 Categories Summarising the Literature Review

The overarching key categories that optimally condense the results of our review can be summarised as follows: (1) quality of evidence and research methods; (2) types of interventions; (3) measurement protocols; and (4) benefits of integrating mindfulness and physical exercises. It was noted that five of these studies were published as conference abstracts or posters with four categorised as *IIb* [38-41] and one as *IV* [42].

Quality of evidence and research methods. First, the Cochrane risk of bias criteria (Table 4a) were applied to the reviewed randomised or nonrandomised control studies. According to the level of evidence criteria, four articles [4, 36, 43, 44] used category *Ib* evidence incorporating a randomised control trial. Two studies [4, 36] were rated low risk in terms of randomisation but some areas of the research design were categorised as unclear. The two remaining studies [43, 44] showed that although they mentioned using a randomisation process, there were many aspects of the design that were rated as high risk or unclear.

The latter two studies [43, 44] applied a paired t-test approach to analyse the effect of the intervention excluding the use of co-factors. In contrast, the former two studies [4, 36] used more sophisticated analyses incorporating several multivariate techniques, such as, the use of multivariate analysis of variance (MANOVA), regression and structural equation modelling.

Two further studies [37, 45] provided evidence using a controlled feature but without randomisation (*IIa*). These studies were essentially prospective, nonrandomized, cohort-controlled studies and attempted to simulate comparisons between those choosing the intervention (mindfulness and physical exercises) and those choosing a similar option (the control). However, much of the design was categorised as high risk.

Second, the Newcastle-Ottawa Scale (Table 4b) was used to assess the quality of reviewed nonrandomised cohort studies. This was the most common research method and they were assigned with a level of evidence category *IIb*. Eight studies [38-42, 46-48] used this method and analysed their data using a repeated-measures approach, such as a paired t-test or repeated-measures analysis of variance (ANOVA). Nonetheless, all these studies showed good levels of selection with reasonable outcome measures, but poor levels of comparability [32]. The study that appeared to have the greatest quality of evidence within this category was the Bond et al study [46], given they reported a good level of detail in their paper including all expected outcomes. In addition, the principal investigator, in the Bond et al study, assigned each student a unique confidential study identification number, suggesting that all researchers other than the principal investigator were blinded to the identity of each survey respondent.

Third, the CASP Checklist was used to assess the quality of reviewed qualitative studies (Table 4c). These remaining three articles [42, 49, 50] used qualitative or descriptive evidence and were assigned a category *IV* level of evidence. In one study [42] interviews were conducted with medical students to investigate their experiences with mindfulness and physical exercise programmes. In the next study [49], medical schools in the USA were surveyed to establish which types of mind-body strategies were being used across 15 Universities. In the final study [50], students were asked about the experiences when involved in a composite lifestyle and nutrition course.

Table 4a Applying the Cochrane Risk of bias criteria by levels of evidence for reviewed randomised or nonrandomised control studies.

Level of evidence	Article	Randomization	Allocation concealment	Blinding	Attrition bias	Reporting bias	Other bias
Ib: Evidence from at least one randomised controlled trial	Biswas (2010)	Unclear	Unclear	High risk	High risk	Unclear	Unclear
	De Vibe et al (2013)	Low risk	Low risk	High risk	Unclear	Low risk	Contamination bias
	Kondam et al (2016)	Unclear	Unclear	High risk	Unclear	Unclear	Unclear
	Shapiro et al (1998)	Low risk	Unclear	Low risk	Low risk	Unclear	Unclear
IIa: evidence from at least one controlled study without randomisation	Rosenzweig et al (2003)	High risk	High risk	High risk	Unclear	Unclear	Unclear
	Van Vliet et al (2017)	High risk	High risk	High risk	High risk	Low risk	Unclear

Table 4b Applying the Newcastle-Ottawa Scale for assessing the quality of reviewed nonrandomised cohort studies.

Level of evidence	Article	Selection	Comparability	Outcome
IIb: Evidence from at least one type of quasi-experimental study, or prospective matched cohort study	Bond et al (2013)	***		***
	Bughi et al (2006)	***	*	**
	Dutton et al (2012)	***		**
	Gupta et al (2016)	***		**
	Harwani et al (2013)	***		**
	Motz et al (2012)	***	*	**
	Parshad et al (2011)	***		**
	Prasad et al (2016)	***		**

Table 4c Applying the CASP checklist for assessing the quality of reviewed qualitative studies.

Level of evidence	Article	Are the results of the study valid?	What are the results?	Will the results help locally?
IV: evidence from expert committee reports or opinions and⁄or clinical experience of respected authorities	Campos et al (2017)*	Valid aims, design, methodology, and data collection. Unclear details on recruitment and researcher bias.	Results and data analysis clearly stated, but ethical considerations unclear.	Implications of results unclear.
	Gordon (2014)	Valid approach to collecting descriptive data for courses in operation in US universities.	Qualitative results and data analysis clearly stated from audit.	Results are valuable for designing future courses and curriculum development.
	Wolf et al (1990)	Valid approach for data collection for describing the health promotion programme.	Descriptive data are analysed and summarised from audit.	Results are useful for showing the potential for future health promotion programmes.

Types of interventions. The first identified intervention that integrated mindfulness and physical exercises involved aspects of yoga practice [37, 40, 43-48, 51]. Some of the interventions used an exclusive yoga approach [40, 43, 44, 51], whilst other research incorporated yoga as part of a collection of activities aimed to promote wellbeing [37, 45-47]. In the studies that researched the yoga sub-components, such as Asanas and Pranayama, the focus was on determining which aspect of the yoga practice had the greater benefit.

The second intervention involved a systems approach such as the MBSR system [52] with an embedded element of physical exercise such as mindful walking [38, 39, 41, 42, 50]. In one further article [49], the author surveyed 15 medical schools with the view to determine the prevalence and efficacy of mind-body programmes for medical students.

Measurement protocols. Different reported measurements were incorporated in the studies reviewed. Most of the studies used standardised self-report questionnaire measures to assess the efficacy of the intervention [4, 36, 37, 39-41, 44-47]. These measures consisted of:

1. Stress, e.g., the Perceived Stress Scale [37, 39, 41, 46].
2. Empathy and self-compassion, e.g., the Jefferson Scale of Physician Empathy, Empathy Construct Rating Scale, and Self Compassion Scale [4, 46].
3. Wellbeing, e.g., The General Well Being Scale [47], the General Health Questionnaire [36], and the Self-Assessment Survey [40].
4. Affect regulation, reflection, and interpersonal reactivity, e.g., the Positive Affect and Negative Affect Scale [37, 39, 41], the Trait Meta-Mood Scale [39], The Profile of Mood States [45], Groningen Reflection Ability Scale [37], and the Interpersonal Reactivity Index[41].
5. Cognition, e.g., Addenbrooke's Cognitive Examination-revised [41].
6. Mindfulness, e.g., Freiburg Mindfulness Inventory [41].

Most of the self-report measurement protocols included more than one self-report measure built into the study design [4, 36, 37, 39, 41, 46, 53].

Three studies incorporated the use of physiological measures [43, 48, 51]. For example, measures included visual and auditory reaction times [43], forced vital capacity and expiratory reserve volume [48], and both systolic and diastolic blood pressure [51].

Two studies used measures that do not appear to be validated, e.g., measures of depression, anxiety, physical health and mindfulness [38] and a generalised lifestyle questionnaire [50]. The remaining data collection approaches used consisted of qualitative methods such as open ended surveys or interviews [42, 49].

Benefits of integrating mindfulness and physical exercises. The key findings (Table 3) indicate the main benefits of the intervention strategies. Several studies [43, 48, 51] showed physiological gains in the intervention groups, e.g., Parshad et al [51] provided convincing evidence of increases in heart rate, stroke volume, cardiac output, total arterial compliance with decreases in total peripheral resistance, inter-beat interval, and ascending arterial characteristic impedance in the intervention group. The self-reported gains were widespread and included decreases in stress [38, 39, 42, 53], improved levels of self-compassion, empathy, self-regulation [4, 46], wellbeing, affect-regulation, and vigour [4, 37-39, 41, 45, 47, 49, 50, 53], and finally enhanced mindfulness [4, 36, 39]. Nonetheless, it needs to be emphasised that in the studies that yielded the highest level of evidence [4, 36] it was clear that the combination of mindfulness and physical exercise enhanced mental health, and reduced stress levels amongst students, and the benefits may assist with interpersonal development, such greater empathetic levels and improved interpersonal responsivity.

4. Discussion

Utilising a systematic review approach, this study evaluated and documented the literature on the use of mindfulness and physical exercise regimens and the impact these interventions have on the wellbeing of medical students. This study makes several contributions to the existing literature, including a novel approach to evaluating the evidence underscoring the benefits of mindfulness based interventions (MBIs) in conjunction with physical exercise regimens. Intuitively it makes sense that a mindfulness approach in conjunction with an exercise system will be more beneficial than only mindfulness or only physical exercise. We wanted to explore the evidence behind this assumption. Second, this systematic review appears to be the first review of the literature pertaining to the benefits of MBIs and physical regimens for medical students. Even though there is a vast literature on medical student burnout, stress and risk of psychopathology [10, 54], and some review studies on MBIs [55], we found no such study that reviewed the purported benefits of combining MBIs and physical exercise. We do note that many MBSR systems commonly use a hatha yoga element as an adjunct system [4, 6, 45]; however our intent was to go further afield and consider all aspects of physical exercise given the wide array of mind-body systems that could be employed [3, 20]. We now discuss our findings and consider the strengths of the claims made and the evidence provided in relation to the wider literature.

4.1 Quality of Evidence and Research Methods

The systematic review showed a wide range of research methods being applied to this topic. In addition, the evidence hierarchy (Table 4a – 4c) was spread over several groupings.

Studies analysed using the Cochrane risk of bias criteria and levels of evidence: Randomised or nonrandomised control studies. The most robust randomised control research designs were found in four cited articles (Table 4a) [36, 43, 44, 56], and these were categorised as level *Ib*. In reference to the two studies with relatively lower risk of bias [4, 36], we noted that mindfulness and physical exercise as a combined system has a positive impact on enhancing mental health, and reducing stress levels amongst students [4, 36]. However, a gender moderation effect was identified [36], and additionally the impact of mindfulness was found to extend beyond purely personal wellbeing issues and include improved interpersonal responsivity [4].

However, the analyses used in the two remaining studies [43, 44] appeared to be unidimensional. In the Biswas study [43], a paired t-test was used and in the Kondam et al study [44] a univariate ANOVA and paired t-test approach were used. In both studies a multivariate analysis would likely be more appropriate given that both studies used one independent variable (group) and several dependent variables [57]. Moreover, checking for several confounding variables in these two studies would likely have been prudent, such as age, gender, previous experience, and prior levels of fitness. This multivariate approach would have captured more explanatory variance. In reference to these two articles, caution needs to be applied to their purported benefits of mindfulness training, which related to increased attention, concentration and visual reaction time [43], and other facets of cognition (e.g., memory and visuospatial skills) [44]. Nevertheless, these studies show that different yoga systems or aspects of yoga systems will likely yield different benefits.

In the two studies [37, 45], categorised as level *IIa* (Table 4a), both used a nonrandomised control strategy, which allowed for a quasi-experimental comparative approach. For example, Van Vliet et al [37] attempted to control for confounding variables. In the Rosenzweig et al study [45] most of the comparisons consisted of univariate approaches to analysis, which limited the validity of findings and interpretations to only pair-wise comparisons. Nonetheless, these two studies were able to generate a list of benefits associated with the intervention by using contemporaneous comparison groups [28]. The cited personal benefits attributed to the mindfulness and physical exercise regimens were decreases in total mood disturbance, personal distress, the perception of stress, tension-anxiety, and confusion-bewilderment with an increase in vigour-activity. In addition, the cited interpersonal benefits included an increase in empathic concern. These benefits resonate with those specified by the low risk randomised studies cited above [4, 36].

Studies analysed using the Newcastle-Ottawa Scale checklist: Nonrandomised cohort studies. The eight articles [38-42, 46-48] that used a level *IIb* strategy for determining the effect of the intervention can be criticised according to voluntary selection bias, lack of randomisation and offering no comparison group. However, the selection of the participants appeared to show representation of the wider community and there were demonstrable interventions yielding verifiable outcome measures [32]. In addition to the problem of comparability, a further limitation associated with these studies is that exposure to the intervention occurred by choice rather than by chance [32, 34]. Therefore, reasons why the students initially engaged in the intervention likely had an impact on outcome [34]. Finally when using multiple measures only Dutton et al[38] employed a correction factor, suggesting that many of these studies ran the risk of type 1 error

[58], or generating a significant effect when there is none. The quality issues attributed to these studies suggests that the results should be treated with caution.

Studies analysed using the CASP: Qualitative studies. The final three reviewed articles (Table 4c) [42, 49, 50], used qualitative or descriptive methods for obtaining information about the effectiveness of the intervention or in one case the prevalence of interventions in higher education in the USA [49]. The arguments concerning the strengths and weaknesses of qualitative research are well established [59], suggesting that the research findings provided in the evaluative article [42] are likely to be useful in terms of understanding and raising salient issues associated with the intervention but can't necessarily be considered to be representative of the wider population. When we applied the CASP checklist [33], the results (Table 4c) showed that all studies had aspects of acceptable validity and each study used a different research design and method of analysis. The two studies using either a case study approach [50] or a descriptive audit approach [49] generated data that will likely be of benefit to their local communities, whilst the benefit of the findings of one study remained unclear [42].

4.2 Types of Interventions

The first intervention system highlighted in the review was the utilisation of the traditional yoga approach, which has inherent elements of both mindfulness and physical exercises within a holistic system [20]. The second system employed a more integrated and newly formed approach utilising the integration of mind and body, such as incorporating the full extent of the MBSR practice [60]. These programmatic practices focus on progressively developing mindfulness. A complete MBSR programme will often include "different forms of mindfulness meditation practice, mindful awareness during yoga postures, and mindfulness during stressful situations and social interactions" [60].

An unexpected finding was the lack of mindfulness and physical exercise regimens used with medical students that included other well-established therapeutic interventions such as Qigong, Tai Chi, Feldenkrais and Alexander technique [20]. For example, Tai Chi has been relatively well researched in the general literature heralding its benefits for students in higher education [21], although not specifically with medical students (a group purported to be at high risk of ill-health). In addition, the Webster et al [21] systematic review of Tai Chi practices in higher education reviewed articles not only in English but also in Chinese, and one of the findings was the greater number of articles in Chinese. Hence, a further search involving databases showing articles written in non-English languages may have created a greater research yield and may have included studies of Tai Chi and other mindfulness and physical exercise programmes being applied to medical students.

4.3 Measurement Protocols

Two measurement protocols were identified in the literature reviewed, namely physiological measures and self-reported measures. For example, some of the physiological measures being employed included forced vital capacity, expiratory reserve volume, peak expiratory flow rate, and maximum voluntary ventilation [48]. In addition, some of the self-reported measures included the Jefferson Scale of Physician Empathy, Cohen's Perceived Stress Scale, the Self-Compassion Scale, and the General Well Being Scale [46, 47].

None of the reviewed studies integrated both physiological and self-reported data, which would have been useful assuming that the two tend to be complementary. Given the studies in this review reported on interventions that were aimed at heightening mindfulness [36, 38], including multiple data sources, as used in other studies [61], would have improved triangulation and the credibility of the results.

One common problem with using self-reported measures to evaluate change is associated with response shift [62, 63]. For example if the measurement standard changes over the pre- and post-period then the ratings could in effect reflect a shift in the standard and/or actual changes, the shift therefore, becomes a form of bias or error masking the true intervention effect. To reduce the confounding effect of response shift, Howard [62] proposes that studies integrate self-report, objective, and behavioural measures when evaluating a treatment intervention. Consistent with our statement above, combining different methods of inquiry inevitably triangulates the different aspects of reality associated with understanding a problem by creating a more complete picture of the complexities associated with measuring behavioural changes [64].

A further issue related to measurement was the use of psychometrically validated questionnaires versus untested questionnaires. Using untested questionnaires has issues associated with reliability and validity which escalates the risk of bias and prevents meaningful interferences being made.[65] However, most of the studies in this review utilised psychometrically tested self-report questionnaires [36, 37, 39, 41, 44, 45, 47, 53, 56] or well-known physiological measures [43, 48, 51]. With psychometrically validated instruments, inferences based on the observed scores can be more rigorously defended [65].

4.4 Benefits of Integrating Mindfulness and Physical Exercises

The research investigating the efficacy of mindfulness and physical exercise regimens has, in general, reported positive results. For example, Grossman et al[60] in their meta-analysis found that MBSR programmes are useful in ameliorating a wide range of deleterious and chronic medical conditions, and can assist with distress and disability. Nonetheless, some negative effects have been shown to be linked to mindfulness exercise programmes, such as decreased job satisfaction, and increased stress and anxiety [66].

In the current systematic review (Tables 3), the benefits appear to be well reported, although most of the studies have likely high risks of bias especially with some of the qualitative studies being exploratory or descriptive. Nevertheless, the studies that have relatively lower risk of bias [4, 36, 37, 45], given they use either external or internal control systems, appear to consistently indicate personal benefits (e.g., reduced stress and mental ill-health and an increase is vigour and vitality). In addition, some of the interpersonal benefits (e.g., greater levels of empathy and responsivity) are also reported in these four studies.

Even though caution should be applied, other reported positive effects included increases in measures of attention, concentration, self-compassion, self-regulation, anxiety, wellbeing, mindfulness, self-care, affect regulation, and physiology.

It is also important to note that some studies did not show any significant improvements related to participating in a mindfulness and physical exercise regimen. Some of these null effects were in reference to reduced depression, and improved levels of self-control, vitality, general health, happiness, positivity, personal satisfaction, self-confidence and patience.

5. Conclusions

This systematic review demonstrates that when mindfulness and physical exercise regimens are combined there are likely to be positive outcomes which will enhance the wellbeing of medical students. A major challenge for further research in this area is to develop a unified operational definition of mindfulness [66, 67]. For example, Van Dam et al [67], reported that some researchers linked mindfulness with aspects of yogic meditation whilst others aligned their definitions with a more westernised definitions related to mindfulness-based stress reduction programmes [52]. However, it is also evident the research is in its infancy.

A further challenge, identified in this review, is related to the understanding and disentangling of the specific elements and effects of integrated interventions when being applied to enhancing wellbeing in medical students. Resolving this challenge will ultimately result in more rigorous and defendable arguments related to the efficacy of mindfulness and physical exercise regimens with this student cohort.

6. Recommendations for Further Research

Future research needs to consider:

1. More robust research methods and measurement protocols to improve credibility of findings.
2. More refined statistical methods so that analyses can involve larger samples and more multivariate techniques to improve our understanding of the variance explained by the domains of interest.
3. More elaborate and robust research designs to tease out the different elements of the intervention so that clearer cause and effect relationships can be determined.
4. Further mixed-methods research so that response bias facets associated with self-report measures can be minimised.
5. Different interventions using mind-body approaches to evaluate their effectiveness, such as the impact of Qigong, Tai Chi, and Feldenkrais.

Author Contributions

All authors contributed to the conception or design of the work analysis, and interpretation of data for the work. All authors contributed to the drafting of the work and revising it critically for important intellectual content. All authors contributed to the final approval of the version to be published. All authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Three authors (TJP, MH, JH) were involved in the initial acquisition of the papers for review.

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Competing Interests

The authors have declared that no competing interests exist.

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