



Invited Review

Mindfulness-based interventions: an overall review

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Abstract

Introduction: This is an overall review on mindfulness-based interventions (MBIs).

Sources of data: We identified studies in PubMed, EMBASE, CINAHL, PsycINFO, AMED, Web of Science and Google Scholar using keywords including ‘mindfulness’, ‘meditation’, and ‘review’, ‘meta-analysis’ or their variations.

Areas of agreement: MBIs are effective for improving many biopsychosocial conditions, including depression, anxiety, stress, insomnia, addiction, psychosis, pain, hypertension, weight control, cancer-related symptoms and prosocial behaviours. It is found to be beneficial in the healthcare settings, in schools and workplace but further research is warranted to look into its efficacy on different problems. MBIs are relatively safe, but ethical aspects should be considered. Mechanisms are suggested in both empirical and neurophysiological findings. Cost-effectiveness is found in treating some health conditions.

Areas of controversy: Inconclusive or only preliminary evidence on the effects of MBIs on PTSD, ADHD, ASD, eating disorders, loneliness and physical symptoms of cardiovascular diseases, diabetes, and respiratory conditions. Furthermore, some beneficial effects are not confirmed in

subgroup populations. Cost-effectiveness is yet to confirm for many health conditions and populations.

Growing points: Many mindfulness systematic reviews and meta-analyses indicate low quality of included studies, hence high-quality studies with adequate sample size and longer follow-up period are needed.

Areas timely for developing research: More research is needed on online mindfulness trainings and interventions to improve biopsychosocial health during the COVID-19 pandemic; Deeper understanding of the mechanisms of MBIs integrating both empirical and neurophysiological findings; Long-term compliance and effects of MBIs; and development of mindfulness plus (mindfulness+) or personalized mindfulness programs to elevate the effectiveness for different purposes.

Key words: mindfulness-based interventions, biopsychosocial health, safety, ethics, compliance, mechanisms

Mindfulness and mindfulness-based interventions

Mindfulness is a moment-by-moment awareness of thoughts, feelings, bodily sensations and surrounding environment. Being mindful is related to be open, nonjudgmental, friendly, curious, accepting, compassionate and kind.¹ Mindfulness practices aim to cultivate mindfulness state. These practices can be formal (e.g. breathing, sitting, walking, body scan) or informal (e.g. mindfulness in everyday life). Many mindfulness-based intervention (MBI) programmes have been established. Among all the MBIs, mindfulness-based stress reduction (MBSR), which was launched by Jon Kabat-Zinn in 1979,² and mindfulness-based cognitive therapy (MBCT) by Segal, Teasdale and Williams based on MBSR,^{3,4} are the two most widely adopted MBIs. These two programmes include eight weekly mindfulness sessions with one-day retreat.

Mindfulness is rooted in Buddhist traditions. However, it has become popular in recent years among various secular populations in healthcare, educational and workplace settings: from pre-school children to older adults across the world. Publications on mindfulness have increased dramatically in the recent decade. The publications on mindfulness is starting to be more comparable to publications on

cognitive behavioural therapy (CBT), which is one of the most widely used psychotherapies (Fig. 1).

Methods used for identifying relevant evidence

Literature in English was searched in MEDLINE, EMBASE, CINAHL, PsycInfo, AMED, Web of Science and Google Scholar using keywords including 'mindfulness', 'meditation' and 'review', 'meta-analysis' or their variations, with no restrictions on the year of publication. The search was conducted in July 2020. In choosing evidence, these general principals were applied: (i) published in more recent years if similar reviews were identified; (ii) included randomized controlled trials or meta-analysis in the review; (iii) presented with more conclusive conclusions. Literature with other types of study design (e.g. randomized controlled trials, cohorts, cross-sectional studies) were also manually searched and included when no systematic review was found or when considered as appropriate. However, while it was intent to include all important literature in a certain area, the review might not exhaust all relevant literature but had only selected key references of interest that we thought to be most pertinent and insightful for a specific topic.

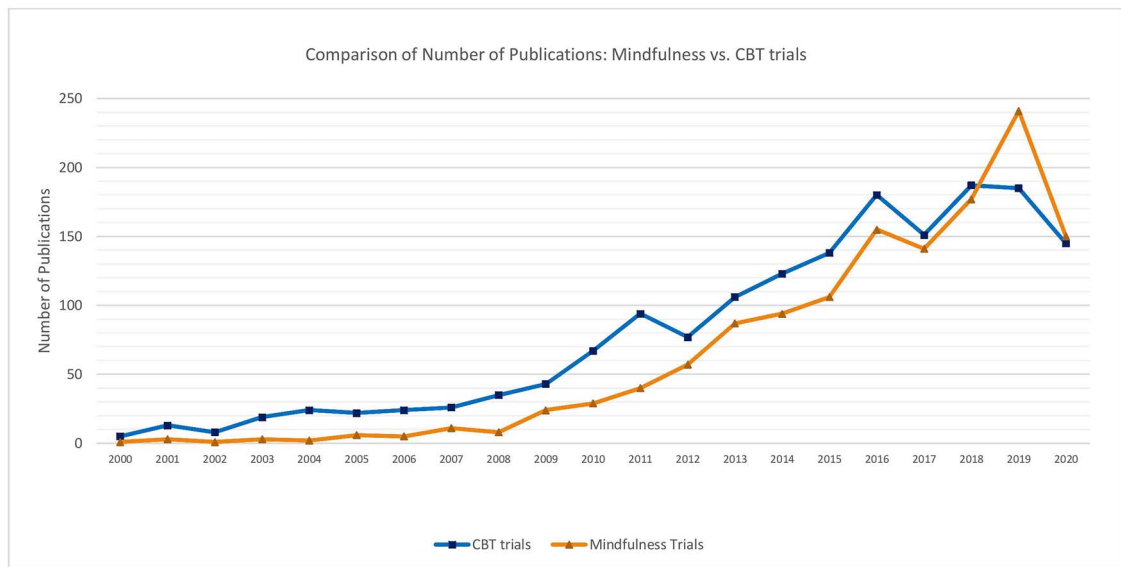


Fig. 1 Comparison on number of publications: mindfulness vs. CBT trials (by August 2020) [Note: Search terms included ('mindful* or meditate*' AND 'trial or random or random* control* trial*'); ('cognitive behavioural therapy or cognitive behavioural therapy or CBT' AND 'trial or random or random* control* trial*') in Title; Databases included MEDLINE, EMBASE and PsycINFO.]

Effects on mental health

MBIs have been shown to be efficacious in improving some of the common mental health problems.⁵

Depression and anxiety

For depression and anxiety, the efficacy of MBIs is sufficiently confirmed with meta-analyses demonstrating moderate to strong effect sizes for the reduction of the two conditions.^{6–8} The effects were also applicable during pregnancy, where a systematic review showed that MBIs helped reducing perinatal anxiety of moderate to large magnitude; however, the effects were less consistent in terms of reducing perinatal depression.⁹ The trending web-based interventions on mindfulness have also shown effectiveness in reducing depression and anxiety among people diagnosed with anxiety disorders as well.¹⁰ It was unclear, however, whether the benefits of mindfulness practices as a stand-alone intervention still exist, as it is difficult to dismantle the effects from social interaction and psychoeducation, which are the other components

integrated in many MBIs (e.g. group MBCT), from standalone mindfulness practices. Therefore, a recent meta-analyses¹¹ of 18 eligible studies investigated the gap, and has demonstrated that even mindfulness practice itself (e.g. breathing space, body scan, sitting meditation, soundscan) had small to medium effects on both anxiety (SMD = 0.39; CI: 0.22, 0.56; PI: 0.07, 0.70; $P < .001$, $I^2 = 18.90\%$) and depression (SMD = 0.41; CI: 0.19, 0.64; PI: -0.05, 0.88; $P < .001$; $I^2 = 33.43\%$).

Stress

Current evidence overall supports a moderate effect of MBIs on reducing stress; however, more robust studies are needed to make clear conclusions among different populations. A meta-analysis of five randomized control trials tested the effects of MBIs on cortisol levels, a stress-mediated hormone, and found that there may be a beneficial effect in healthy adult populations.¹² Yet, the overall effect size was moderately low ($g = 0.41$; $P = 0.025$).¹² On the other hand, another meta-analysis indicated that there was a

significant, medium effect of meditation interventions on cortisol levels, but the effect was only present for at-risk samples such as those living in stressful life situations.¹³ There are also studies done among specific populations such as tertiary education students¹⁴ and older adults,¹⁵ showing inconclusive results. Among tertiary education students, the effect sizes of interventions for stress were moderate ($g=0.42$, 95% CI: 0.27–0.57), but most studies were of poor quality.¹⁴ Among older adults, no clear evidence was found that MBIs can reduce the perception of stress.¹⁵

Insomnia

The current evidence on the effects of MBIs on insomnia and sleep disturbance is promising. A meta-analysis concluded that MBIs are effective in improving symptoms of insomnia and sleep quality when compared to attention/education and waitlist control with medium to large effects ($g=0.67$, 95% confidence interval [CI]=0.30–1.05) and that the effects seem to endure at 3 months postintervention ($g=1.06$, 95% CI=0.48–1.64).¹⁶ Several other meta-analyses also found similar results, which all showed significant improvement in insomnia or sleep quality as measured by the Pittsburgh Sleep Quality Index.^{17–19}

Eating disorders

Current studies provided preliminary evidence on the potential effects of MBIs on eating disorders (EDs). One systematic review and meta-analysis showed a within-condition effect of MBIs on ED symptoms, emotional eating, negative affect and body dissatisfaction, and on the body mass index (BMI) in anorectic and bulimic participants relative to pre-assessment.²⁰ Another systematic review and meta-analysis also found that MBIs may help reducing body image concern and negative affect, while promoting body appreciation.²¹ Both authors concluded that more rigorous studies are needed before the efficacy of MBIs on EDs can be confirmed.^{20,21}

Addiction

Literature supports the efficacy of MBIs in both substance and behavioural addictions. A systematic review of 54 randomised controlled trials found that MBIs were successful in the reduction of dependence, craving and other symptoms related to addiction, and the improvement of mood state and emotion dysregulation.²² Two other meta-analytic results also revealed significant small-to-large effects of MBIs in reducing levels of perceived craving,^{23,24} severity of stress,^{23,24} frequency and severity of substance misuse,²³ anxiety and depressive symptoms,²⁴ negative affectivity,²⁴ and post-traumatic symptoms²⁴ for the treatment of substance misuse. Although the effectiveness is promising, more research is needed especially on longer follow-up assessments and among diverse populations.

Psychosis

It seems that MBIs have potential benefits for people with psychosis, but further research is warranted.²⁵ A systematic review and meta-analysis on 434 patients found short-term moderate evidence of MBIs on total psychotic symptoms, positive symptoms, hospitalization rates, duration of hospitalization, and mindfulness as short-term effects and total psychotic symptoms and duration of hospitalization as long-term effects in patients with psychosis.²⁶ Another systematic review also confirmed that MBIs are feasible for individuals with psychosis and it could provide a number of significant benefits over routine care such as improving negative symptoms and measures of functioning.²⁷ Future large trials adopting randomization procedure are suggested to gain greater insight into the mechanisms and long-term effectiveness of MBIs among people with psychosis.

Post-traumatic stress disorder

MBIs among post-traumatic stress disorder (PTSD)-diagnosed participants were less conclusive. A systematic review and meta-analysis of 10 trials on meditation interventions have shown that the effects for PTSD were positive but not statistically

significant.²⁸ The variety of meditation intervention types, the short follow-up times and the quality of studies limited the analyses.²⁸ Other systematic reviews reported similar findings, where they reported MBIs such as mindfulness, yoga and relaxation studies maybe useful for the mind-body treatments for PTSD but many of the trials suffered from methodologic weaknesses or were of low to moderate methodological rigor.^{29,30} Further high-quality studies are needed on MBIs among PTSD-diagnosed participants in order to increase confidence in its effectiveness.

Attention-deficit hyperactivity disorder

There is a need for further research before determining the effectiveness of MBIs on attention-deficit hyperactivity disorder (ADHD) despite current studies showed that it can be a promising intervention. A systematic review and meta-analysis has found statistically significant effect of MBIs in decreasing the severity of ADHD core symptoms such as inattention, hyperactivity or impulsivity (children/adolescents: Hedge's $g = -0.44$, 95% CI -0.69 to -0.19 , I^2 0%; adults: Hedge's $g = -0.66$, 95% CI -1.21 to -0.11 , I^2 81.81%).³¹ However, the authors concluded that there is insufficient methodologically sound evidence to support the effectiveness due to limited number of studies, heterogeneity across studies and high risk of bias.³¹ Similar results and conclusions were also noted in several other systematic reviews.³²⁻³⁴

Autism spectrum disorders

Current literature on MBIs for people with autism spectrum disorders (ASD) or their carers is very limited. A systematic review done in 2017 analysed 16 eligible studies but definitive recommendations could not be made on the effects of MBIs for people with ASD or their carers.³⁵ This was because those studies included very diverse age groups and outcome measures, including behavioural, social and psychological symptoms, as well as the subjective well-being of children and adults with ASD and their parents.³⁵ Overall, there may be some potential

benefits of MBIs among people with ASD, these include: reducing anxiety,^{35,36} thought problems,^{35,36} rumination,³⁵ aggression,³⁶ parental stress³⁷, and increasing subjective well-being³⁸ as well as parental psychological wellbeing.³⁷

Cognition

The current available evidence to support MBIs on cognition is weak. A systematic review conducted in older adults with mild cognitive impairment found that MBIs improved participant's cognitive function and everyday activities functioning.³⁹ However, the available studies had small sample sizes, lack of control comparison and lack of follow-up to understand the effects on preventing progression of dementia.³⁹ Further high-quality trials and on different populations are required to confirm the effectiveness of the benefits of MBIs on cognitive function.

Effects on physical health

MBIs can provide positive effects on physical health and evidence is strong regarding benefits of MBIs on the psychological symptoms among people with chronic diseases.

Pain

The evidence of benefits of MBIs on pain is abundant among different populations.^{40,41} A systematic review and meta-analysis of 30 RCTs on chronic pain conducted in 2017 showed improvement on chronic pain management after mindfulness meditation intervention.⁴⁰ The percent change of the mean in pain for intervention subjects was -0.19% (SD, 0.91; min, -0.48 ; max, 0.10), which was significantly higher than the control groups (-0.08% (SD, 0.74; min, -0.35 ; max, 0.11)).⁴⁰ A network meta-analysis found MBSR is effective for chronic pain, and the effects are not significantly different between MBSR and CBT; though more studies are needed to confirm this.⁴¹ Furthermore, for the effects of brief MBIs with a total contact time of less than 1.5 hours, current evidence is inadequate to confirm the effectiveness on acute and chronic pain.⁴²

Hypertension and cardiovascular diseases

A few systematic reviews and meta-analyses suggested that MBIs can reduce blood pressure (BP).^{43–45} A systematic review and meta-analysis of five studies on MBSR showed reduction on systolic and diastolic blood pressure in people with hypertension or elevated blood pressure. However, most of the studies were related to clinical blood pressure only and evidence on ambulatory blood pressure is needed.⁴³ A systematic review among people with non-communicable diseases found systolic BP was reduced after the eight-week MBSR (−6.90 mmHg [95% CI: −10.82, −2.97]), followed by the 12-week breathing awareness meditation (−4.10 mmHg [95% CI: −7.54, −0.66]), and eight-week mindfulness-based intervention (−2.69 mmHg [95% CI: −3.90, −1.49]) and diastolic BP was reduced after eight-week MBSR (−2.45 mmHg [95% CI: −3.74, −1.17]) and the eight-week MBI (−2.24 mmHg [95% CI: −3.22, −1.26]).⁴⁴ Another systematic review among patients with CVD in 2020 showed benefits on systolic BP ($d_+ = 0.89$, 95% CI = 0.26, 1.51) and psychological symptoms ($d_+s = 0.49–0.64$), but not diastolic BP.⁴⁵ Another systematic review by Zou evaluated the effect of mindful exercises for patients after stroke showed significantly improvement on the sensorimotor function on lower limb (SDM = 0.79; 95% CI, 0.43–1.15; $I^2 = 62.67\%$) and upper limb (SDM = 0.7; 95% CI, 0.39–1.01; $I^2 = 32.36\%$).⁴⁶ Further studies can assess gait speed, leg strength, aerobic endurance, motor function, cognitive function and gait parameters.

Weight control and obesity

Overweight and obesity are a significant health risk factor leading to tremendous disease burden due to the associated comorbidities.⁴⁷ Mindful eating is an effective intervention for weight control, especially among people with binge eating or emotional eating tendency. Mindful eating might have longer-term effects when comparing to conventional diet programmes, which involves limiting energy intake and restricting food choices, because mindful eating

tends to be more sustainable and also deal with emotional problems that may influence unhealthy diet.^{48–52} A systematic review and meta-analysis in 2019 evaluated ten mindful eating and weight control studies, and found significant weight reduction after mindful eating program when compared with control groups (−0.348 kg, 95% CI: −0.591 to −0.105).⁵³ Furthermore, effects of MBIs were equal to conventional diet programmes.⁵³ However, limitations were found in the studies, such as short duration and biased samples (unbalanced sex ratio, source and place of living). Hence, further studies with longer duration and modifications of subject selection could be beneficial to evaluate long-term improvement among different populations.

Diabetes

The current evidence to support the effect of MBIs on the physiological outcomes of diabetes is inconclusive. One systematic review found mixed results on the effectiveness of MBIs for physiological outcomes (glycaemic control and blood pressure) on both types 1 and 2 diabetes patients.⁵⁴ Another systematic review and meta-analysis found that meditative movements significantly improved the glycaemic control including fasting blood glucose, glycated haemoglobin (HbA1c) and postprandial blood glucose in type 2 diabetes mellitus (T2DM) patients.⁵⁵ Nonetheless, the authors noted it is difficult to conclude the extent to which MBIs are effective because of the small sample size, short duration and diverse delivery methods within the published studies.⁵⁵ Apart from glycaemic control, systematic reviews also found improvement in psychological symptoms such as anxiety,⁵⁴ distress symptoms,^{54,56} depression^{54,57} and quality of life.⁵⁷ Further research addressing the limitations is necessary to gauge the efficacy of MBIs for diabetes.

Cancer

There may be some benefits of MBIs on the physical health outcomes in cancer patients especially on cancer-related fatigue and pain, besides

psychological benefits.^{58,59} A systematic review and meta-analysis found that MBIs led to a statistically significant reduction in cancer-related fatigue (CRF) score among cancer patients (SMD = -0.51, 95%CI [-0.81-0.20]),⁵⁹ especially among lung cancer patients.⁶⁰ Apart from CRF, a range of other outcomes such as improvements in sleep disturbances, pain and other psychological symptoms including anxiety, depression, fear of cancer recurrence were also found in another systematic review and meta-analysis.⁶¹ Overall, although MBIs appeared effective in reducing CRF and other symptoms, further high-quality studies are still required to provide additional insights and to confirm the existing evidence.

Respiratory health (COPD, asthma, etc.)

The effectiveness of MBIs on respiratory health remained unclear. A systematic review and meta-analysis of 16 studies found that meditative movement may have the potential to enhance lung function and physical activity in Chronic obstructive pulmonary disease (COPD) patients.⁶² When compared to nonexercised group, the intervention enhanced the 6-minute walking distance (3 months: mean difference [MD]=25.40 m, 95% CI: 16.25–34.54; 6 months: MD=35.75 m, 95% CI: 22.23–49.27), as well as functions on forced expiratory volume in 1 s (FEV₁) (3 months: MD=0.1 L, 95% CI: 0.02–0.18; 6 months: MD=0.18 L, 95% CI: 0.1–0.26).⁶² However, taking into considerations of the limitations of the studies such as small sample sizes, inconsistency in study quality and the diverse style of meditative movement in studies, the authors noted that further trials are needed to substantiate the findings.⁶² Other systematic reviews and meta-analyses on COPD⁶⁵ and asthma⁶³ also concluded that further high-quality trials are needed to confirm the effectiveness of MBIs on respiratory health.^{63,64}

Effects on social health and prosocial behaviours

There is evidence supporting effects of MBIs on social health and prosocial behaviours (i.e. voluntary behaviour intended to benefit another).^{65,66}

A systematic review found medium effects on prosocial behaviours for both correlational and intervention studies, and the effects are similar to known and unknown others.⁶⁵ The results suggest that mindfulness fosters ethical and cooperative behaviour across a range of interpersonal contexts and may reduce intergroup biases.⁶⁵ Another recent review with 29 studies also find similar results with small to medium effect sizes, suggesting MBIs reliably improve compassionate helping and reduces prejudice and retaliation.⁶⁶ Furthermore, MBIs can effectively reduce anger,⁶⁷ violence⁶⁸ and aggression.⁶⁹ It also may help improve social and ecological sustainability, by improving individuals' subjective well-being and benign connection with others, the society and the nature.⁷⁰

Loneliness and social isolation are an increasing public health concern, especially during COVID-19 and for older adults. Some preliminary studies indicated that mindfulness training might have positive effect in mitigating loneliness.^{71–74} A preliminary study showed MBSR effectively reduced loneliness in older adults.⁷¹ Another study found positive effect on mitigating the loneliness of women with HIV.⁷² A study among Chinese college students found a positive relationship between mindfulness and loneliness reduction.⁷³ Lindsay et al. raised that mindfulness both reduced loneliness and increased social interactions in daily life compared with an active control program, in the experiment of smartphone-based mindfulness training.⁷⁴

Mindfulness in different settings

Mindfulness among professionals in healthcare settings

Mindfulness has been adopted as a stress management tool for healthcare professionals, with a medium effect size was found ($r = 0.342$, CI = 0.202–0.468).⁷⁵ Systematic reviews and meta-analyses have shown the promising effects on the other psychological indicators among healthcare professionals and students, e.g. reducing depression and burnout and improving emotional resilience.^{76,77} However,

both benefits and challenges (time limitations and feasibility) were perceived at the same time,⁷⁸ and there are insufficient studies on indirect outcomes of MBIs among healthcare professionals, e.g. how it may influence professional-patient communication, relationship and patient outcomes.

Mindfulness in schools

Mindfulness programmes in schools are increasingly popular. Many different school mindfulness programmes (e.g. 'b', mindful schools, well and resilience program) have been implemented across the world.^{79,80} These programmes can target at students, teachers, and even parents or caregivers.⁸¹ Recent systematic reviews found MBIs hold promises in particular in improving resilience to stress, cognitive performance such as attention, and emotional problems in children and youths.^{82,83} The reviews showed a significant effect for resilience in regards to well-being, positive and constructive emotions or affect, social skills and positive relationships, self-concept and self-esteem. The effects (effect size = 0.36–0.80) are comparable or better than the effects (overall effect size = 0.30) of school-based social and emotional learning programs as revealed in the meta-analysis.⁸⁴ It is promising in applying MBIs as a life skill within pre-, elementary, middle or high schools. Students might be benefited from 90-min mindfulness practice per week (i.e. 18 minutes on average per day).⁸⁵ In building up mindful schools, a whole school approach is valuable to integrate mindfulness through the curriculum, professional development of teachers, leadership practice and across the learning environment.⁸⁶

Mindfulness in workplace

A systematic review on 58 592 adults from non-clinical samples showed that trait mindfulness was positively associated with confidence, job satisfaction, performance and interpersonal relations, and negatively associated with burnout and work withdrawal.⁸⁷ A recent systematic review on 56 randomized controlled trials shows that MBIs are beneficial to employees in reducing stress, burnout, mental distress and somatic complaints, while improving

mindfulness, well-being, compassion and job satisfaction—all with small to large effect sizes ranging from Hedge's $g = 0.32$ – 0.77 , but effects on work engagement and productivity were limited by low number of studies.⁸⁸

Cost-effectiveness of MBIs

MBIs are likely to be cost-effective and value for money as it can be provided in group format or as self-help interventions,⁸⁹ and it can also be integrated into educational programmes for clinicians, educationalists and other professionals to directly and indirectly benefit themselves, students, their clients and people around them.⁹⁰ While the benefits are almost equal to cognitive behavioural interventions, mindfulness may require less professional training and take less time for both workers and clients to master, and they are probably less expensive to provide.⁹¹ For example, studies showed that the training cost for teachers in a mindfulness training program ranged from US\$515 to US\$1850 per teacher depending on the number of teachers being trained and the ancillary and opportunity costs.⁹² However, more studies are needed to confirm their cost-effectiveness. Preliminary evidence support its cost-effectiveness,⁹³ including but not limited to pain in breast cancer,⁹⁴ fibromyalgia,⁹⁵ low back pain⁹⁶ and caregiver training.⁹⁷ It is also a cost-saving treatment for improving quality of life for distressed cancer patients using both online or face-to-face MBCT.⁹⁸ However, uncertainties existed in workplace,⁹⁹ and yet it needs cost-effectiveness studies on many other health problems as well.

Compliance of MBIs

Non-compliance is a barrier to learning mindfulness¹⁰⁰ and research shows that the drop-out rate can reach 25% or higher.^{101,102} Inconsistent findings were shown in previous studies regarding who might or might not comply with MBIs. Although in general, women, those with higher openness to experience, higher resistance to change and severer symptoms showed higher levels of compliance.^{103,104} The relationship between participants' compliance and

intervention outcomes is inconsistent, ranging from no correlation to a positive correlation,¹⁰⁵ although one recent systematic review based on 28 studies found a small but significant association between participants' self-reported home practice and intervention outcomes ($r = 0.26$, 95% CI: 0.19–0.34).¹⁰⁶ In terms of factors associated with better compliance, a good natural setting is found to be important, especially for beginners.¹⁰⁰ And some researchers suggested to identify meditation exercises that can balance optimizing effectiveness and enhancing adherence to strengthen the compliance to MBIs.¹⁰⁷ It still needs more research to understand who might comply with and benefit from which type of MBIs the most, and to look into factors and strategies enhancing compliance.

Mechanisms of MBIs

Studies suggested that the mechanisms of MBIs include changes in mindfulness, rumination, worry, self-regulation, compassion or meta-awareness, which predicted or mediated the treatment effects, which are theoretically predicted mechanisms of MBIs.^{108–111} Preliminary results also suggested alterations in attention, memory specificity, self-discrepancy, emotional reactivity and momentary positive and negative affect, can be part of the mechanisms.¹⁰⁸ Recently, the mindfulness-to-meaning (MMT) approach has also been recognized as providing a theoretical framework to investigate specific mindfulness components and their contributions to the positive health outcomes.^{112,113} In this approach, the iterative cycle of appraisal, decentering and metacognition would lead to positive reappraisals of broader contexts that extinguish negative affect and promote positive effects and eudaimonic meaning in life.^{112,113} Yet, there are still many unknowns regarding the mechanisms of MBIs.

Neurophysiological findings

The changes on brain and biomarkers of immune function and stress might have provided

neurophysiological basis for explaining the positive effects of MBIs. Systematic reviews have consistently found effects of MBIs on brain activity that involves in processing self-relevant information, self-regulation, focused problem-solving, adaptive behaviour and interoception, among both healthy populations and patient groups.^{114–119} Eight brain regions key to meta-awareness (frontopolar cortex), body awareness (sensory cortices and insular), memory consolidation and reconsolidation (hippocampus), self and emotion regulation (anterior and mid cingulate; orbitofrontal cortex), and intra- and interhemispheric communication (superior longitudinal fasciculus; corpus callosum) consistently altered with a medium effect size after mindfulness practices.¹¹⁸ In expert meditators, both functional and structural brain modifications have been induced, especially in areas involved in self-referential processes such as self-awareness and self-regulation, though not enough evidence suggests structural brain modifications in short-term meditators.¹¹⁴ Among people with major depressive disorders, MBIs have also modulatory effects on several brain regions (e.g. the prefrontal cortex, the basal ganglia, the anterior and posterior cingulate cortices and the parietal cortex).¹¹⁵ Another systematic review on 78 functional neuroimaging (fMRI and PET) studies of meditation found patterns of brain activation and deactivation for common styles of meditation (focused attention, mantra recitation, open monitoring and compassion/loving-kindness), with medium effects for both activations ($d = 0.59$) and deactivations ($d = -0.74$), suggesting potential practical significance.¹¹⁶ The systematic review on EEG results suggested that mindfulness is associated with increased alpha and theta power in both healthy populations and patient groups, which may signify a relaxed alertness state contributing to mental health.¹¹⁷

Systematic reviews on RCTs revealed that mindfulness meditation have effects on stress and immune-related physiological markers of inflammation, cell-mediated immunity and biological aging: reductions in the activity of the cellular transcription

factor NF-kB, reductions in circulating levels of C-reactive protein, increases in CD4+ T cell count (in HIV-diagnosed individuals), and increases in telomerase activity.¹²⁰ Another systematic review on RCTs found that, compared to an active control (relaxation, exercise or education), mindfulness meditation reduced physiological markers of stress, such as cortisol, C-reactive protein, systolic blood pressure, heart rate, triglycerides and tumour necrosis factor-alpha, in various populations.¹²¹ And a greater number of hours of meditation are associated with a greater impact on telomere biology.¹²² However, these tentative findings need further replication and the review authors call for studies to include physiological markers as primary outcome of RCTs.^{120–123}

Ethics of MBIs

Ethical questions are fundamental and essential in guiding the future directions of MBIs to use the right mindfulness rightly, and also the application of MBIs should not overstate the organizational and social determinants of ill health. In the books of ‘Practitioner’s Guide to Ethics and Mindfulness-Based Interventions’ (edited by Lynette Monteiro, Jane Compson and Frank Musten) and ‘Handbook of Ethical Foundations of Mindfulness’ (edited by Stanley Steven, Ronald Purser and Nirbhay Singh), ethical questions of mindfulness are discussed extensively. Many questions on ethics are yet to be addressed for MBIs. For example, paradox in teaching mindfulness in business and military settings, depriving superiors to make use of subordinates through mindfulness regardless of other organizational factors causing work-related stress or depression. On the other hand, there are many virtues and strengths in MBIs in providing personally meaningful and prosocial values,¹²⁴ and MBIs can improve ethical standards, that mindfulness promotes greater ethical intentions and lesser ethical infractions, with more mindful people revealed a greater emphasis on moral principles than those who are less mindful.¹²⁵

Safety of MBIs

MBIs are regarded as relatively safe interventions.¹²⁶ Like many other psychological intervention trials, adverse events and adverse effects of MBIs are largely underreported. A previous systematic review on safety of MBSR and MBCT indicated that fewer than one in five trials had mentioned the monitoring of adverse effects.¹²⁶ Program-related factors, participant-related factors, and clinician- or teacher-related factors are potential sources of adverse effects.^{1,126–132} A safety checklist is yet needed to be built based on previous studies and empirical experiences. Practitioners and researchers in future MBI programmes are advised to report the potential adverse events using such a checklist, and also continue to take safety precautions such as screening and caring for vulnerable individuals. These individuals could be those with PTSD, seizure disorder/epilepsy, acute psychosis, mania, suicidality or other health problems of concern.¹³³

Future directions

Despite the increasing trend of mindfulness studies and applications, there are still many areas need exploration. First, higher quality of research studies is needed. The most frequent limitations mentioned in the systematic reviews on effectiveness and cost-effectiveness of MBIs are low quality of study design, small sample size, short follow-up period, and inconsistent terminology and measurement tools. Future more robust studies are needed to address these caveats. Second, more studies on online MBIs intervention and training are needed to understand if online alternatives have equal or better effects and cost-effectiveness, though preliminary benefits are seen.^{10,134,135} Online alternatives might be important, especially given the pandemic of COVID-19. Third, more understanding of the mechanisms by integrating both empirical findings and neurophysiological findings. Fourth, more research is needed to explore the acceptance and compliance of MBIs to understand who might benefit more from MBIs, and barriers and respective

strategies (e.g. better meditation environment) for improving the acceptance and compliance, taken into considerations of safety issues and ethical concerns. And a closer look at the long-term compliance is needed. This may call for large-scale cohort studies on MBIs. Fifth, develop more mindfulness related research and services guidelines and regulations, e.g. on adverse events monitoring and safety guarantee, and qualifications of mindfulness teachers. These might be important when MBIs are provided as a collective action in schools, companies or organizations. Sixth, exploration of Mindfulness Plus (Mindfulness+), i.e. combination of MBIs with other effective interventions (for example, mindfulness plus medications, mindfulness plus behavioural activation,¹³⁶ mindfulness plus reflection training¹³⁷ and mindfulness plus Qigong movement therapy¹³⁸), or exploration of personalized/individualized mindfulness-based interventions for individuals with different characteristics and needs, selecting from many different mindfulness programs. This would provide more potential to improve the effects of MBIs for different goals.

Conclusion

MBIs are effective for many common mental, physical and social health conditions among different populations. Beneficial effects of MBIs have been found on depression, anxiety, stress, insomnia, addiction, psychosis, pain, hypertension, weight control, cancer-related symptoms and prosocial behaviours. Current evidence suggested MBIs can be beneficial for healthcare professionals and within schools and workplaces although more studies are still needed to look into its efficacy on many different biopsychosocial health conditions. MBIs are relatively safe. Ethical aspects should always be taken into account during mindfulness-based trainings and interventions. Mechanisms of MBIs have been suggested in both empirical and neurophysiological findings. Cost-effectiveness is found for some health problems (e.g. breast cancer, fibromyalgia, low back pain or caregiver training). More high-quality studies with adequate sample size and longer follow-up

duration are needed to confirm its effectiveness and cost-effectiveness in many other problems and among sub-groups. Some other areas needing additional research are suggested in this review.

Conflict of interest statement

None.

Data availability statement

There are no new data associated with this article.

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