Received: 8 March 2023 | Accepted: 5 July 2023

DOI: 10.1111/aphw.12472

REVIEW ARTICLE

The effect of mindfulness-based interventions on reducing stress in future health professionals: A systematic review and meta-analysis of randomized controlled trials

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Abstract

Students in health professions often face high levels of stress due to demanding academic schedules, heavy workloads, disrupted work–life balance, and sleep deprivation. Addressing stress during their education can prevent negative consequences for their mental health and the well-being of their future patients. Previous reviews on the effectiveness of mindfulness-based interventions (MBIs) focused on working health professionals or included a wide range of intervention types and durations. This study aims to investigate the effect of 6- to 12-week MBIs with 1- to 2-h weekly sessions on stress in future health professionals. We conducted a systematic review and meta-analysis of randomized controlled trials published in English by searching Embase, Medline, Web of Science, Cochrane Central Register of Controlled Trials, and PsycINFO. We used post-intervention stress levels and standard deviations to assess the ability of MBIs to reduce stress, summarized by the standardized mean difference (SMD). This

Chia-Ping Lu and Stijntje W. Dijk shared first authorship.

Funding information
This study was conducted as part of the DEcrease STress through RESilience training for Students (DESTRESS) Study. The DESTRESS study is funded by the Erasmus University Medical Center Rotterdam from the budget for quality improvement ("Studievoorschotmiddelen") as an intervention to promote student well-being. Project token: ProjectSVM 108332. Erasmus MC, Department of Education, PO Box 2040, 3000 CA Rotterdam, The Netherlands. This funding source had no role in the design of this study and will not have any role in its execution, analyses, interpretation of the data, or decision to submit results.

review is reported according to the PRISMA checklist (2020). We identified 2932 studies, of which 11 were included in the systematic review and 10 had sufficient data for inclusion in the meta-analysis. The overall effect of MBIs on reducing stress was a SMD of 0.60 (95% CI [0.27, 0.94]). Our study provides evidence that MBIs have a moderate reducing effect on stress in students in health professions; however, given the high risk of bias, these findings should be interpreted with caution, and further high-quality studies are needed.

KEYWORDS
health occupations students, medical education, mindfulness, occupational stress, psychological resilience, systematic review and meta-analysis

BACKGROUND

The rising levels of stress and burnout among students in health professions demand the urgent attention of educational institutions, health professionals, and society at large. Recent reports estimate that between 35% and 65% of nurses, physicians, medical students, pharmacy students, and residents show high levels of stress and substantial signs of burnout (National Academies of Sciences and Medicine, 2019; Ribeiro et al., 2018). Multiple studies have demonstrated that students in health professions often experience higher levels of stress compared to those in other disciplines (Alkatheri et al., 2020; Amanya et al., 2018; Dyrbye et al., 2018; Henning et al., 1998). Factors such as intense academic schedules, high performance expectations, sleep deprivation, peer competition, and a lack of balance between education and personal life can increase the risk of burnout, depression, fatigue, and even suicide (Luberto et al., 2020; Mladen et al., 2019).

In addition, there is evidence that long-term exposure to high stress harms students' career development and academic achievement (Chisholm-Burns et al., 2021; Kötter et al., 2017). This stress can also continue to impact their mental health even after graduation, potentially leading to decreased empathy, lower professional performance, and strained relationships with patients (Beach et al., 2013; Shapiro et al., 1998; van Vliet et al., 2017). Therefore, it is imperative to address stress and burnout among students in health professions at an early stage of their careers.

Stress and burnout can be addressed at both the system level (addressing work- and study-related factors such as competitive environments, excessive workloads, irregular schedules, educational debt) and the individual level (such as the ability to cope with stress and perfectionism) (Frajerman et al., 2019; West et al., 2016, 2018). One effective way to reduce stress and improve mental well-being at the individual level is through mindfulness-based interventions (MBIs). Mindfulness involves becoming aware of one's thoughts and feelings in a non-judgmental way (Nilsson & Kazemi, 2016). This conscious awareness is hypothesized to interrupt the automatic cognitive processes that can lead to adverse psychological outcomes, improving mental well-being. The practice of mindfulness has been shown to decrease stress, anxiety, hostility,

depression, and medical symptoms (Segal et al., n.d.; Goyal et al., 2014; Kabat-Zinn, 1982; Kabat-Zinn et al., 1992). In healthcare professions specifically, MBIs have been shown to increase patient satisfaction and quality of care while reducing costs (Burton et al., 2017).

While there have been several systematic reviews that have examined interventions to reduce stress in students in health professions, these studies have several limitations. Many include non-randomized studies (Aloufi et al., 2021; Alzahem et al., 2014; Daya & Hearn, 2018; Witt et al., 2019) and combine a wide range of interventions such as MBIs, stress management training, psychoeducation, relaxation training, telephone counseling, exercise, peer mentoring, music therapy, hypnosis, audio-guided mindfulness, biofeedback, omega-3 fatty acid supplementation, journaling, and curricular changes (Aloufi et al., 2021; Hathaisaard et al., 2022; Li et al., 2018; Shiralkar et al., 2013; Witt et al., 2019). Additionally, these studies combine interventions lasting from one session or a few hours (Aloufi et al., 2021; Spinelli et al., 2019; Witt et al., 2019) to more than 16 weeks (Aloufi et al., 2021; Witt et al., 2019), and many only examine a specific health profession (Alzahem et al., 2014; Hathaisaard et al., 2022; Li et al., 2018; Shiralkar et al., 2013; Witt et al., 2019) or include both trainees and healthcare or other professionals (Lomas et al., 2018; Spinelli et al., 2019). Some also had set year limits embedded in the search strategy (Aloufi et al., 2021; Daya & Hearn, 2018). The wide range of interventions and varying durations within these studies makes it difficult for educationalists and policy-makers to decide where to direct their attention for further research, and on the implementation of potentially effective programs. Mindfulness-based intervention programs are generally conducted for 8 to 10 weeks and include sessions of up to 2 h per week (Carmody & Baer, 2009) although slightly less intensive and more intensive programs have also been developed. Our systematic review and meta-analysis therefore aim to investigate the effectiveness of Mindfulness-based interventions for students in health professions with a duration lasting between 6 and 12 weeks and offered as 1- to 2-h weekly sessions, studied within randomized controlled trials.

METHODS

This study is reported according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) 27-item checklist (Higgins et al., 2022a; Page et al., 2021).

Causal inference considerations

Our aim is to investigate the effect of being randomized to MBIs on stress levels in students in health professions. To illustrate this relationship, we have provided a graphical representation our assumptions of this relationship in a directed acyclic graph (DAG) in Figure 1 (Hernán & Robins, 2020) that underline our choices in extraction items and discussion.

The arrows in the DAG represent an assumed causal relationship and the direction this effect is in. We assume a direct effect of the MBI (A, exposure) on perceived stress (Y, outcome). By limiting our search to only RCTs, randomization (Z) ensures that we can assume that any effect of baseline characteristics such as participants' age, sex, motivation, perfectionism, or similar other factors (L) that may influence stress at baseline will be equivalent in the MBI and control arms of the study and therefore will not affect the estimated treatment effect. By doing this, we can estimate the true treatment effect of the MBI on stress without having to adjust for these factors in our analysis. However, it is important to consider potential bias that may be

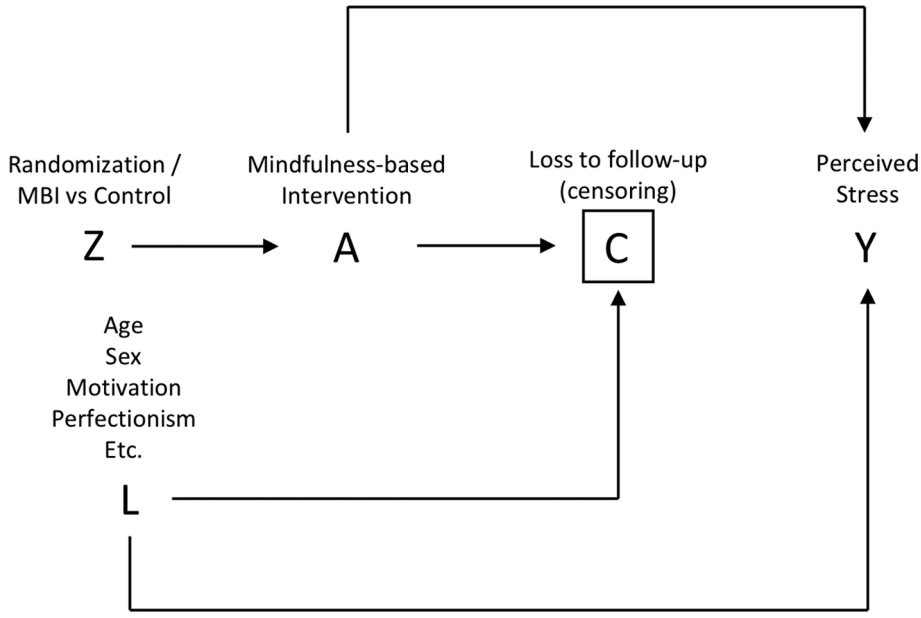

FIGURE 1 Directed acyclic graph depicting the assumed relationship between the investigated intervention (MBI) and the outcome of interest (perceived stress).

introduced if there is non-random loss to follow-up. If investigators analyzed only censored data, loss to follow-up could create differential selection bias. Analysis of censored data is equivalent to conditioning on censoring. Since censoring is a collider in the DAG (Figure 1) conditioning on censoring would open a backdoor path (A-C-L-Y) giving rise to bias in the relationship between MBI (A) and perceived stress (Y). To better understand the possible presence of this bias, it is important to extract data on loss to follow up in included studies.

Inclusion and exclusion criteria

In order to be eligible for inclusion in our review, articles needed to meet the following criteria:

1. P (Population): The study population included students in health professions. Health profession students refer to individuals who are pursuing a degree to provide health care services, including but not limited to degrees in medicine, pharmacy, dentistry, dietetics, nursing, psychology, podiatry, occupational therapy, and physical therapy.
2. I (Interventions): The intervention was a mindfulness-based intervention lasting between 6 and 12 weeks, with sessions lasting between 1 and 2 h per week (excluding time for homework assignments or one-time day-retreats). The duration of MBIs may influence their effectiveness and comparability (Baer et al., 2012). The number of weeks was based on the minimum duration of the official Mindfulness Based Stress Reduction (MBSR), which is described as 6- to 7-week sessions of 2–2.5 h plus a 1-day session. The maximum duration was listed as two times the minimum number of weeks (12) to not miss those studies with

altered durations (for example, due to practical reasons such as curricular restraints) while still including only those studies that we deemed comparable.
3. C (Control): The study included any type of non-mindfulness-based control condition.
4. O (Outcome): The study outcomes included pre- and post-intervention stress levels measured immediately after the intervention using any appropriate tool, along with their corresponding standard deviations. Common measures of stress include but are not limited to the Perceived Stress Score (PSS) (Cohen et al., 1983), Depression Anxiety Stress Scales-21 (DASS-21) (Lovibond & Lovibond, 1995), and the Brief Symptom Inventory (Derogatis, 1975). All outcomes were summarized as standardized mean differences (SMD), which is the primary outcome in our meta-analysis.
5. S (Study design): The study was a randomized controlled trial published in English.

Search strategy

The literature search was conducted and optimized with the help of an information specialist from the Erasmus MC Medical Library. Citations were identified from five databases:

1. Embase (1971 to March 28, 2022),
2. Medline (1946 to March 28, 2022),
3. Web of Science Core Collection (1975 to March 28, 2022),
4. Cochrane Central Register of Controlled Trials (1922 to March 28, 2022), and
5. PsycINFO (1806 to March 28, 2022).

We reviewed the reference section of systematic reviews identified by the search for additional citations. The full search strategy for each database is available in Appendix A.

Study selection and data extraction

We imported identified articles into Rayyan QCRI, a free web software for systematic reviews and meta-analyses (Ouzzani et al., 2016). Duplicated articles were removed. Two reviewers assessed for inclusion (CL and AP) and data extraction (CL and KH). Disagreements were resolved by a third reviewer (SD).

Data collection items included the sample sizes of the intervention and control groups, pre- and immediate post-intervention stress levels and their respective standard deviations, loss to follow up, the duration of the experimental intervention (expressed in weeks and hours), participant incentives, the location where the study was conducted, the academic disciplines of the participants, and the control methodology employed in the control group. An overview of study characteristics is provided in Table 1.

Quality assessment and bias

We used the Cochrane risk of bias 2 (ROB2) tool (Sterne et al., 2019) to assess potential bias in studies across five domains: 1. Randomization process, 2. Deviations from intended

TABLE 1 Study characteristics.

Study	Location	Participants	Intervention type	Control type	Participation	Reward for participation	Exclusion criteria for participation	Intervention duration (weeks)	Intervention duration (hours)
Chan et al., 2021	Hong Kong	Undergraduate counseling trainees	MBCT	Waitlist	Voluntary	HK$50 (US$6.40)	Previous participation in the program or currently practicing mindfulness meditation	8	16
Damião Neto et al., 2020	Portugal	1st year medical students	MMP	Course on organizational aspects medical school	Mandatory course	n.r.	<18 years	6	12
Danilewitz et al., 2016	Canada	Pre-clerkship (1st and 2nd year) medical students	MMP	Waitlist	Voluntary	A credit on medical school performance record	Not one of the first 30 respondents to invitation to participate	8	10
Erogul et al., 2014	U.S.A	1st year medical students	MBSR	No intervention	Voluntary	US$50	None	8	10
Hanley et al., 2019	Norway	1st and 2nd year medical and clinical psychology students	MBSR	No intervention	Voluntary	US$50 book voucher	None	7	10.5
Kang et al., 2009	Korea	3rd and 4th year nursing students	MBSR	No intervention	Voluntary	n.r.	No participation in clinical training, history mental disease, non-female	8	14
Karaca & Şişman, 2019	Turkey	2nd year nursing students	MMP	No intervention	Electives course	3 ECTS credits	None	12	24
Song & Lindquist, 2015	Korea	Nursing students	MBSR	Waitlist	Voluntary	n.r.	Regular meditation/yoga practice, psychiatric symptoms, contra-indication to exercise	8	16

TABLE 1 (Continued)

Study	Location	Participants	Intervention type	Control type	Participation	Reward for participation	Exclusion criteria for participation	Intervention duration (weeks)	Intervention duration (hours)
Van Dijk et al., 2017	The	1st year clinical clerkship medical students	MBSR	No intervention	Voluntary	No reward	<18, non-Dutch speaking, previous participation in MBSR, lack of time/ interest	8	16
Waechter et al., 2021	U.K	1st year medical students	MBSR	No intervention	Voluntary	Lottery for 1 of 3 USMLE prep scholarships	n.r	12	24
Martínez-Rubio et al., 2022	Spain	Final year psychology students	MCBP	Waitlist	Voluntary	n.r	<18, not fluent in Spanish, unable to attend all sessions, psychiatric diagnosis, undergoing psychological treatment, substance use	6	9

Note: Effect and loss to follow up are reported as immediately post-intervention.
Abbreviations: BSI, Brief Symptom Inventory; DASS, Depression Anxiety Stress Scales; ECTS, European Credit Transfer System; GHQ, General Health Questionnaire; MBCT, mindfulness-based cognitive therapy; MBSR, mindfulness-based stress reduction; MCBP, mindfulness- and compassion-based program; MMP, mindfulness meditation program; n.a., not applicable; NESC, Nursing Education Stress Scale; n.r., not reported; PSS, Perceived Stress Score; PWI-SF, Psycho Social Well-Being Index – Short Form.

TABLE 1 (Continued)

Study	Outcome measurement	Initial total sample size	Sample size in control group	Sample size in intervention group	Loss to follow up total (%), post-intervention	Loss to follow up intervention group	Loss to follow up control group	Baseline stress level in intervention group (*SD*)	Baseline stress level in control group (*SD*)	Post-intervention stress score in intervention group (*SD*)	Post-intervention stress score in control group (*SD*)
Chan et al., 2021	DASS-21	50	25	25	3 (6%)	1	2	10.50 (4.77)	10.70 (3.65)	7.66 (n.a.)	10.05 (n.a.)
Damião Neto et al., 2020	DASS-21	141	71	70	27 (19.14%)	13	14	8.68 (4.16)	7.54 (3.98)	8.18 (4.03)	7.76 (4.40)
Danilewitz et al., 2016	DASS	30	15	15	8 (26.6%)	2	6	17.30 (7.66)	15.80 (9.80)	12.30 (6.60)	14.70 (7.90)
Erogul et al., 2014	PSS-10	59	30	29	1 (1.69%)	1	0	17.60 (5.50)	18.30 (7.10)	13.30 (5.10)	17.30 (7.70)
Hanley et al., 2019	GHQ	288	144	144	10 (3.47%)	6	4	12.44 (5.97)	12.95 (6.22)	9.21 (3.95)	13.06 (6.04)

TABLE 1 (Continued)

Study	Outcome measurement	Initial total sample size	Sample size in control group	Sample size in intervention group	Loss to follow up total (%), post-intervention	Loss to follow up intervention group	Loss to follow up control group	Baseline stress level in intervention group (*SD*)	Baseline stress level in control group (*SD*)	Post-intervention stress score in intervention group (*SD*)	Post-intervention stress score in control group (*SD*)
Kang et al., 2009	PWI-SF	41	20	21	9 (21.95%)	5	4	23.69 (5.12)	19.50 (5.70)	17.27 (5.18)	21.40 (7.47)
Karaca & Şişman, 2019	NESC	114	72	42	0 (0%)	0	0	64.24 (12.17)	61.41 (16.47)	50.07 (16.43)	67.14 (13.73)
Song & Lindquist, 2015	DASS-21	50	25	25	6 (12%)	4	2	34.50 (12.50)	30.00 (12.20)	7.40 (4.90)	13.70 (8.90)
Van Dijk et al., 2017	BSI	167	84	83	26 (15.68%)	10	16	0.38 (0.26)	0.42 (0.29)	0.31 (0.26)	0.36 (0.28)
Waechter et al., 2021	PSS	51	27	24	9 (17.64%)	7	2	21.77 (5.04)	20.12 (7.94)	20.65 (7.67)	25.04 (10.14)
Martínez-Rubio et al., 2022	PSS-14	30	15	15	6 (20%)	1	5	27.86 (8.05)	30.30 (4.92)	18.14 (4.35)	27.50 (6.72)

Note: Effect and loss to follow up are reported as immediately post-intervention.

Abbreviations: BSI, Brief Symptom Inventory; DASS, Depression Anxiety Stress Scales; ECTS, European Credit Transfer System; GHQ, General Health Questionnaire; MBCT, mindfulness-based cognitive therapy; MBSR, mindfulness-based stress reduction; MCBP, mindfulness- and compassion-based program; MMP, mindfulness meditation program; n.a., not applicable; NESC, Nursing Education Stress Scale; n.r., not reported; PSS, Perceived Stress Score; PWI-SF, Psycho Social Well-Being Index – Short Form.

interventions, 3. Missing Outcome data, 4. Measurement of the outcome, 5. Selection of the reported result. Risk of bias was expressed as "low risk," "some concerns," and high "risk."

We used a funnel plot to examine publication bias, where absence of publication bias is represented by a roughly symmetric plot.

Statistical analysis

Articles that provided sufficient information for data analysis were also eligible for inclusion in the meta-analysis. All statistical analyses were conducted in Rstudio (version 1.4.1106) (RStudio Team, 2021) using the meta, metafor, and tidyverse packages.

We calculated effect sizes for each study expressed as the standardized mean difference (SMD) with a 95% confidence interval (CI), using the post-intervention stress score difference between the intervention and control groups.

We applied the random effects model, which assumes moderate (I^2 from 25% to 50%) to high heterogeneity (I^2 beyond 50%) (Higgins & Thompson, 2002). The random effects model provides a more conservative confidence interval on effect size estimates than an equal-effects model and is preferred for I^2 of 25% or more.

As the number of included articles was below 20, the SMD was adjusted using Hedges' *g* equation to account for the small sample size (Hedges, 1981).

We interpreted the overall pooled effect size (SMD) as follows: ≤0.20 was a small effect, 0.21–0.79 was a moderate effect, and ≥0.80 was a large effect, which are commonly chosen in social sciences when valid estimates of minimal clinical relevance are lacking (Cohen, 2013).

Meta-regression was used to investigate the effect of intervention duration on treatment effect-size. Meta-regressions examine the relationship between an outcome variable (in our study effect size in SMD) and predictor variable (in our study intervention duration in weeks) across the included studies. Regression coefficients provide an estimate of the magnitude of change in the intervention effect associated with a one-unit increase intervention duration, and positive coefficients indicate a positive association between longer intervention durations and larger effect sizes.

Sensitivity analyses

We identified studies with significantly different effect sizes as outliers and evaluated the impact of their exclusion on our analysis. Similarly, we identified influential studies, which had a large impact on the overall results of the meta-analysis. We re-evaluated our results after excluding these studies to understand how outliers and influential studies contribute to the heterogeneity of our results without excluding them from the meta-analysis.

RESULTS

Search results

We conducted the search on March 28, 2022. After removing the duplicates, we screened 2932 unique studies on title and abstract screening and 201 full-text papers. A total of 11 papers met

the inclusion criteria for the systematic review, and 10 papers had sufficient data to be included in the meta-analysis. Figure 2 shows the PRISMA flowchart of the study selection process (Page et al., 2021).

Description of studies

In this study, we included 11 articles with a total of 1021 participants. The number of participants in each individual study ranged from 30 to 288 ($M = 92.81$, $SD = 75.98$), with

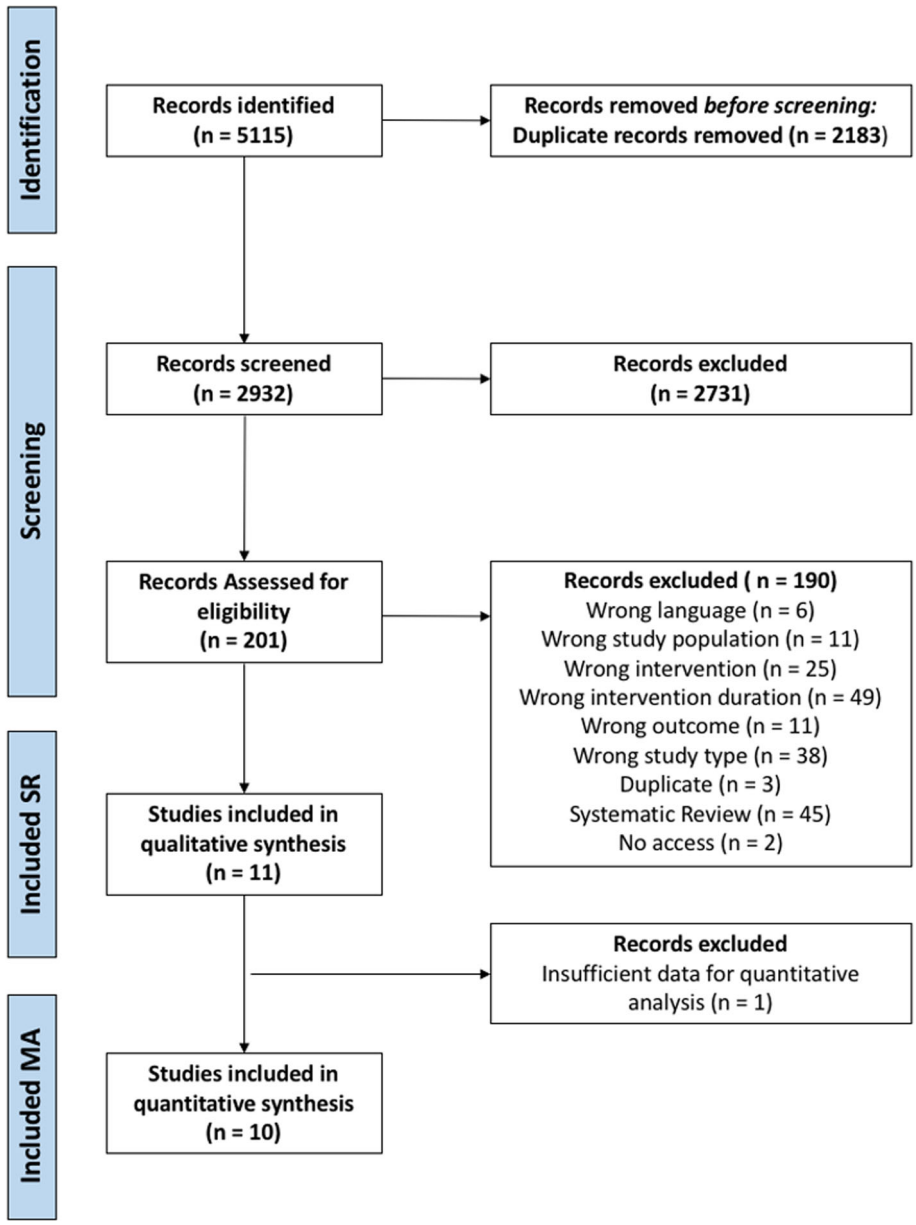

FIGURE 2 Study selection.

493 (M = 44.81, *SD* = 37.84) students assigned to the intervention groups and 528 (M = 48.00, *SD* = 38.61) to the control groups. Table 1 shows the features of the included articles.

Intervention and control conditions

The duration of the MBIs ranged from 6 to 12 weeks and between 9 and 24 h. MBIs included mindfulness-based stress reduction (MBSR), mindfulness meditation (MM), mindfulness-based cognitive therapy (MBCT) and mindfulness- and compassion-based program (MCBP).

Among the 11 studies, only two did not assign homework assignments to their participants (Kang et al., 2009; Waechter et al., 2021). The remaining nine studies required participants to practice at home, although six did not report on homework engagement, and the three studies that did all reported low levels of participation.

Nearly all studies used a waitlist or no-intervention control condition, except for the study by Damião Neto et al. (2020). In this last study, students participated in a course on organizational aspects of medical school (Damião Neto et al., 2020).

Incentive to participate

Of the 11 studies included in the analysis, nine had participants who voluntarily enrolled in the interventions (Chan et al., 2021; Danilewitz et al., 2016; Erogul et al., 2014; Hanley et al., 2019; Kang et al., 2009; Martínez-Rubio et al., 2022; Song & Lindquist, 2015; van Dijk et al., 2017; Waechter et al., 2021). In contrast, the intervention in the study by Karaca and Şişman (2019) was offered as an elective, and Damião Neto et al. (2020) combined the intervention with a mandatory course.

Additionally, six of the studies reported offering rewards to the participants after the intervention (Chan et al., 2021; Danilewitz et al., 2016; Erogul et al., 2014; Hanley et al., 2019; Karaca & Şişman, 2019; Waechter et al., 2021), and one explicitly reports not providing any incentives for participation (van Dijk et al., 2017). The remaining papers did not report on this matter.

Loss to follow up

Across all 11 studies, 115 out of 1021 participants (11.26%) were lost to follow-up. To address this missing data, five studies employed an intention-to-treat analysis (Chan et al., 2021; Damião Neto et al., 2020; Danilewitz et al., 2016; Hanley et al., 2019; I. van Dijk et al., 2017), and six studies either did not correct for participants lost to follow-up or actively excluded the data of participants who missed a certain number of sessions (Erogul et al., 2014; Kang et al., 2009; Karaca & Şişman, 2019; Martínez-Rubio et al., 2022; Song & Lindquist, 2015; Waechter et al., 2021).

Two studies performed some manner of missing data imputation (Danilewitz et al., 2016; van Dijk et al., 2017). van Dijk et al. (2017) performed a sensitivity analysis using multiple imputations to replace missing values and found no influence on the results. Danilewitz et al. (2016) on the other hand carried the baseline observations forward as a manner of imputing missing data (Last Observation Carried Forward).

Baseline scores of students were compared between those who completed follow-up and those who were lost to follow-up in the study by Waechter et al. (2021). The authors found a mean difference in perceived stress of −3.27 (95% CI [−6.61, 0.07], $p = 0.06$), suggesting that those who drop out of the study have higher stress levels at baseline.

Risk of bias

The assessment of risk of bias is shown in Figure 3 and in more detail in Appendix B. All included papers scored high risk of bias in the domain of measurement of the outcome since outcomes were measured through questionnaires. Other common areas of some concern were in the selection of reported outcomes (72.2% of papers) and deviations from the intended interventions (54.5%).

We generated a funnel plot presented in Figure 4. The plot shows that studies were distributed fairly symmetrically, suggesting the absence of publication bias.

Meta-analysis: effect MBIs on stress

As the study by Chan et al. (2021) reported effect size using a different measure (partial eta squared) that cannot be converted to SMD, we excluded this study from the quantitative analysis. Our meta-analysis therefore included 10 papers.

Our study found that MBIs had a moderate effect on reducing stress in students in health professions, with an SMD of 0.60 (95% CI [0.27, 0.94], $p < 0.01$) and considerably high between-study heterogeneity (I-squared index = 77%) (Higgins et al., 2022b). The prediction interval ranged from −0.36 to 1.57, with values below zero indicating that future RCTs of MBIs may potentially identify a negative effect on student stress.

The forest plot in Figure 5 shows that only one study (Damião Neto et al., 2020) found an effect size below 0. Martínez-Rubio et al. (2022) demonstrated the largest effect size with an SMD of 1.61, which is generally considered a large effect in reducing student stress.

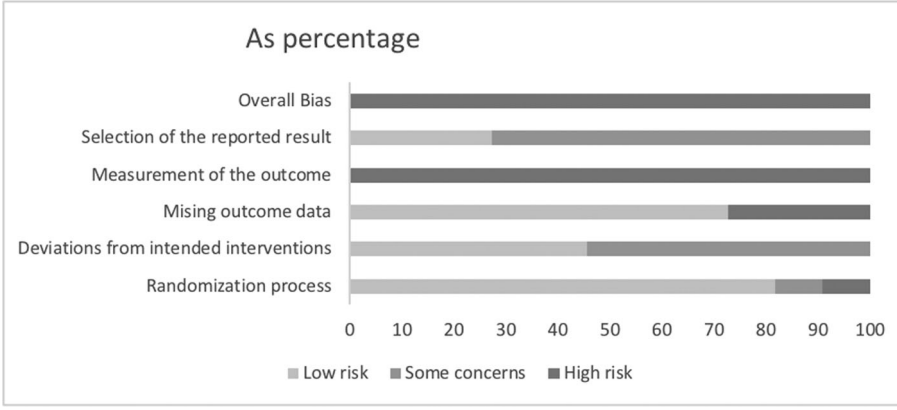

FIGURE 3 Overall risk of bias.

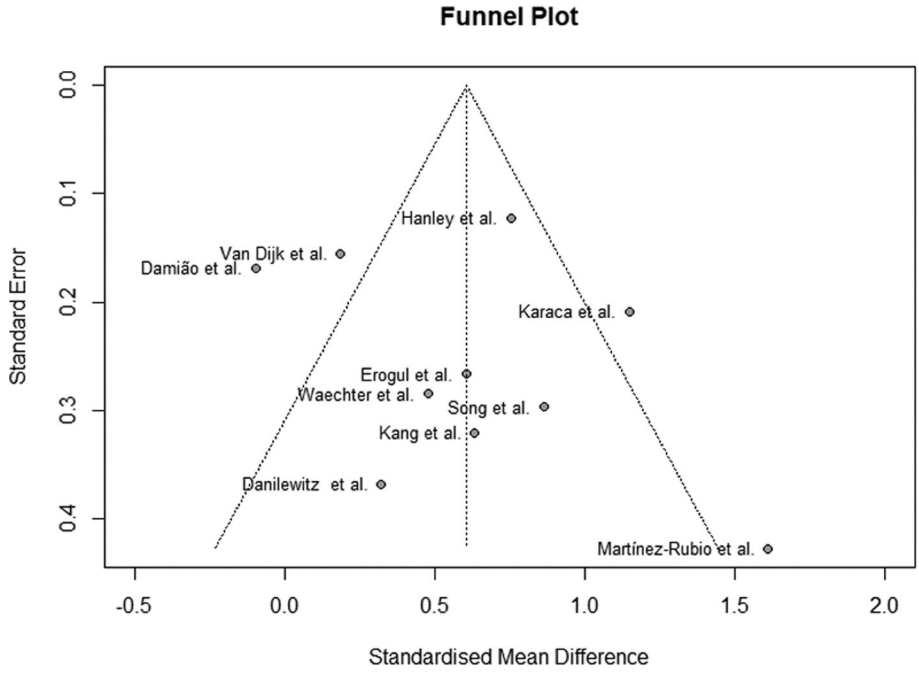

FIGURE 4 Funnel plot of studies included in meta-analysis. The plot shows that studies were distributed fairly symmetrically, suggesting the absence of publication bias.

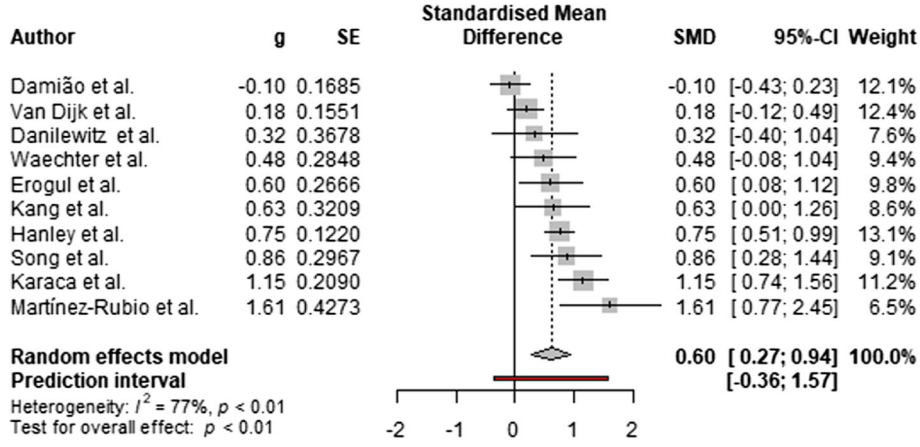

FIGURE 5 Forest plot. Effect of mindfulness-based interventions on students in health professions' stress post-intervention. The pooled effect is 0.60 SMD (95% CI [0.27, 0.94], $p < 0.01$, $I^2 = 77\%$).

The meta-regression in Figure 6 shows a non-significant positive relationship between intervention duration and effect size, with a coefficient of 0.0529 ($p = 0.5$) that represents an increase in SMD of 0.0529 for each additional week of MBI.

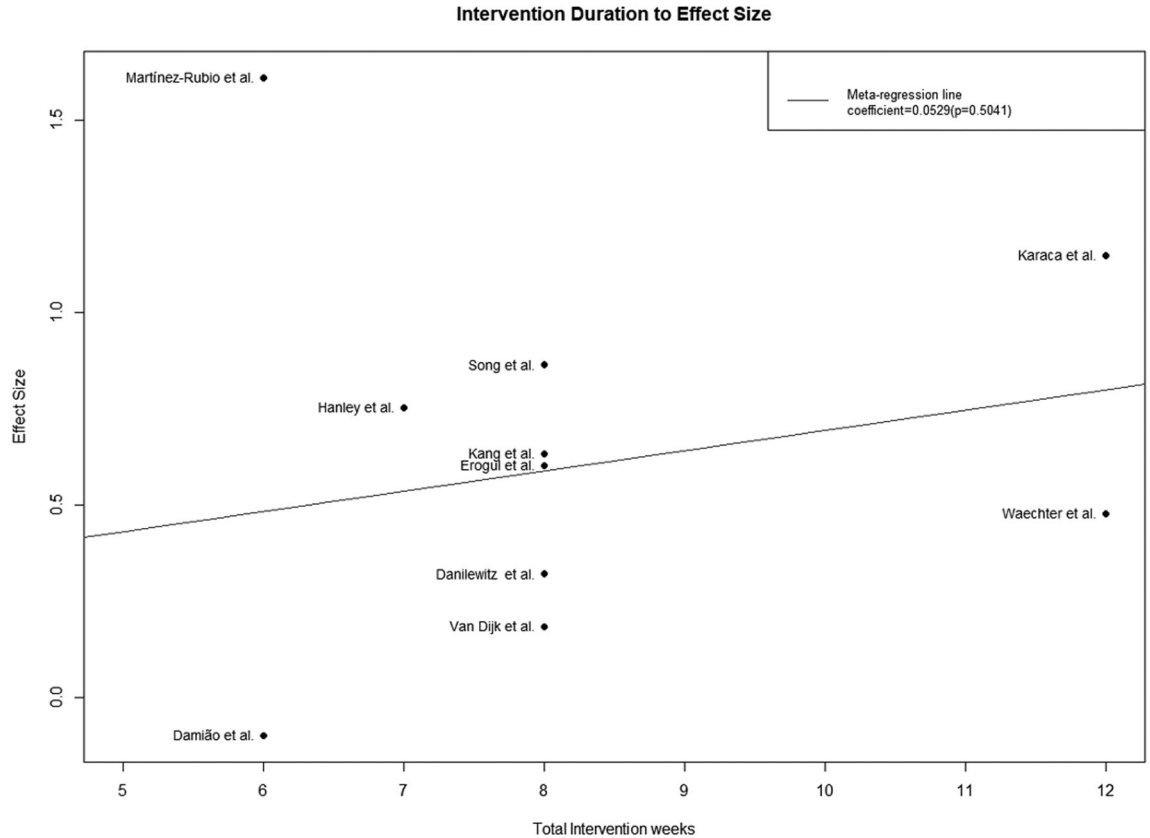

FIGURE 6 Meta-regression plot—association between intervention duration and effect size, with a coefficient of 0.0529 per additional week of the intervention (p-value = 0.5).

Sensitivity analyses

Our study had high between-group heterogeneity, with an I-squared index of 77%. The study by Damião Neto et al. (2020) was considered both the outlier as well as influencer in our analysis (Appendix C). When this study was excluded from our analysis, the I-squared index decreased to 63.9%, and the effect size increased to 0.69 (95% CI [0.39, 1.00]).

DISCUSSION

Our research suggests that mindfulness-based interventions can significantly reduce stress levels among students in health professions, with an effect size of 0.60 SMD (95% CI [0.27, 0.94]).

Almost all of the studies included in our analysis found that MBIs reduced stress in the active intervention group compared to the control group, with the exception of one study (Damião Neto et al., 2020). One reason for this might be that the study by Damião Neto et al. (2020) was the only study that applied an active control group, consisting of a course on the organizational aspects of the medical school, such as student assistance, "being a doctor," and how evaluations and how medical departments function. However, this study was also the only study where participation in the MBI was mandatory, which may have contributed to its less favorable results, and which contributed to the meta-analysis heterogeneity and made this study an outlier. The authors suggest that therefore a required course may not be the most appropriate form of an MBI (Damião Neto et al., 2020). Previous research supports the hypothesis that non-mandatory participation may lead to greater acceptance and satisfaction among participants (Aherne et al., 2016; Dyrbye et al., 2017). In the study by Karaca and Şişman (2019, which found an effect size of 1.15 SMD (95% CI [0.74, 1.56]), the MBI was also part of the formal curriculum but was offered as an elective for which students earned academic credits. It is possible that voluntary sign up in other included studies influences the composition of the included study population. Included students may have above average stress levels (Song & Lindquist, 2015), for example due to their interest to address their stress, or highly stressed students may not sign up as they are already overburdened, limiting the generalizability to the overall student population.

Our meta-regression analysis showed a statistically non-significant increase in the effect of MBIs (0.05 SMD) with each additional week of duration, or an increase of 0.3 SMD when comparing 12 to 6 weeks of intervention. This suggests that there may be a substantial effect of duration, however, due to the limited number of studies we had insufficient power to show statistical significance. Additionally, there are several important limitations to consider when performing meta-regression on aggregate data, including that associations may not reflect true associations between individual patient-level treatment effects, and that meta-regression analyses are easily overfitted (Geissbühler et al., 2021). It is also possible that our inclusion criteria, which selected studies of comparable duration may have influenced this lack of influence which had been observed in previous literature (Baer et al., 2012; Pepping et al., 2016).

Strengths and limitations

There are several strengths and limitations to our research. One strength is that our systematic review includes a DAG that transparently represents our hypothesis and guided our decisions on

inclusion and exclusion criteria (RCTs) and data extraction elements (loss to follow-up). In contrast to some of the previous systematic reviews (Aloufi et al., 2021; Alzahem et al., 2014; Daya & Hearn, 2018; Witt et al., 2019), we only included RCTs, providing a strong level of evidence for the effectiveness of MBIs and helping to control for confounding variables at baseline. Non-randomized trials run a risk of being affected by sources of bias at baseline that might influence effectiveness of MBIs, such as age, sex, perfectionism, and motivation to participate (DAG Figure 1).

Another strength is that we narrowed our search to specific types and durations of MBIs. We also included a broader range of health professions, compared to existing systematic reviews (Aloufi et al., 2021; Alzahem et al., 2014; Hathaisaard et al., 2022; Li et al., 2018; Shiralkar et al., 2013; Witt et al., 2019). This choice was made to improve the interpretability of our findings for local decision-makers that are interested in the effectiveness of specific implementations at the university level (Daya & Hearn, 2018).

The funnel plot indicated a fairly symmetrical distribution suggesting the absence of publication bias.

There are also several limitations to our research. One limitation is that our search yielded a low number ($n = 11$) of studies that met our inclusion criteria, which limited our ability to conduct further subgroup analysis and investigate the long-term effects of MBIs.

All included papers were rated as having a high risk of bias due to the use of self-reported questionnaires to measure participants' stress. However, self-reporting is an acceptable method of measurement for this type of research when considering stress as a subjective feeling since the subjective experience is the main symptom of concern. When we exclude the outcome domain, some or high concerns of risk of bias remain present in 8 out of 11 studies.

As indicated by the path A-C-L-Y in our DAG (Figure 1), selection bias is an important source of potential bias in our study. Loss to follow-up across studies was 10%, with busy or changing schedules cited as reasons for dropping out (Danilewitz et al., 2016). In the study by Waechter et al. (2021), students who dropped out of the study had higher baseline stress levels than those who remained. This is concerning, because it may indicate that these MBIs unintentionally burden students, causing them to drop out, but also if there is differential dropout between study arms and this is not properly addressed, it can affect the reliability of the study.

Some studies applied an intention-to-treat analysis in an attempt to obtain a less biased conclusion (Gupta, 2011; McCoy, 2017; Ranganathan et al., 2016). However, even if intention-to-treat estimates are applied, these can still result in an overestimate of a treatment's effect in the presence of differential adherence (Hernán & Hernández-Díaz, 2012). None of the included studies used statistical techniques such as inverse probability weighting or g-estimation in order to further reduce the bias introduced by non-adherence and loss to follow-up (Dijk et al., 2022; Hernán & Hernández-Díaz, 2012).

While we conducted a thorough search using comprehensive strategies to identify relevant articles, we acknowledge that the characteristics of the study population were limited in their representation of a broader range of health professional students, namely, medicine, nursing, counseling, and psychology.

Future directions

Our results suggest that mindfulness-based interventions can significantly reduce stress levels among students in health professions. Given the high prevalence of stress and burnout among health professionals and health professional students and their effect on health providers as

well as patients, providing MBIs could be considered an effective tool to reduce stress in students and should be considered further by researchers, educational policy-makers and faculty. Given the limitations of this study, including high risk of bias of individual studies, high heterogeneity, a limited sample size, limited appropriate adjustments for censoring, and limited number of health professions, further research could contribute to the robustness and generalizability of these findings. Additionally, all except one study did not apply active control settings, limiting the ability to control for placebo effects.

Teaching students in health professions how to cope with stress at early stages of their careers is imperative to ensure their well-being, support students' well-being and positively impact patient health and the overall medical system. Therefore, future research should investigate the effects of MBI on learning and successfully completing the educational program, and more importantly, the long-term effects on chronic stress, burn out and lower work performance when working as a health professional after graduation. Furthermore, while MBIs can reduce stress by influencing how (future) health professionals cope with stress, effective strategies to reduce stress-causing factors such as high-pressure work environments should likewise be addressed in future research.

CONCLUSION

Six- to twelve-week mindfulness-based interventions can effectively reduce stress in students in health professions. However, given the high risk of bias these findings should be interpreted with caution and further high-quality studies are needed.

ACKNOWLEDGMENTS

We would like to thank Maarten Engel, information specialist from the Erasmus University Medical Center library, for helping with the construction and optimization of the search strategy.

CONFLICT OF INTEREST STATEMENT

Apart from funding for this study as mentioned, MH receives (or received in the past 36 months) royalties from Cambridge University Press for a textbook on Medical Decision Making, reimbursement of expenses from the European Society of Radiology (ESR) for work on the ESR guidelines for imaging referrals, reimbursement of expenses from the European Institute for Biomedical Imaging Research (EIBIR) for membership of the Scientific Advisory Board, and research funding from the American Diabetes Association, the Netherlands Organization for Health Research and Development, the German Innovation Fund, and the Gordon and Betty Moore Foundation.

DATA AVAILABILITY STATEMENT

All collected data was provided in this paper.

ETHICS STATEMENT

This paper did not involve the use of human or animal subjects, and as such, ethics approval was not required.

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How to cite this article: Lu, C.-P., Dijk, S. W., Pandit, A., Kranenburg, L., Luik, A. I., & Hunink, M. G. M. (2023). The effect of mindfulness-based interventions on reducing stress in future health professionals: A systematic review and meta-analysis of randomized controlled trials. *Applied Psychology: Health and Well-Being*, 1–28. https://doi.org/10.1111/aphw.12472

APPENDIX: FULL SEARCH STRATEGY

Embase

('mindfulness'/exp OR 'Mindful Attention Awareness Scale'/exp OR 'meditation'/exp OR 'mindfulness based stress reduction'/exp OR 'mindfulness based intervention'/exp OR 'wellbeing'/de OR 'emotional well-being'/de OR 'psychological well-being'/de OR 'spiritual well-being'/de OR 'psychological resilience'/de OR 'breathwork'/de OR 'yoga'/exp OR 'breathing exercise'/exp OR 'relaxation training'/de OR (mindful* OR meditation* OR meditate* OR MBSR OR MBCT OR wellbeing* OR well-being* OR wellness* OR resilience* OR ((mind) NEAR/1 (body)) OR breath-work* OR breathwork* OR self-regulation* OR yoga* OR breathing* OR ((relaxation*) NEAR/6 (training* OR method* OR technique* OR therap*))):ab,ti,kw) AND ('student'/exp OR ((student* NOT student-t*) OR students OR trainee* OR learner*):ab,ti,kw) AND ('physiological stress'/exp OR 'mental stress'/exp OR 'stress assessment'/exp OR 'stress reduction'/de OR 'stress management'/de OR (stress OR PSS OR burnout OR burnouts OR burn-out OR burn-outs OR mental-tension* OR emotional-exhaust*):ab,ti,kw) AND ('randomized controlled trial'/exp OR 'Controlled clinical trial'/exp OR 'Crossover procedure'/de OR 'Double-blind procedure'/de OR 'Single-blind procedure'/de OR 'systematic review'/de OR 'meta analysis'/exp OR (RCT OR RCTs OR random* OR factorial* OR crossover* OR (cross NEXT/1 over*) OR placebo* OR ((doubl* OR singl*) NEXT/1 blind*) OR assign* OR allocat* OR volunteer* OR trial OR groups):ab,ti,kw OR (systematic-review* OR meta-analy*):ti) NOT ((animal/exp OR animal*:de OR nonhuman/de) NOT ('human'/exp)) NOT ([Conference Abstract]/lim)

Medline

(Mindfulness/ OR Mind-Body Therapies/ OR Meditation/ OR Resilience, Psychological/ OR Breathing Exercises/ OR Yoga/ OR Relaxation Therapy/ OR (mindful* OR meditation* OR meditate* OR MBSR OR MBCT OR wellbeing* OR well-being* OR wellness* OR resilience* OR ((mind) ADJ1 (body)) OR breath-work* OR breathwork* OR self-regulation* OR yoga* OR breathing* OR ((relaxation*) ADJ6 (training* OR method* OR technique* OR therap*))).ab,ti,kf.) AND (exp Students/ OR ((student* NOT student-t*) OR students OR trainee* OR learner*).ab,ti,kf.) AND (exp Stress, Physiological/ OR (stress OR PSS OR burnout OR burnouts OR burn-out OR burn-outs OR mental-tension* OR emotional-exhaust*).ab,ti,kf.) AND (exp Controlled Clinical Trial/ OR Cross-Over Studies/ OR Double-Blind Method/ OR Single-Blind Method/ OR Systematic Review/ OR Meta-Analysis/OR (RCT OR RCTs OR random* OR factorial* OR crossover* OR (cross ADJ over*) OR placebo* OR ((doubl* OR singl*) ADJ blind*) OR assign* OR allocat* OR volunteer* OR trial OR groups).ab,ti,kf. OR (systematic-review* OR meta-analy*).ti.) NOT (exp animals/NOT humans/) NOT (news OR congres* OR abstract* OR book* OR chapter* OR dissertation abstract*).pt.

Cochrane

((mindful* OR meditation* OR meditate* OR MBSR OR MBCT OR wellbeing* OR well-being* OR wellness* OR resilience* OR ((mind) NEAR/1 (body)) OR breath-work* OR breathwork* OR self-regulation* OR yoga* OR breathing* OR ((relaxation*) NEAR/6 (training* OR method* OR technique* OR therap*))):ab,ti) AND ((student* OR students OR trainee* OR learner*):ab,ti) AND ((stress OR PSS OR burnout OR burnouts OR burn-out OR burn-outs OR mental-tension* OR emotional-exhaust*):ab,ti)

Web of Science

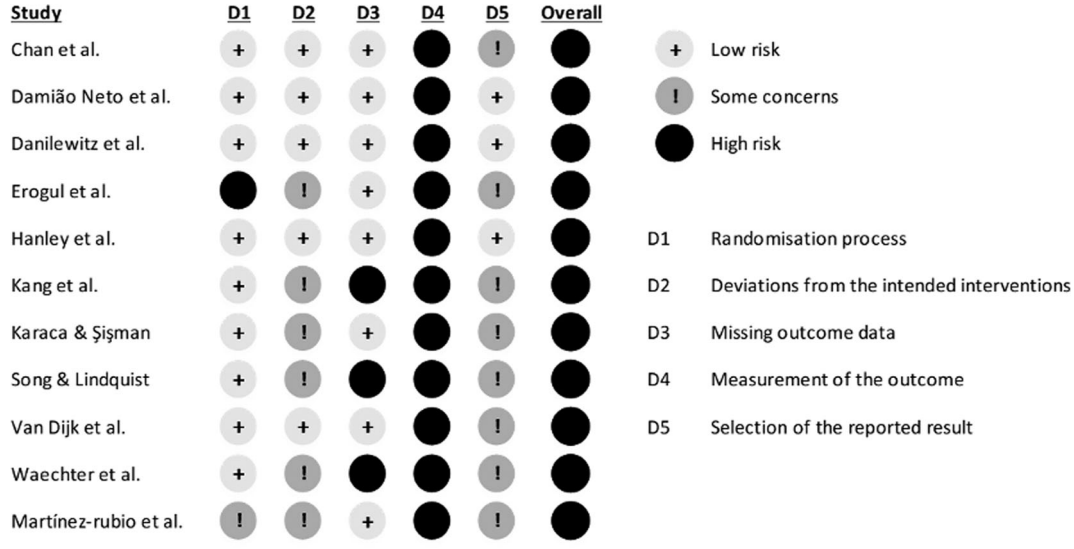
TS=(((mindful* OR meditation* OR meditate* OR MBSR OR MBCT OR wellbeing* OR well-being* OR wellness* OR resilience* OR (("mind") NEAR/1 ("body")) OR breath-work* OR breathwork* OR self-regulation* OR yoga* OR breathing* OR ((relaxation*) NEAR/5 (training* OR method* OR technique* OR therap*))))) AND (((student* NOT student-t*) OR trainee* OR

learner*)) AND ((“stress” OR PSS OR burnout OR burnouts OR burn-out OR burn-outs OR mental-tension* OR emotional-exhaust*)) AND (RCT OR RCTs OR random* OR factorial* OR crossover* OR (“cross” NEAR/1 over*) OR placebo* OR ((doubl* OR singl*) NEAR/1 blind*) OR assign* OR allocat* OR volunteer* OR “trial”) NOT ((animal* OR rat OR rats OR mouse OR mice OR murine OR dog OR dogs OR canine OR cat OR cats OR feline OR rabbit OR cow OR cows OR bovine OR rodent* OR sheep OR ovine OR pig OR swine OR porcine OR veterinar* OR chick* OR zebrafish* OR baboon* OR nonhuman* OR primate* OR cattle* OR goose OR geese OR duck OR macaque* OR avian* OR bird* OR fish*) NOT (human* OR patient* OR women OR woman OR men OR man))) AND DT=(Article OR Review OR Letter OR Early Access)

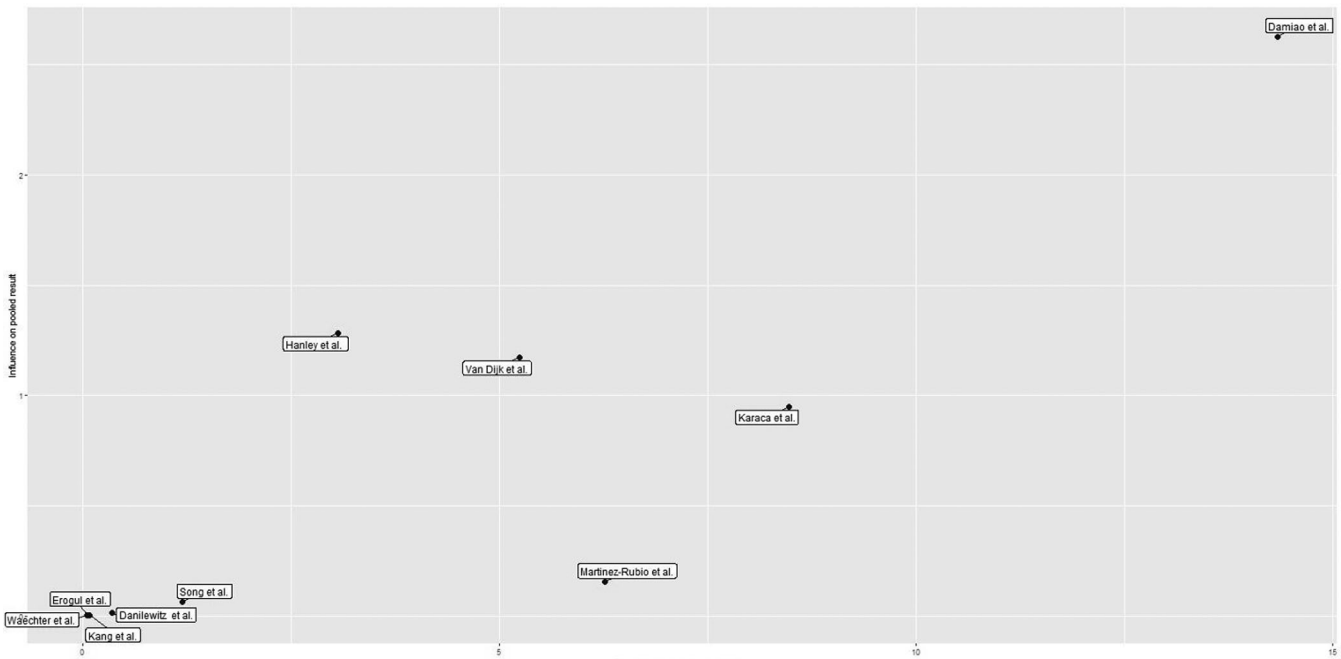
PsycINFO

(Mindfulness/ OR Mindfulness-Based Interventions/ OR Mind Body Therapy/ OR Meditation/ OR “Resilience (Psychological)”/ OR Yoga/ OR Relaxation Therapy/ OR (mindful* OR meditation* OR meditate* OR MBSR OR MBCT OR wellbeing* OR well-being* OR wellness* OR resilience* OR ((mind) ADJ1 (body)) OR breath-work* OR breathwork* OR self-regulation* OR yoga* OR breathing* OR ((relaxation*) ADJ6 (training* OR method* OR technique* OR therap*))).ab,ti.) AND (exp students/ OR ((student* NOT student-t*) OR students OR trainee* OR learner*).ab,ti.) AND (exp Stress/ OR (stress OR PSS OR burnout OR burnouts OR burn-out OR burn-outs OR mental-tension* OR emotional-exhaust*).ab,ti.) AND (exp Clinical Trials/ OR Systematic Review/ OR Meta Analysis/OR (RCT OR RCTs OR random* OR factorial* OR crossover* OR (cross ADJ over*) OR placebo* OR ((doubl* OR singl*) ADJ blind*) OR assign* OR allocat* OR volunteer* OR trial OR groups).ab,ti. OR (systematic-review* OR meta-analy*).ti.) NOT ((animal.po. OR exp animals/) NOT human.po.) NOT (news OR congres* OR abstract* OR book* OR chapter* OR dissertation abstract*).pt.

APPENDIX: RISK OF BIAS PER STUDY



APPENDIX: SENSITIVITY ANALYSIS



APPENDIX: PRISMA CHECKLIST

Section and topic	Item #	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review.	1
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	4
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	4
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	6
Information sources	6	Specify all databases, registers, websites, organizations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	6–7
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Appendix A
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	7
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	7
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if	7

(Continues)

Section and topic	Item #	Checklist item	Reported on page #
		not, the methods used to decide which results to collect.	
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	7
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	8
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	8–9
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis [item #5]).	6
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	NA
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	7
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	8
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	8
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	9

Section and topic	Item #	Checklist item	Reported on page #
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	8
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	9
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Figure 2
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	NA
Study characteristics	17	Cite each included study and present its characteristics.	10–12, Table 1
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	12, Figure 3, Appendix B
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Figure 5
Results of syntheses	20a	For each synthesis, briefly summarize the characteristics and risk of bias among contributing studies.	10–12, Table 1, Appendix B
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	13
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	13
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	13–14, Appendix C
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	12, Figure 4

(Continues)

Section and topic	Item #	Checklist item	Reported on page #
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	13, Figure 5
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	14–15
	23b	Discuss any limitations of the evidence included in the review.	15–17
	23c	Discuss any limitations of the review processes used.	15–17
	23d	Discuss implications of the results for practice, policy, and future research.	17
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	The protocol was registered within the university database and is available upon request.
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	18
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	NA
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	19
Competing interests	26	Declare any competing interests of review authors.	19
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	18