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Mindfulness and Cardiovascular Disease Risk: State of the Evidence, Plausible Mechanisms, and Theoretical Framework

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Abstract The purpose of this review is to provide (1) a synopsis on relations of mindfulness with cardiovascular disease (CVD) and major CVD risk factors, and (2) an initial consensus-based overview of mechanisms and theoretical framework by which mindfulness might influence CVD. Initial evidence, often of limited methodological quality, suggests possible impacts of mindfulness on CVD risk factors including physical activity, smoking, diet, obesity, blood pressure, and diabetes regulation. Plausible mechanisms include (1) improved attention control (e.g., ability to hold attention on experiences related to CVD risk, such as smoking, diet, physical activity, and medication adherence), (2) emotion regulation (e.g., improved stress response, self-efficacy, and skills to manage craving for cigarettes, palatable foods, and sedentary activities), and (3) self-awareness (e.g., self-referential processing and awareness of physical sensations due to CVD risk factors). Understanding mechanisms and theoretical framework should improve etiologic knowledge, providing customized mindfulness intervention targets that could enable greater mindfulness intervention efficacy.

Keywords Mindfulness · Cardiovascular disease · Etiology

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Introduction

Scientific findings on the role of mindfulness in health are becoming clearer as larger numbers of increasingly methodologically rigorous studies are published [1••, 2••]. Systematic reviews and meta-analyses of randomized controlled trials suggest protective effects of mindfulness practices on depression relapse and non-clinical anxiety symptoms [1••, 3, 4]. Research about the impacts of mindfulness on cardiovascular disease (CVD) risk is in a much more nascent phase, but recent systematic reviews and meta-analyses suggest possible benefits for obesity, blood pressure, and smoking [5, 6, 7•, 8]. CVD remains the primary cause of mortality worldwide [9]. However, mindfulness studies on CVD risk are relatively few, and many are of fairly low methodological quality, often utilizing small sample sizes and brief follow-up times. Furthermore, the mechanisms and theoretical framework by which mindfulness may influence CVD have been minimally explored or discussed. Understanding the mechanisms, and delineating a theoretical framework, will not only allow for improved etiologic knowledge but will also provide targets that mindfulness interventions can be tailored to better engage with [10••]. More specifically, identifying the mechanisms of

change through which mindfulness interventions could influence CVD risk is critical for developing the most effective and simple interventions, as recommended in the National Institutes of Health Stage Model for Intervention Development [10••]. If we understand the mechanisms through which an intervention is working, we can then better customize the intervention to act on those mechanisms. By knowing which plausible mechanisms are not important, those can be trimmed out of interventions to make them more cost-effective [10••].

The purpose of this review is to provide (1) an overview on the relationship of mindfulness with CVD and major CVD risk factors including smoking, diet, physical activity, obesity, lipids, blood pressure, and diabetes, and (2) an initial consensus-based overview of the mechanisms and theoretical framework by which mindfulness might influence CVD.

What Is Mindfulness?

Mindfulness is often defined as the ability to attend in a non-judgmental way to one's own physical and mental processes during ordinary, everyday tasks [11]. A consensus two-component mindfulness definition stated that "The first component involves the self-regulation of attention so that it is maintained on immediate experience, thereby allowing for increased recognition of mental events in the present moment. The second component involves adopting a particular orientation toward one's experiences in the present moment, an orientation that is characterized by curiosity, openness, and acceptance" [12]. Other traditional versions of mindfulness definitions include elements of "remembering" or "holding something in mind," which could be important if what is held in mind are aspects that can positively influence well-being [13, 14••]. "Dispositional mindfulness" represents an inherent, yet modifiable, trait, where all people have varying capacities to attend and to be aware of what is occurring in the present moment [15].

The current review included studies that evaluated either mindfulness interventions or dispositional mindfulness. As there is an increasing variety of mindfulness interventions, we attempt to state the types of interventions when possible. For example, mindfulness-based interventions derived from mindfulness-based stress reduction (MBSR) have strong emphases on meditation [16]. MBSR is a multicomponent intervention providing systematic training in formal mindfulness meditation practices, and the informal application of mindfulness in daily life. It also includes gentle stretching and mindful yoga, as well as psychoeducation about the applications of mindfulness to support improved health, health-enhancing behaviors, and stress reduction. Subsequent adaptations of MBSR have been developed for a variety of conditions such as preventing relapse of recurrent depression, named mindfulness-based cognitive therapy (MBCT) [17]. Other mindfulness interventions such as acceptance and commitment therapy (ACT) overlap a reasonable amount theoretically with mindfulness-based interventions such as MBSR but have less emphasis on formal meditation practice [18]. There have been almost no explanatory studies in the cardiovascular literature to identify active components of mindfulness interventions [19••, 20••]. Consequently, we present interventions that address any type of mindfulness in order to be inclusive of the range of possible approaches. We also include studies that evaluated dispositional mindfulness assessed via questionnaires with validation evidence. There is current debate on the accuracy of self-reported mindfulness [21•, 22•]. Readers are referred to a systematic review of self-reported mindfulness questionnaires for further information on validity and reliability [22•]. We aim to clearly distinguish between these categories of evidence to allow readers to evaluate findings according to distinct mindfulness measures and interventions.

Is Mindfulness Predictive of CVD Risk or Cardiovascular Health?

There is some evidence that dispositional mindfulness may be related to cardiovascular health, based on a cross-sectional study of 382 US participants who showed a 86 % higher likelihood (prevalence ratio 1.86; 95 % confidence interval (CI) 1.08, 3.19) of having good cardiovascular health with high versus low dispositional mindfulness levels [23•]. However, there is virtually no evidence on whether mindfulness is related to cardiovascular events. Despite this, there is a small but growing body of evidence on the relation between mindfulness and CVD risk factors. This review focuses on conventional CVD risk factors and components of cardiovascular health including physical activity, smoking, diet, obesity, blood pressure, lipids, and diabetes, described below and shown in Fig. 1.

Physical Activity

Mindfulness-based interventions have potential to positively influence physical activity; however, there has been relatively little research in this area. To date, cross-sectional observational studies typically demonstrate that higher levels of dispositional mindfulness are associated with greater physical activity levels [23•, 24, 25]. A prospective observational study demonstrated that individuals with higher levels of dispositional mindfulness were more likely to follow through with baseline intentions to be physically active at 5 weeks follow-up [26]. A few ACT randomized controlled trials (RCTs) showed promising effects on increasing physical activity after 1 h to 6 months of follow-up time [27–30]. A recent observational study showed that mindfulness was associated with

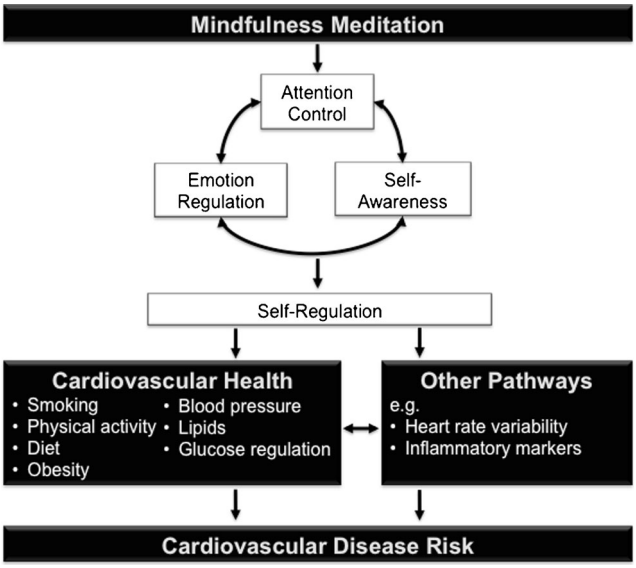

Fig. 1 Conceptual framework suggesting plausible mechanisms by which mindfulness meditation may influence cardiovascular disease risk

physical activity levels only in participants with weak habits for regularly doing physical activity [31]. These findings need to be replicated in intervention studies but suggest early evidence for possible ceiling effects, where mindfulness may be most effective in those with lower physical activity levels.

Smoking

A small number of RCTs evaluated efficacy of mindfulness training for smoking cessation [8]. For example, mindfulness training for smoking cessation was significantly more efficacious than the American Lung Association's Freedom From Smoking for abstinence at a 4-month follow-up (31 vs 5 % abstinence, respectively) [32]. More recently, a mindfulness intervention called "Mindfulness Training for Smokers" reported significant differences in abstinence between treatment initiators and controls in a disadvantaged population (39 vs 21 %), but no difference in a more generalizable population (25 vs 18 %) [33]. There is very recent early evidence that expansion into app- and web-based delivery may be effective [34–36]. The intervention findings are supported by a meta-analysis of 11 observational studies that showed significant inverse associations between dispositional mindfulness and smoking (aggregate $r=-0.14$; $p<0.001$) [37]. Overall, recent review articles suggest that mindfulness may have promise as a treatment for smoking cessation, but also highlight the need for more adequately powered and controlled trials, replication of findings, and identifying the important active components of the mindfulness interventions that may be most effective for long-term smoking cessation [8, 38, 39].

Diet

The evidence for mindfulness approaches to changing dietary intake is preliminary but promising. RCTs of mindfulness interventions showed reduced caloric intake in diabetic participants (using the Mindfulness-Based Eating Awareness Training for Diabetes intervention) [40] and improved dietary composition in men with prostate cancer (using a diet intervention that incorporated mindfulness training) [41]. A prospective evaluation of MBSR in a general community population showed increased fruit and vegetable intake, and reduced consumption of desserts and other sweets, at program completion versus baseline assessments, in a study without a control group [42]. Another uncontrolled prospective MBSR study, in a sample comprising of war veterans, showed no changes in dietary patterns at preprogram versus postprogram completion [43]. Higher levels of dispositional mindfulness have been associated with more restrained eating, and less emotional and external eating behavior, in morbidly obese adults and diabetics [44, 45]. Evidence to date on effects of mindfulness on dietary patterns related to CVD is preliminary but offers an early signal of potential effects. Well-designed observational studies and RCTs of mindfulness interventions targeting dietary patterns that influence CVD have potential to show effects.

Obesity

Several systematic reviews evaluated mindfulness interventions for weight loss and obesity-related eating behaviors [5, 6, 46, 47]. One review consisting of nine weight loss studies used a narrow definition of mindfulness-based interventions requiring that mindfulness practices be a component of every session [47]. Overall, effects on weight loss post-intervention were small or non-significant, but significant effects were observed in the three studies focusing on weight loss as a primary outcome [47]. Two other systematic reviews used broader definitions of mindfulness interventions that included any study in which at least one session focused on mindfulness skills training. One review focusing on weight loss as the primary outcome found that weight loss was documented in 13 of 19 studies [48]. The other review, which focused on interventions for eating behaviors associated with weight gain [5], found that weight loss or maintenance was demonstrated in 9 of 10 studies, with a small effect size (Cohen's $d=0.19$). Intervention findings are consistent with other observational study data showing those with higher dispositional mindfulness significantly more likely to have healthy BMI levels (≥ 18.5 and <25.0 kg/m^2) [23•]. The role of mindfulness interventions in weight loss has been reviewed in greater detail by our group elsewhere [49]. Future directions include the need for more rigorous, fully powered randomized trials with longer follow-up periods, and inclusion of diverse populations.

Blood Pressure

A recent systematic review and meta-analysis of four mindfulness-based interventions found significant but heterogeneous effects on blood pressure [7•]. The overall effect was statistically significant (standardized mean difference for mindfulness intervention versus control: −0.78 for systolic blood pressure, p=0.03; −0.67 for diastolic blood pressure, p=0.03) [7•]. Methodological rigor for several of the studies was limited, including fairly high loss-to-follow-up for some studies, and brief follow-up periods with the exception of one study that had a 1-year follow-up period [50]. Reasons for differences in effect size between studies may be floor effects, where the largest effects were seen in the study that had participants with the highest blood pressure (unmedicated stage 1 or 2 hypertension) [51] versus other studies that included participants with unmedicated stage 1 hypertension [50] or prehypertension [52] or those who did not have blood pressure level inclusion criteria [53]. Other reasons may be that analyses showing greater effects used resting blood pressure as the outcome [51–53] instead of ambulatory blood pressure [50, 52]. The field will be helped with methodologically rigorous, well-powered RCTs evaluating impacts of standardized and customized mindfulness interventions for blood pressure reduction [54].

Lipids

One cross-sectional observational study in 346 middle-aged participants showed no associations between dispositional mindfulness and total cholesterol [23•]. The relation between mindfulness and lipids remains almost completely unexplored.

Diabetes and Glucose Regulation

Several studies investigated contributions of mindfulness interventions to glucose regulation in diabetic patients. Of the five RCTs to our knowledge, two demonstrated significant reductions in glucose regulation measures including HbA1C and fasting glucose [55, 56], and three showed null findings [53, 57, 58]. Both interventions that demonstrated significant improvements in glucose regulation specifically trained participants in mindfulness as well as behaviors that improve glucose regulation, such as diet, physical activity, glucose monitoring, and diabetes medication use (using the mindfulness interventions ACT or mindful eating/yoga) [55, 56]. Studies failing to show improvements in glucose regulation tested standardized mindfulness-based interventions, specifically MBCT [57, 58] and MBSR [53]. These standardized interventions provide some training in mindful eating and mindful movements but do not deliberately link the importance of these factors to diabetes control and do not address diabetes medication adherence or glucose monitoring [59, 60•]. Mindfulness interventions targeted toward improving mindfulness skills for glucose regulation may increase effect sizes. With regard to dispositional mindfulness, one study showed that participants with high versus low mindfulness were significantly more likely to have normal glucose levels, but these findings need replication [23•].

Other Pathways

Other CVD risk markers and risk factors may also be important in explaining mechanisms by which mindfulness interventions could influence CVD risk (Fig. 1). For example, a number of studies have explored the role of mindfulness interventions to influence heart rate variability [61, 62] and inflammatory markers [63–65]; however, in order to allow some depth of exploration into specific CVD risk factors, the current review is focused on conventional independent CVD risk factors.

How Could Mindfulness Influence CVD Risk?

The mechanisms and theoretical framework proposed herein build on important foundational work of others, particularly Holzel et al. [66•], Vago and Silberstein [67], and Tang et al. [2••] who focused reviews on mechanisms by which mindfulness could influence mental health. As shown in Fig. 1, preliminary evidence suggests that mindfulness meditation may influence health particularly through improved self-regulation, via enhancing (1) attention control, (2) emotion regulation, and (3) self-awareness [2••, 66•, 67]. These pathways are explored below in relation to CVD risk.

It should be noted that these plausible mechanisms are presented with the invitation to rigorously test them using methods such as RCTs and prospective observational studies, incorporating formal mediation analyses [68•] to evaluate if they truly are mediators between mindfulness and CVD risk. At the current time, there is limited quantitative evidence. However, based on theoretical underpinnings and evidence to date of mechanisms of mindfulness on health [2••, 66•, 67, 69•], and determinants of CVD [70, 71], these are likely some of the strongest candidates. Understanding mechanisms will not only improve etiologic knowledge but also greatly assist in identifying targets for customized mindfulness interventions, described above [10••].

Attention Control

Attention control is emphasized in mindfulness meditation and improves as a result of meditation practices [66•, 72]. In mindfulness-based interventions, attention control is frequently trained through bringing awareness to a single object, such

as the breath [66•]. Through this technique, it appears that brain regions such as the anterior cingulate cortex are altered, facilitating executive attention and control [2••]. Attention can also be directed toward more emotionally challenging objects. Related to CVD risk, improved abilities to hold attention to positive, and often predominantly negative, sensations associated with risk factors such as smoking, overeating, sedentary activities, or medication adherence could be important [6, 8, 31]. Often the mind has some aversion to emotionally strong objects (particularly negative emotions), and attention can be diverted to more emotionally neutral sensations. However, theoretical underpinnings of mindfulness meditation support the benefits of bringing gentle, non-judgmental, curious attention to difficult emotions and thoughts, to explore their characteristics and roots [16]. For example, a smoker can hold attention to each moment associated with cigarette smoking, both enjoyable (e.g., having a break from work) and difficult (e.g., chronic cough due to smoking, and other health effects). Training the mind to hold each and every moment in awareness can start to highlight the short- and longer-term effects of smoking, or other CVD risk behaviors such as overeating, sedentary activities, and medication adherence, thereby helping people see more clearly, creating cognitive dissonance [73], enhancing intrinsic motivation [74] and internalization [75]. This can allow a more informed decision to be made about the personal value of engaging in CVD-related behaviors.

Emotion Regulation

Stress Response

A systematic review and meta-analysis of 118,696 participants demonstrated a risk ratio of 1.27 (95 % CI 1.12, 1.45) for the relation of high versus low perceived stress with incident CVD [76]. A meta-analysis of 197,473 participants demonstrated that those with job strain versus those with no job strain had 1.17 (95 % CI 1.05, 1.31) higher hazard ratio for incident CVD, after adjusting for age, sex, and socioeconomic status, with a fairly small population attributable risk of 3.4 % [77•]. A systematic review and meta-analysis of 31 cohorts found that laboratory-induced stress reactivity was significantly associated with resting systolic (r=0.12, 95 % CI 0.08, 0.16) and diastolic blood pressure (r=0.08, 95 % CI: 0.05, 0.11), but not with subclinical measures of CVD such as coronary artery calcification (r=0.01, 95 % CI −0.01, 0.03) [78]. Furthermore, slow recovery from laboratory-induced stress was significantly associated with resting systolic (r=0.08, 95 % CI 0.01, 0.15) and diastolic blood pressure (r=0.08, 95 % CI 0.03, 0.13), and coronary artery calcification (r= 0.14, 95 % CI 0.05, 0.23) [78].

Mindfulness-based interventions often explicitly address stress, particularly through normalizing stress experiences, and enhancing awareness of how one responds to stress [59, 60•]. Often stress reactions can evoke additional stress through persistent negative thinking or rumination about the event for sustained time periods [69•]. Mindfulness-based interventions often emphasize bringing awareness to the stressor, noticing inner drives for reacting, and allowing some space in between the stressor and response, to allow for a more careful response to the stress rather than a reaction [59, 60•]. Certain types of meditations can also focus in on stressors themselves, allowing for a form of exposure therapy, to allow the stressors to be experienced in controlled ways, thereby practicing more effective responses to frequently experienced stressors [2••]. Acute stress can involve rapid activation of the amygdala to allow for immediate responses that can be life-saving [79]. The prefrontal cortex, responsible for executive function and control, modulates amygdala activity, allowing for top-down regulation of limbic information processing [79]. The impact of mindfulness training on stress response in the brain is supported by neurophysiological evidence demonstrating reduced amygdala activation, increased prefrontal cortex activation, and increased hippocampal gray matter density following mindfulness interventions [2••]. A recent systematic review and meta-analyses of nine RCTs showed evidence that mindfulness mediation programs may reduce stress compared to non-specific active control groups; however, the strength of evidence to date was considered low [1••]. Overall, evidence suggests stress as a plausible pathway; however, stronger evidence is needed on the population attributable risk of stress reactivity and stress recovery for CVD, as well as higher-quality studies evaluating if mindfulness interventions impact stress, including stress response and recovery.

Craving

Evolutionarily, humans have had good cause to crave high caloric palatable foods and physical rest [80, 81]. In many current industrialized societies, this craving no longer achieves the same adaptive benefits due to much greater food availability, and sedentary occupations and pastimes [80]. Craving and resulting behaviors can lead to excessive food consumption, obesity, and poor physical conditioning [80, 81]. Mindfulness has been positively associated with greater self-regulation and ability to notice cravings without acting on them [32, 82]. Treating emotions and physical sensations as passing events can help people tolerate cravings and overcome addictions, whether it is for cigarettes [32] or potentially for high caloric palatable foods, or sedentary activities such as electronic screen use [6, 83]. In the mindfulness training for smoking cessation RCT, mindfulness practice was found to moderate decoupling of the link between craving and smoking [84]. Neurophysiological studies showed that regions of the prefrontal cortex, including the dorsolateral prefrontal cortex and anterior cingulate cortex, are implicated in self-regulation

and inhibitory control related to limiting excessive hedonic (i.e., pleasure-focused) feeding behavior [80]. Mindfulness meditation has been shown to influence these same regions [2••].

Self-Efficacy and Sense of Control

Self-efficacy is the extent or strength of belief in one's own ability to complete tasks and reach goals. Sense of control is a related concept, often operationalized as personal mastery (a person's sense of efficacy or effectiveness in carrying out goals) and perceived constraints (the extent to which one believes there are obstacles or factors beyond one's control that interfere with reaching goals) [85]. Deciding to initiate a health behavior change depends on interactions between motivation and confidence about successful change [86]. Confidence about making change is often related to self-efficacy [87] and perceived behavioral control [88–90]. Self-efficacy and sense of control have been linked to CVD mortality and CVD risk behaviors, although replication of findings in high-quality prospective studies is needed [91, 92]. A trial of a mindfulness-oriented intervention for addictive disorders demonstrated enhanced perceived control over motor activity related to impulsive behavior [93]. Patients with chronic pain, chronic illness, or stress-related problems taking MBSR were shown to have significantly higher self-efficacy, related to their confidence to manage conditions on a regular basis, at 1-year follow-up compared to baseline [94]. A recent cross-sectional mediation analysis showed preliminary evidence that sense of control may be a mediator between dispositional mindfulness and cardiovascular health [23•].

Self-Kindness and Self-Compassion

Self-kindness and self-compassion are interrelated plausible pathways that could link mindfulness to CVD risk. During MBSR and MBCT, group leaders often convey implicit messages about the importance of being kind and gentle with oneself, encouraging strong determination in meeting practice goals while also emphasizing self-kindness when goals are not met [95]. Mindfulness-based interventions, such as MBSR and MBCT, may enhance participants' self-compassion [95]. One study found self-compassion to be a mediator of the effects of MBCT on depression [96], although replication is needed. Self-compassion may be particularly effective for patients with CVD risk factors that have societal stigma such as obesity [97] and tobacco dependence [98]. Self-compassion is associated with increased motivation and persistence after task failure [99] and healthier behaviors such as physical activity and regular doctor visits [100].

Social Support

Social support and related inverse constructs such as social isolation and loneliness are potentially important for CVD and mortality [101–103]. For example, in a systematic review of prospective studies on participants with existing coronary heart disease, 9 of 10 studies showed significant associations between social support and incidence of fatal coronary heart disease, non-fatal myocardial infarction, or all-cause mortality [102]. Associations in healthy participants are more heterogeneous, where five of eight studies showed significant inverse associations between social support and incidence of coronary heart disease [102]. Mindfulness meditation is often practiced in meditation groups [65]. The group support may be an important component of meditation training, and for providing continued meditation practice support afterward, similar to behavioral change programs for alcohol abstinence (e.g., Alcoholics Anonymous) and weight loss (e.g., Weight Watchers) [104, 105]. A study that randomized 170 participants trying to lose weight to practice mindfulness meditation for 6 weeks within a group versus practicing alone demonstrated, using intent-to-treat analyses, that the group setting produced significantly ($p<0.001$) greater weight loss (mean 1.66 kg) than the individual setting (mean 0.45 kg) [104]. Another randomized controlled trial ($n=40$) demonstrated significant reductions in loneliness in the group randomized to MBSR versus waist-list control [65].

Self-Awareness

Self-Referential Processing

Self-referential processing is defined as self-reflection about internal thoughts and feelings, in the absence of external stimulus processing [106, 107]. Brain networks that have most consistently been implicated in self-referential processing include the default-mode network [106, 108]. Importantly, the main hubs of this network, including the medial prefrontal cortex and posterior cingulate cortex, have been shown to be specifically deactivated in experienced meditators relative to novices, across several different types of meditation [109]. More recently, direct links have been made between increased activation in midline brain regions such as the posterior cingulate cortex and the experience of being "caught up" in self-related states that may be related to CVD risk, such as craving [110]. Mindfulness meditation training has been directly associated with decreased activity in this same brain region [111–113].

Mindfulness interventions appear to strengthen a metacognitive ability to step back from getting caught up in emotional reactivity, habitual behaviors, and self-narratives, in a process referred to as decentering [114–117]. Decentering is

typically defined as the process of observing one's thoughts and feelings as passing events in the mind, rather than as valid reflections of reality or central aspects of the self [115–117]. Individuals high in decentering tend to exhibit lower blood pressure reactivity [118]. Studies that formally evaluate whether decentering is a risk factor for CVD, and if it mediates the relation between mindfulness practices and CVD risk, would provide important information.

Values Clarification

Values clarification, or the recognition and delineation of what is truly meaningful or valuable in one's life, is another potential mechanism of mindfulness interventions [18, 119]. Individuals tend to be more motivated and likely to engage in behaviors consistent with their values, especially clearly identified values [120]. Since mindfulness is associated with greater ability to identify and discriminate between different emotions (i.e., emotional clarity), mindfulness might also help to clarify values, and therefore enhance motivation for valued behaviors [121–123]. Studies suggest that meditation practice is associated with increases in values clarification and purpose and that values clarification is associated with positive psychological states and sense of control [124, 125]. Furthermore, observational studies demonstrated that higher values clarification levels were associated with lower temptation to drink alcohol and lower drinking frequency and drinking-related consequences [126], and that values clarification mediated associations between dispositional mindfulness and alcohol-related problems [127].

Awareness of Present-Moment Experiences

Present-moment experiences are felt through physical sensations, thoughts, and emotions [59]. In many mindfulness interventions that bring curious, non-judgmental awareness to thoughts, emotions, and physical sensations, the resulting improvements in interoception shift self-processing away from narrative toward experiential self-processing in part by favoring body-based sensory experiences [128]. Interoceptive body awareness is the ability to notice subtle bodily sensations [129, 130] and is reported to be enhanced with meditation [66•, 131, 132]. Awareness to body sensations may be particularly important for CVD risk reduction, especially enhancing awareness related to body-specific positive experiences (e.g., eating healthy palatable foods and physical exercise completion) and negative experiences (e.g., physical limitations due to inadequate physical activity, lethargy following sugar consumption, joint pain associated with obesity, and cigarette craving) [130, 133–135]. Through enhancing awareness to each moment, participants can be trained to clearly feel the short- and longer-term effects of CVD risk behaviors and potentially make healthier behavior decisions as a result.

Conclusions and Future Directions

Overall, studies to date suggest promising but still inconclusive evidence of associations of mindfulness with cardiovascular health [23•], and CVD risk factors, specifically smoking, blood pressure, diabetes, physical activity, obesity, and diet [5, 6, 7•, 8, 23•, 24–32, 37, 38, 40–43, 46, 47, 53, 55–58]. Areas needing further work include performing adequately powered RCTs adhering to CONSORT guidelines [136–138], careful consideration of control groups for pragmatic versus explanatory trials [19••, 20••, 105], longer-term follow-up [50, 58], and comparative effectiveness of tailored versus standardized general mindfulness interventions. It is important to identify which participants are most likely to benefit from mindfulness interventions, and to explore customizing mindfulness interventions to target populations [33]. The theoretical framework described here suggests that three main components may be active processes by which mindfulness interventions can exert cardiovascular effects, specifically (1) attention control (e.g., ability to hold attention on experiences related to CVD risk, such as smoking, diet, physical activity, and medication adherence), (2) emotion regulation (e.g., improved stress response, self-efficacy, and skills to manage craving for cigarettes, palatable foods, and sedentary activities), and (3) self-awareness (e.g., self-referential processing and awareness of physical sensations due to CVD risk factors). These proposed pathways need much further testing to determine which, if any, are particularly important. Customized mindfulness interventions may want to consider engaging with these plausible mechanisms of change to evaluate if doing so increases intervention effectiveness on CVD risk.

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Compliance with Ethical Standards

Conflict of interest Eric B. Loucks, Zev Schuman-Olivier, Willoughby B. Britton, David M. Fresco, Gaelle Desbordes, Judson A. Brewer, and Carl Fulwiler declare that they have no conflict of interest.

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- • Of importance
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