

Mindfulness-Based Interventions and Cardiovascular Risk Factors in US Racial/Ethnic Minority Populations: A Systematic Review of Implementation Data to Address Health Disparities

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Abstract

Cardiovascular disease (CVD) is a persistent public health challenge. Mindfulness-based Interventions (MBI) have been researched for CVD risk factors, though their effectiveness, generalizability, and potential for implementation to racial and ethnic minorities remain unclear. This review examines studies of MBI on CVD risk for characteristics of and variations in implementation (i.e., intervention design, delivery, uptake, and contextual factors) and analyzes potential barriers and challenges to implementation. A systematic review in February 2020 identified 30 studies from 5 databases and hand searches. Included studies were randomized controlled trials testing meditation or mindfulness-based interventions against any control to measure change or improvement in cardiovascular health measures or risk behaviors in adults living in the United States or territories. Analysis of the implementation characteristics and contextual factors of included studies was conducted using the Oxford Implementation Index. Thirty reports from 26 distinct trials were selected for inclusion, examining outcomes related to diet (k [number of studies] = 13), smoking (k = 11), obesity (k = 9), exercise (k = 4), diabetes (k = 3), and blood lipids (k = 2). All studies were published between 2011 and 2020 and correspond to early stages of research. As such, numerous limitations and implementation characteristics with potential consequence for CVD risk disparities were reported. This review outlines several potential targets for future research. Based on reported findings across all included studies, MBI could be of benefit for cardiovascular disease risk. Further research is needed to explore acceptability, feasibility, and effectiveness in minority populations.

Introduction

In the United States (US), cardiovascular disease (CVD) is the leading cause of death among adults [1], with CVD and risk factors disproportionately impacting racial and ethnic minorities [2-6]. Cardiovascular risk factors have been outlined by leading health organizations in the United States and include the following modifiable risk conditions and behaviors: (1) diabetes mellitus (type-2), (2) smoking, (3) obesity, (4) sedentary lifestyle, (5) unhealthy diet [1, 3].

Disparities in cardiovascular disease and risk.

Significant disparities in cardiovascular disease for racial and ethnic minorities are well-documented. Factors contributing to these disparities occur at the level of the patient, the provider, and the overall healthcare system, and include health behaviors, genetics, provider bias (intentional or unintentional), and access to healthcare coverage [7]. Black Americans have higher rates of heart attack, heart failure, and stroke [8-9]. Hypertension prevalence is higher in Black Americans than in White Americans, occurs at younger ages, and is often accompanied by higher blood pressure, correlating with increased overall risk of cardiovascular disease [4]. Along with Mexican-Americans, black patients have the highest rates of high blood pressure and exhibit greater difficulty controlling blood pressure levels, relative to other

demographic groups [10]. Black women are also 3 times more likely to die from preeclampsia caused by hypertension than their white counterparts [11].

Significant disparities also exist for the risk factors of cardiovascular disease in the United States. In April 2019, the National Center for Health Statistics reported that Hispanic and Non-Hispanic Black men were most likely to be obese and to have diabetes from 2015-2016 [12]. Levels of fitness for Black and Mexican Americans were also low [7, 13]. Smoking rates are disproportionately high in Native Americans at an estimated 40-50% in some Native American community populations [13], and blacks are more likely to die of smoking-related illnesses than whites, despite having lower rates of smoking [14]. There are interactions between risk factors as well, with cigarette smoking leading to a 30-40% increased risk of diabetes, according to a report by the US Department of Health and Human Services in 2014. Obesity prevalence is also disproportionately high in several minority groups, including black women, Mexican-Americans, Puerto Ricans, and Native Americans [15]. In light of these documented racial/ethnic disparities, inclusive and culturally relevant interventions are necessary to promote equity and reduce CVD risk factors in these groups.

Description of the Intervention.

Mindfulness is described as “paying attention in a particular way: on purpose, in the present moment, and non-judgmentally” [16] and has been operationally defined using a two component model emphasizing the maintaining of attention on a target and the nonjudgmental appraisal of experience [17].

Mechanistically, mindfulness meditation is proposed to act on behavior change targets through enhanced emotional and attentional regulation, increased bodily awareness, and changes in static self-perception [18-19].

Mindfulness-Based Interventions have their roots in Buddhist practice and were popularized in the United States after the development of Mindfulness-Based Stress Reduction (MBSR), an 8 week long, group-based intervention [19]. Since that time, the amount of research on MBI and the underlying mechanisms of mindfulness as a health intervention for various conditions has increased dramatically. Popularly studied MBIs still include MBSR, which incorporates didactic training and body sensing components such as yoga and tasting exercises (i.e. the raisin task) into meditation or mindfulness practice [16]. While MBSR was originally conceived as a treatment option for chronic pain [20], its basic structure has been modified by subsequent researchers to target a wide range of conditions, including CVD risk factors [21]. Examples of tailored MBIs included in this review include Mindfulness-based Eating Awareness Training (MB-EAT), which adapts the body sensing components of MBSR to sensations around hunger and satiety [22].

Mindfulness practice in the United States.

Mindfulness practice has been on the rise in the United States. A 2016 study revealed that over 11 million adults reported having practiced meditation at least once in their lives, with over 78% reporting practice within the last 12 months. Predictors of meditation use included being white, female, college-educated (or higher), and living in the Western United States [23]. A 2017 study estimated that 18.6% of the population (46.1 million, or roughly 1 in 5) had practiced some form of meditation, and also found that these participants were more likely to be young, female, highly educated, and white [24]. Underserved populations with health disparities and men are less likely to engage in mindfulness/meditation practice, and educational attainment beyond high school is significantly more associated with engagement [25]. Research on MBI has been found to be even more skewed toward white participants. In a review of 69 randomized controlled trials of MBIs, 79% of participants in 56 articles identified as white [26]. The implication for demographic trends in mindfulness/meditation use suggest barriers to engagement in underserved populations in the US.

MBI for cardiovascular risk.

While investigation into the underlying mechanisms of MBIs is ongoing, a current review of the literature reveals that evidence supports MBI for CVD risk most strongly for smoking, blood pressure, diabetes, diet, obesity, and exercise [20]. Numerous reviews have been conducted into the efficacy of MBIs for CVD risk factors and suggest benefits for weight loss, diabetes, and exercise [27-28], smoking [29], and dietary intake [30-31]. Studies increasingly point to several common mechanistic pathways by which these practices may provide health benefits. Loucks and colleagues propose that MBIs act by increasing attentional control, improved emotional regulation, and increased self-awareness [21]. These domains are proposed to increase ability to stick to predetermined behavior change goals, reduced stress reactivity, improved ability to resist cravings, increased self-efficacy and control, reification of goals and values, and increased bodily awareness [32].

Evidence suggests that MBIs are a low-cost, feasible, and efficacious treatment option [33-34], and further research suggests benefit and acceptability for health disparities. A 2017 qualitative study with a majority black sample seeking mental health treatment, participants conveyed perceived benefits of MBI on physical health conditions, such as diabetes and blood pressure [35]. Furthermore, studies which have adapted complementary & alternative medicine (CAM) interventions (including MBSR and yoga) have been found feasible and acceptable in minority populations with depression, breast cancer, substance use, and other health conditions [36], suggesting that adapting MBI for minority CVD risk are worth exploring.

Summary and Aims.

Mindfulness-based Interventions (MBI) are increasingly studied for the treatment of CVD and risk factors [21, 37]. According to a scientific statement from the American Heart Association [3], the current literature suggests that MBI are a low-cost, low risk adjunctive treatment for the modification of lifestyle related to cardiovascular risk. Despite the disparate rates of CVD morbidity, mortality, and risk in US racial/ethnic minority populations, the effectiveness and implementation potential of these interventions for US racial/ethnic minorities remains largely unexplored. In light of this gap in current scholarship, this systematic review summarizes variations in study design and implementation (i.e., intervention design, delivery and uptake, and contextual factors) and explores targets for future tailoring to underserved populations with higher risk for cardiovascular disease.

Methods

Protocol & registration.

The protocol for this review was developed in consultation with a subject librarian as well as experts in mindfulness-based interventions, public health interventions, and systematic reviews. This protocol was registered with the Prospero International Prospective Register of Systematic Reviews (registration number CRD42019141454) on 09/27/2019.

Population	Healthy or unhealthy adults (18+) residing in the United States or territories.
Intervention/Exposure	Meditation or mindfulness-based intervention with a predetermined curriculum consisting of at least 1 practice session.
Control	Any control group. Active and/or passive control groups.
Outcomes	Change or improvement in cardiovascular health measures or risk behaviors.
Study Design	Randomized Controlled Trials (RCTs)

Table 1: PI(E)COS Outline.

Search and selection of articles.

The search strategy for this systematic review was guided by specification of the research question parameter, based on PI(E)CO (Table 1). This strategy included crossing terms specific to a) our interventions of interest, and b) our defined comparison (RCTs and semi-randomized trials), and did not cross these terms with specific health conditions of interest or populations in order to widen our search. Searches were limited to all studies in: a) the English language and, b) to adult human studies published in the United States and territories. Database-specific search strategies were created to accommodate truncation and MeSH or Emtree terms. The search was conducted on February 9, 2020. The following five electronic databases were searched: PubMed, EMBASE, PsycINFO, Cochrane Library (CENTRAL) and CINAHL using search strategies outlined in the study protocol (See Appendix 1). Additionally, the electronic database OpenGrey was searched and no eligible studies were discovered. We also conducted forward and backward citation tracking for included studies, key papers, and relevant systematic reviews. Search results and other relevant articles were to a web-based systematic

review tool designed to facilitate the process of screening, data extraction, and analysis (<http://www.covidence.org>).

The primary author performed initial screening of all identified titles and abstracts generated by our search strategy and removed studies which clearly did not meet inclusion criteria (see Table 1). A second author independently screened 10% of these studies and met at least 80% agreement between authors. Full-text articles were obtained of all selected abstracts and screened for inclusion. Two authors performed an independent review of articles to determine final eligibility with differences resolved through a senior author. Finally, a subject expert was consulted prior to the conclusion of this research to verify that included studies were representative of the current literature and appropriate for the study's aims and objectives. The results of this screening are summarized by the PRISMA diagram in *Figure 1*.

Inclusion and exclusion criteria.

This review considered randomized controlled trials of meditation or mindfulness-based interventions (as defined by Crane et al., 2016 [38]) conducted in the United States and territories using adult subjects, available in English. Studies were limited to the United States to maintain focus on the unique healthcare considerations and other US-specific racial/ethnic disparities present there. “Mindfulness-informed” therapies (as defined by Crane et al. 2016 [38]) where mindfulness or meditation practice is optional or may not be considered to be the intervention's core component—such as Dialectical Behavioral Therapy (DBT) and Acceptance and Commitment Therapy (ACT)—were excluded. Similarly, studies using psychotherapies such as Cognitive Behavioral Therapy (CBT) were also excluded. Interventions including multivariate components to tailor interventions to health conditions or populations were considered eligible for inclusion.

This review was narrowed to include studies of MBI for the improvement of the following six modifiable risk factors for CVD: (1) diabetes mellitus (type-2), (2) smoking, (3) obesity, (4) sedentary lifestyle, (5) unhealthy diet, (6) blood lipids (high cholesterol). This set of risk factors was chosen in part due to previous work by Loucks and colleagues [21, 32], who have proposed a theoretical framework and potential mechanisms for mindfulness on cardiovascular risk. To qualify for inclusion, studies needed to measure at least one physical or behavioral outcome relating to these risk factors (ie: weight, glycemic levels, emotional eating, cigarettes smoked). Primary correlational findings (ie: predictive studies on trait mindfulness) were not considered. Potential secondary outcomes of interest were also considered. These included (1) onset of CVD or other disease condition (e.g. diabetes), mortality from CVD, and incidence of hospitalization or surgical remediation due to CVD, (2) changes to or improvements in diagnosed CVD conditions, such as hypertension, coronary artery disease, peripheral artery disease, or atherosclerosis, (3) changes in psychological outcomes such as depression measures, stress levels.

Data extraction and analysis.

The Oxford Implementation Index [39] was used to guide the extraction and analysis of implementation data relevant for this review (see Appendix 2). Five key domains from this Index were selected based on their relevance to the implementation of MBI: 1) dosage; 2) delivery method; 3) staff characteristics; 4) settings, locations, and dates/times; and 5) participant characteristics. Dosage in high amounts or for long periods of time may lead to worse outcomes or attrition due to schedule conflicts or childcare needs. Delivery method—particularly in-person classes or sessions—may pose a barrier if the classes are non-representative/held in noncommunity locations. In-person classes may also have schedules which are more rigid as opposed to mobile interventions which can be tailored to a subject's own needs. Similar to dosage and delivery methods, settings, locations, and dates/times of interventions may pose a barrier to engagement in certain populations due to scheduling constraints, travel constraints, or discomfort with the setting (laboratory settings on college campuses). Finally, non-representative staff and/or participant characteristics have the potential to act as a barrier to engagement, as often, minority subjects report [40]. We also

made note of potential sources of contamination where applicable, in which aspects of study design could influence either the subjects recruited or the study's outcomes.

The Oxford Implementation Index acknowledges the potential for variation across intervention studies in design and implementation aspects, thus allowing reviewers to appraise this data for potential sources of bias and its generalizability across populations. Risk of bias analysis was not deemed necessary for the purposes of this study, as efficacy reviews have been conducted elsewhere and study quality was not the primary focus of this review. Examination of implementation factors provided a critical framework for this review to examine generalizability to and potential barriers to intervention engagement by minority populations.

Results

Overview of included studies.

Electronic database searches produced 10,630 articles with 2,075 remaining after the removal of duplicates. After screening the title and abstract of each, the full text of 91 articles was retrieved for further review. A total of 30 articles reporting findings from k [number of studies] = 26 distinct intervention trials were selected for final inclusion, all of which were hand-searched for additional studies. A full breakdown of this search process including reasons for exclusion can be seen in *Figure 1*. Numerous studies ($k=11$) examined more than one risk factor. Of the included studies, the majority examined outcomes related to diet ($k=13$), obesity ($k=9$), and smoking ($k=11$). The remaining studies examined outcomes related to exercise ($k=4$), diabetes ($k=3$), and blood lipids ($k=2$). Number of participants ranged from 18-412 with $k=20$ studies having $n < 100$ participants. All articles included were published between 2011-2020. Six articles that met inclusion criteria were part of the same two parent studies [65-70] and present the same basic implementation characteristics.

Table 2. Overview of Included Studies ($k=30$ published reports from 26 distinct trials)

Study	n	Risk factor(s)	Participants	Intervention*	Control(s)*	Outcomes measured	Primary Findings
Arch et al., 2016	391	Diet	Undergraduates (~20 years of age)	Brief Mindfulness Instruction	Distraction, No Instruction	Affect, perception of hunger, calories consumed	Evidence supports treatment for reduction of calories consumed.
Brewer et al., 2011	88	Smoking	Adult smokers	Mindfulness training adapted for smokers	FFS	Abstinence from smoking	Treatment reduced cigarette use, cravings, trends toward increased abstinence.
Carmody et al., 2012	36	Diet	Prostate cancer patients	Novel	Waitlist	Prostate-specific antigen, body weight, quality of life, dietary changes, BMI	Reductions in prostate-specific antigen correlating with mindfulness and positive eating behaviors.
Carpenter et al., 2019	75	Diet, Obesity	Obese adults	MYW	Weight Talk (WT)	Weight, emotional eating	Feasibility & acceptability supported. No significant between-group difference in weight loss, but with increased weight loss predicted in treatment group.
Chacko et al., 2016	18	Diet, Obesity	Post-bariatric patients	Novel	TAU	Feasibility & acceptability of intervention; changes in weight, eating behaviors, psychosocial outcomes, and metabolic and inflammatory biomarkers	Feasibility & acceptability supported. Reduced emotional eating in treatment group at 6 mo but no significant between-group reduction in weight. Sig. increase in HbA1C.
Corsica et al., 2014	53	Diet	Overweight adults at risk for obesity	Modified MBSR	Stress-eating intervention, MBSR	Weight, stress-related eating	Reduced stress-eating; moderate effect on weight loss in treatment group..
Davis et al., 2013	55	Smoking	Smokers with binge-drinking	MTS	Interactive learning for smokers	Smoking abstinence and reduction in alcohol intake	Higher prevalence of abstinence in treatment group 2 weeks post-quit.
Davis et al., 2014a	198	Smoking	Low-SES smokers	MTS	TAU	6-month smoking abstinence	Feasibility & acceptability supported. Significantly higher abstinence rates in treatment-initiators

							at 4 weeks, 6 months. Significant improvements in emotional regulation.
Davis et al., 2014b	135	Smoking	Low-SES smokers	MTS	FFS Enhanced	Smoking abstinence	No between-group difference in abstinence found at 4 weeks. Nonsignificant improvement in abstinence at 24 weeks. Reductions in urge intensity correlated to increased mindfulness.
Garrison et al., 2018	325	Smoking	Adult smokers	Novel app	Alternative app	Craving, abstinence from smoking	No group difference found in abstinence at 6 mo. Nonsignificant reduction in smoking. Reductions in craving observed in treatment group.
Gillman & Bryan, 2020	78	Exercise	Adults with insufficient exercise	Brief-MP	Distraction, associative attentional focus	Perceptions, duration and frequency of exercise	Higher positive affective response over controls. No difference in minutes of exercise.
Ingraham et al., 2017	80	Diet, Exercise, Obesity, Lipids	Adult obese lesbians >40 years old	WHAM	Delayed start group	Mindful eating, fruit & vegetable intake, water consumption, physical activity, Hemoglobin A1c, fasting lipids	Statistically significant improvements in cholesterol levels and increased vegetable intake observed in treatment group.
Janes et al., 2019	33	Smoking	Adult smokers	Novel	QuitGuide	Decline in smoking predicted by reduced activity in the posterior cingulate	Reduction in posterior cingulate activity relative to smoking cues; fewer cigarettes smoked over controls.
Lotfalian et al., 2020	60	Smoking	Adult smokers	Ujjay breath	Coping strategy & no treatment	Smoking craving, withdrawal, and negative affect	Smoking reduction 24 hours post treatment over controls. Decreased craving over no treatment.
Miller et	52	Diabetes,	Overweight	MB-EAT-D	Smart	Dietary intake,	Treatment produced

al., 2012		Diet, Exercise	adults with diabetes		Choices	physical activity, weight, glycemia, and fasting insulin	significant decrease in energy intake, reduction in weight, and decrease in glycemic load. No differences between-group in weight change, BMI, waist circumference, fasting glucose, HbA1c, or insulin.
Miller et al., 2014	52	Diabetes, Diet	Overweight adults with diabetes	MB-EAT-D	Diabetes self-management education (DSME)	Regulation of food intake, weight	Comparable but not superior to control intervention for diabetes self-management.
Raja-Khan et al., 2017	86	Obesity	Overweight women	MBSR	Health education	Fasting glucose, weight, A1c and lipid profile, cortisol, psychological stress, mindfulness	MBSR showed significant decreases in fasting glucose versus control.
Ruscio et al., 2015	44	Smoking	Adult smokers	Brief-MP	Sham meditation	Negative affect, craving, cigarettes smoked	Nonsignificant reductions in craving & negative affect and significant reductions in cigarettes smoked over time.
Singh et al., 2014	51	Smoking	Smokers with intellectual disabilities	Mindfulness training	TAU	Number of cigarettes smoked	Significant reduction in smoking & improved abstinence at 1-year vs control.
Smith et al., 2018	36	Diet, Obesity	Overweight menopausal women	MEAL	Matched active control without meditation	Weight, body mass index, waist-hip ratio, binge eating, interleukin-6, C-reactive protein (CRP), psychological measures	Reductions in weight loss, BMI, and waist-to-hip ratio in both treatment and control.
Spadaro et al., 2018	46	Diet, Obesity	Overweight adults	Standard behavioral weight loss program + Mindfulness Meditation	Standard behavioral weight loss programs	Weight loss, dietary intake, eating behaviors, physical activity, mindfulness	Significant group by time interaction found for weight loss favoring treatment over control. Eating behaviors and dietary restraint improved significantly in

							treatment compared with controls.
Tang et al., 2013	60	Smoking	Healthy students, half smokers	IMBT	Relaxation Training	Smoking reductions, nicotine dependence self-report (FTND), number of cigarettes smoked, brain measures relating to smoking reductions/self control measuring fractional amplitude of low-frequency fluctuation (fALFF) with fMRI	Increased activity in brain areas associated with self-control (anterior cingulate, prefrontal cortex). Significant decrease in smoking (60%) over controls (no reduction).
Timmerman & Brown, 2012	35	Diet, Obesity	Perimenopausal women who dine out	MRE	Waitlist	Weight, waist circumference, self-reported daily calorie and fat intake, self-reported calories and fat consumed when eating out, emotional eating, diet related self-efficacy, and barriers to weight management when eating out	Significant reduction in weight, lower average daily calorie and fat intake, increased diet-related self-efficacy in treatment group.
Vidrine et al., 2016	412	Smoking	Low-income smokers	MBAT	Usual Care, Cognitive behavioral therapy	Nicotine dependence, mindfulness technique practice during treatment, smoking abstinence, relapse	No significant overall treatment effects. Significant overall recovery of abstinence.

Multiple reports from the same RCT intervention

Daubenmier et al., 2016	194	Diet, Lipids, Obesity	Overweight adults	Novel MB-EAT	Novel active Control	Fasting glucose, triglycerides, waist circumference, C-reactive protein, blood pressure.	Significant reduction in triglycerides in mindfulness group over controls.
Mason et al., 2016a	194	Diet, Exercise, Obesity	Overweight adults	Novel MB-EAT	Novel active Control	Reward-based eating, psychological stress, and weight	Significant reductions in reward-driven eating which predicted weight loss post-intervention.
Mason et al., 2016b	194	Diet, Exercise, Obesity	Overweight adults	Novel MB-EAT	Novel active Control	Mindful eating, eating of sweets, and fasting glucose	Nonsignificant reduction in sweets consumption.
Radin et al., 2020	194	Diet, Obesity	Overweight adults	Novel MB-EAT	Novel active Control	Compulsive eating, stress eating, fasting blood glucose	Nonsignificant reduction in weight loss. Significant improvement in fasting blood glucose & weight in participants with high compulsive eating scores.

Daubenmier et al., 2011	47	Diet, Obesity	Overweight or obese women	Novel MB-EAT	Waitlist	Mindfulness, psychological distress, eating behavior, weight, cortisol awakening response (CAR), and abdominal fat	Reductions in dining out (external eating) in treatment group. Reductions in CAR in obese patients. No between-group difference in weight.
Daubenmier et al., 2012	47	Diabetes, Diet, Obesity	Overweight or obese women	Novel MB-EAT	Waitlist	Primary: Telomerase activity. Secondary: correlations of telomerase activity with psychological distress, eating behavior, and metabolic factors	No effect on telomerase. Moderate effect on weight loss vs controls.

Abbreviations: Brief Mindfulness Practice (Brief-MP), Freedom from Smoking (FFS), Integrated Mind Body Therapy (IMBT), Mindfulness-Based Addiction Treatment (MBAT), Mindful Eating and Living (MEAL), Mindfulness-Based Eating Awareness Training (MB-EAT), Mindfulness Eating for Diabetes (MB-EAT-D), Mindfulness-Based Stress Reduction (MBSR), Mindful Restaurant Eating (MRE), Mindfulness Training for Smokers (MTS), Mind Your Weight (MYW), Whole Health Action Management (WHAM)

Table 3. Overview of Intervention Characteristics (k=30 published reports from 26 distinct trials)

Study	Implementation Characteristics			Contextual Factors	
	Dosage	Delivery Method	Staff Characteristics	Settings, locations, dates/times	Participant characteristics
Arch et al., 2016	A single session of 5-7 minutes	In person via headphones. Small groups, but with individual administration at computer.	1 male experimenter. No facilitator.	College campus under laboratory conditions. Location & dates/times not described.	Young (av. 20 yo), college students, mostly male, mixed racial/ethnic background. Average annual family income: 60-70k.
Brewer et al., 2011	Bi-weekly 1.5 hr sessions over 4 weeks (8 sessions total) with ~30 min of home practice per session	In person. Group format. CD used for home practice.	Therapist with 13+ years experience in mindfulness	Setting/location & times not described. Sessions on Mondays and Thursdays.	Majority men (~46 yo), 45.5% racial/ethnic minority. Over half college educated. Half unmarried.
Carmody et al., 2012	11 weekly classes of 2.5 hours each	In person. Group format.	Not described.	College university teaching kitchen & conference area. Dates/times not described.	Men (~69 yo), majority non-Hispanic white. 91% married.
Carpenter et al., 2019	At least 11 weekly or biweekly sessions of 20-30 min each	Telephone.	Registered dietitians, health coaches with ≥ 200 hours of training	Not described.	Majority women (~46 yo), 65% white, college-educated (~94%).
Chacko et al., 2016	Ten weekly classes with a half-day (4 hour) retreat. Home practice of undescrbed length 6 days/wk	In person. Group format.	Qualified mindfulness instructor	Not described.	Majority white women (~53yo), college-educated (100%). Income <75k (67%).
Corsica et al., 2014	Once-weekly 90-minute sessions for 10 weeks. Home practice of 30-45 min daily.	In person. Group format.	Not described.	Not described.	Majority women (~45yo); college-educated (m=16.7 years), mixed racial/ethnic diversity.
Daubenmier et al., 2011; Daubenmier et al., 2012	Nine 2.5-hour weekly classes, one 7-hour retreat day. Home practice 30 minutes/day, 6 days/week.	In person. Group format.	Not described.	Evenings & weekends. Location/setting not described.	Majority white women (~40yo). Other demographics not described.
Daubenmier et al., 2016;	Total of 16 2-2.5 hr sessions (weekly or	In person. Group format.	Mindfulness meditation instructors with 5 days	Evenings and weekends.	Majority white (~47yo) women,

Mason et al., 2016 a, Mason et al., 2016 b, Radin et al., 2020	biweekly). One 6.5 hr retreat. Home practice of 30 min/day, 6 days/week.		training in mindful eating, registered dietitian	Location/setting not described.	educated (69% bachelor's degree).
Davis et al., 2013	Six 2-hour weekly classes, one 7-hour retreat day, 30 min of home practice daily.	In person. Group format.	2 instructors with Master's level education, equivalent experience with smoking cessation interventions	Not described.	Majority white men (~22yo). Other demographics not described.
Davis et al., 2014a	7-hour introductory class, 4 weekly 90 min classes, one 7-hour retreat day, 30 minutes daily home practice	In person. Group format.	2 instructors who completed 2-day training in MTS and no formal addiction training	Not described.	77% white men & women (~45 yo). 40% High school or less.
Davis et al., 2014b	Seven 2.5 hr classes, one 6.5 hr retreat day, 15-30 min home practice daily	In person. Group format.	Master's in psychology or PhD in Sociology and no formal addiction training	Not described.	88.1% white men & women (~45yo) with high school and above (60%).
Garrison et al., 2018	22 daily modules of 1-15 min	Mobile phone app	Not described/not applicable	Not described/not applicable	Majority white women (~43yo). Married (>50%). Educated (87% high school +).
Gillman & Bryan, 2020	150 min/week for 2 weeks	Email	Not described/not applicable	Not described/not applicable	Majority white women (~27yo). Other demographics not described.
Ingraham et al., 2017	12 weeks. Session number and length not described.	In person. Group format.	Personal trainer, registered dietician, licensed social worker, clinical psychologist	Not described.	Majority white, lesbian women (~53yo). Educated (61% college graduates or postgrad). 53% reported incomes <30k.
Janes et al., 2019	22 daily modules of 1-15 min	Mobile phone app	Not described/not applicable	Not described/not applicable	Majority white men & women (~46yo). Majority unmarried, some college or higher.
Lotfalian et al., 2020	One 20-minute session	In person.	Researcher.	Laboratory setting.	Majority black men & women (~40yo), low-income.
Miller et al., 2012	8 weekly and 2 biweekly 2 1/2 hour sessions, home practice 6 days/wk	In person. Group format.	Facilitators trained in the intervention protocol	Not described.	Majority white women (~54yo). Married (67%), nearly half college graduates

	of undetermined length				making ≥ 60k annually.
Miller et al., 2014	8 weekly and 2 biweekly 2 1/2 hour sessions, home practice 6 days/wk of undetermined length	In person. Group format.	Facilitators trained in the intervention protocol	Not described.	Majority white women (~54yo). Married (67%), nearly half college graduates making ≥ 60k annually.
Raja-Khan et al., 2017	8 weekly 2.5 hr sessions & one 6-hr retreat day. 25-30 min home practice	In person. Group format.	Professional MBSR training, 9 years experience	Not described.	Majority white women (~45yo). Other demographics not described.
Ruscio et al., 2015	1 guided meditations per day (5 total)	Via Personal Digital Assistant	Not described.	Naturalistic environment.	Demographics not described.
Singh et al., 2014	4 week baseline at 5-45 min. 36 week intervention from 20-50 min	In person (small group) or via Skype	Trainer with 35 years experience with intellectual disability and personal mindfulness practice.	Variable.	Majority men (~33yo). Other demographics not described.
Smith et al., 2018	6 weekly 2-hr meetings. Home practice of undetermined length/frequency.	In person. Groups up to 20 subjects.	Not described.	Not described.	Women (~58yo). Demographics not described.
Spadaro et al., 2018	One hour weekly for 6 months.	In person. Group format.	Co-investigator doctoral student in exercise physiology with significant experience, training, and on-going supervision in weight loss interventions	Tuesday evenings. Location/setting not described.	Majority white women (~45 yo), educated (46% bachelor's and above).
Tang et al., 2013	10 sessions of 30 minutes over 2 weeks	In person. Group format.	Not described.	Evenings. Setting/location not described.	Young (~21yo). Demographics not described.
Timmerman & Brown, 2012	6 weekly 2-hour sessions	In person. Group format.	Not described.	Not described.	Women (~50yo), over half white. Educated (89% some college), most over 50k annual income.
Vidrine et al., 2016	8 weekly 2-2.5 hour sessions. Home practice of 30 min daily.	In person. Group format.	Described as therapists. No other detail.	Not described.	Nearly half black (48.2%), over half women. Unmarried (70%), with high school diploma or less (one third), most making <30k annually

Primary Study Findings.

Primary outcomes for each study are reported in Table 2 and summarized here briefly. Mindfulness-based interventions produced positive results in smoking outcomes. Two studies reported a statistically significant reduction in smoking over controls [58-59]. Another two studies found smoking abstinence outcomes superior in the treatment group [48, 54, 59, 64] while others found comparable between-group outcomes for smoking reduction [49] and abstinence [42, 49-50]. Reductions in craving were also observed [42, 49-50, 54, 58] and support for the effect of MBI on craving was demonstrated by a reduction in brain activity related to smoking cues, correlated to an overall reduction in cigarette consumption in the intervention condition [53]. Additionally, brain areas relating to self-control (the anterior cingulate and prefrontal cortex) showed increased activity with meditation, and demonstrated a 60% reduction in smoking, with no reduction shown in the control group [62].

Positive dietary changes and/or changes in eating behaviors associated with MBI were supported in numerous studies [41, 44-46, 52, 55, 61, 69] and decreases in emotional eating behavior were reported in 3 studies [44-45, 68]. Reductions in dining out were reported in one study [69]. Treatment was also found to produce nonsignificant reductions in the consumption of sweets [67]. Reductions in cholesterol levels were observed in 2 studies [52, 65].

Mindfulness was found to be as effective as a standard diabetes self-care treatment in one study [56] and produced significant decreases in fasting glucose levels compared with controls [57]. Significant increases in HbA1C concentrations—a test which reveals average blood sugar over 2-3 months—were found in the mindfulness group in one study [45] and nonsignificant between-group outcomes were reported in another [55]. Finally, significant improvements in fasting blood glucose were found in participants with high compulsive eating scores post-intervention [68].

Weight loss or maintenance was reported for MBI to varying degrees, with some studies producing greater results than control interventions [46, 55, 68-69] and others found nonsignificant between-group improvements [44-45, 56-57, 60]. Mindfulness was found to improve positive affective response to exercise but did not increase minutes exerted relative to controls [51]. Weight loss was also found to be predicted post-intervention by reductions in reward-based eating [66].

The included pilot feasibility studies found MBI feasible and acceptable for weight loss [44], emotional eating [45], dietary changes in prostate cancer patients [43], and smoking abstinence [48]. While both the benefits and the feasibility and acceptability of mindfulness-based interventions in American minorities is understudied, the research presented in this review points to potential benefits of MBI as a treatment option for CVD risk and provides a basis for future research in this area.

Oxford Implementation Index: Implementation characteristics.

Table 3 presents information extracted from primary studies regarding implementation characteristics of the primary studies. *Dosage* varied widely across studies, with the majority closely modeled after the multi-week, multi-hour model set forth by MBSR and its contemporaries. Program length ranged between 1 day and 6 months, with $k=24$ studies consisting of ≥ 6 sessions. Session durations ranged between 5 minutes and 7 hours. Dates and times of program delivery remained largely undescribed. Thirteen studies reported home practice of between 15-45 minutes for between 5-7 days per week. *Delivery method* was largely in-person in a group setting ($k=19$), with 2 delivered in person individually, and 5 delivered remotely or digitally. *Staff characteristics*—which were at least partially detailed in 16 studies—were universally described in terms of vocation and training, with no descriptive characteristics of the staff/providers described in the primary studies (age, racial/ethnic

background). No *proscribed/incompatible activities* or details of *meetings/communication between staff* were reported. Numerous studies reported *differences between trial arms* which did not directly relate to the research question of this review and are therefore not outlined herein.

Several sources of possible *contamination* were found. In nearly all studies, previous interest in, knowledge of, or experience with mindfulness was not controlled for or was not described. One study excluded participants' current or recent (previous 6 months) mindfulness or meditation practice [45], another explicitly excluded participants with prior participation in a mindfulness program [46] and two [69-70] excluded participants with prior MBSR experience or a current meditation or yoga practice. Additionally, it was unclear in most studies if recruitment or screening materials mentioned mindfulness or meditation, which may contribute to self-selection. Two studies [48, 60] avoided mention of mindfulness in recruitment materials to avoid potential self-selection or the contamination of the control group. One study [58] lists the mention of mindfulness as a limitation. Two additional studies listed limitations for not excluding based on prior mindfulness experience [58] or not screening for prior exposure [62]. Finally, one study [64] did include subjects with previous experience which they report did not impact findings. Additional potential sources of contamination existed in several studies.

Another potential source of *contamination* was observed in most studies, such that it was unclear if the experimenter also served as a facilitator for either treatment or control group, which could create demand effects. In one study [61] the facilitator was described as being a co-authoring doctoral student. An additional source of contamination was found in two studies which focused on low-SES smokers. These studies explicitly stated that participants could not be blinded, as many participants "worked odd hours" and it was necessary to allow them to decline if they could not attend all sessions [48-49]. This lack of blinding may bias study results to favor participants with the ability to attend sessions, and points to a potential structural barrier to engaging with in-person, group-based mindfulness interventions in low-SES individuals.

Oxford Implementation Index: Contextual factors.

Table 3 presents contextual factors extracted from primary report that were deemed relevant to this review. *Setting, geographic location, and dates/times* were at least partially described in 10 studies. Three reported campus or laboratory settings [41, 43, 54] and two reported home or naturalistic settings [51, 58]. The other sixteen studies provided no description of these factors. *Participant characteristics* were at least partially described in 22 studies (see *Table 3*). A total of 17 studies reported majority white participants, with 5 reporting mixed race or majority black, and 4 not reporting participant demographics (see *Table 2*).

Other salient characteristics were partially described (see *Table 3*). Median age ranged from 20-69 across all studies. Women were disproportionately represented in 15 studies (>50% female), 5 studies reported over 50% males, and 4 studies had a combination of the two. Gender identity was not reported in any study, and LGBTQ+ demographics were considered in one study [52], which consisted of lesbian participants. Educational attainment was reported in 15 studies and revealed that the majority of recruited participants had at least some college education (11 studies). Income was only described in seven studies, five of which were comprised of participants making >50k annually. Three studies specifically focused on low-SES participants [48-49, 64], though two of these studies did not describe income-based inclusion criteria or annual income for participants, instead focusing on "low-income neighborhoods" during recruitment [48-49].

In addition to these factors, it should be noted that the majority of studies were described as being in the early stages of research, either as preliminary research or pilot trials. This may account for many commonly reported limitations including small sample sizes, convenience sampling, high attrition rates, and lack of generalizability. Future research will

need to address these limitations, and reasons for attrition should be explored vis-à-vis racial and ethnic background.

Discussion

While research points to potential benefits of MBI for cardiovascular risk, this review finds that the current literature might not generalize to the US racial/ethnic minorities who are most disproportionately affected, due to limitations in the current literature with regard to inclusion/engagement of diverse populations and consideration of cultural or social factors that might affect program relevance and effectiveness with racial/ethnic minorities. Furthermore, data for many of the implementation factors needed to tailor these interventions to underserved populations are underreported in the literature. Men, racial and ethnic minorities, and individuals of low socioeconomic status were underrepresented in the included literature. This systematic review found that research into the primary risk factors for cardiovascular disease is still in the early stages, with the majority of studies showing promising effects on outcomes for smoking reduction and abstinence, weight loss, and changes in eating behaviors. Considering that the included studies report beneficial findings for cardiovascular risk—which occurs at disparate rates in minorities—the lack of representation presented in these findings presents a clear gap in the literature which should be addressed in future studies. Details on implementation factors (implementation site/provider/delivery factors, contextual factors, participant factors) were unevenly reported in the primary papers. Notably, participant characteristics, staff characteristics, and study settings, locations, times and dates were underreported. No intervention effectiveness or studies otherwise meant to tailor MBI to minorities at risk for CVD have been conducted at this time.

Prior knowledge, beliefs, and social norms about mindfulness/meditation may drive participant engagement and outcomes, as supported by behavior change theories [71-72]. The need for considering prior knowledge, beliefs, and social norms about mindfulness in minority groups is also consistent with literature on tailoring interventions to minorities [35, 73-74]. While some studies described explicit exclusion for either mindfulness training or practice (see *Results*), the potential effects of prior knowledge of, interest in, or experience with mindfulness or meditation remains unclear across all studies. Several studies included in this review highlight these gaps in understanding. The 2016 study by Daubenmier and colleagues [65] on obesity and weight loss found that treatment participants who were missing 18-month data reported less benefits from the study, compared with controls. These participants also demonstrated less engagement and less improvement. The researchers suggest that this may indicate a lack of interest in mindfulness and cite motivation and engagement as strong factors. Additionally, in the 2017 study by Ingraham and colleagues [18], some participants appear to have had an established prior practice, and felt the intervention was too basic for their needs. These findings support the need to understand the perceived cultural relevance of these interventions in underserved populations.

Lack of reporting on staff characteristics—particularly facilitator characteristics—was one of the major findings of this review. Minority groups are less likely to find representation in mindfulness practice [23] and are more likely to respond to a MBI program facilitator with whom they can identify or whom they feel represents their community [35, 73-74]. This lack of understanding was highlighted directly by one of the studies included in this review. In Davis et al., 2014a [48], preference for one or the other study arm was cited as a secondary reason for attrition, with expressed preference for the mindfulness group among participants who had higher levels of education. Daubenmier and colleagues, 2016 [65] also reported that participants in the intervention group who rated their instructor as more helpful had a significant difference in weight loss compared to controls. This finding suggests that results may be instructor-dependent and is especially relevant in underrepresented minorities who may be less likely to identify with their facilitator. This finding also underscores the importance of reporting and evaluating staff characteristics in future research.

In our literature review, we found that MBI may be effective for cardiovascular disease risk outcomes. However, our findings regarding the current limitations in reported studies highlight significant gaps in the literature, leaving the potential efficacy of MBI in minority communities in question. In light of this, we propose several suggestions for future research. As is the case with most intervention effectiveness studies, future research on this topic should seek to elucidate attitudes, social norms, and perceived barriers to engaging in MBI as well as exploring their efficacy in real-world circumstances. These insights can help to better tailor interventions to the specific needs of the population. Limitations should be further investigated to understand the potential role of race, self-selection, and motivation toward or identification with the intervention. Likewise, future studies to establish effectiveness in minority populations should seek to expand generalizability and may seek to recruit from community centers and/or churches, as supported by scholarship on intervention tailoring [75].

Our findings highlight several potential targets for tailoring mindfulness-based interventions to cardiovascular risk disparities in racial/ethnic minorities in the US. Many studies currently center around in-person group sessions. Using this format, tailoring studies should seek facilitators who are representative of the group and who speak the language of the group being tailored to. Accessible and acceptable intervention locations should be considered. Likewise, practice groups should represent greater diversity. Acceptability to the population should be explored along with the potential role of prior knowledge, experience, perceptions, expectations, and social norms around mindfulness and meditation in self-selection and engagement with interventions. Alternatives to lengthy, intensive, in-person sessions with fixed times and dates should be explored, such as in the case of app-based interventions and brief/ultra-brief formats.

Limitations.

This study presents several limitations. As with all systematic reviews, this study may have missed identification of studies meeting eligibility criteria. This study was also limited to articles available in the English language. The inclusion of a meta-analysis was not possible given the lack of homogeneity of included studies and this study is therefore limited to the scope of a narrative review. Considering that this study does not assess intervention efficacy, the homogeneity of across variables of included studies itself does not present a limitation, though it should be stated that the intervention effects may not be equivalent across all studies. The risk factors presented here were researched independent of their role in cardiovascular risk or disease, and this paper does not explore the potential interactions between these (e.g. diet and diabetes, or diabetes and CVD).

Conclusions

This study outlines several potential targets for future research. As all included studies indicate promise for these interventions, there is cause to believe that MBI could be of benefit to minority groups at risk for cardiovascular disease, perhaps as a complement to standard forms of treatment. Further research is needed to explore acceptability, feasibility, and effectiveness in minority populations.

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Availability of data and material: The lead author (TS) affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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Authors' contributions: TS conceived this research with guidance from EKS and DO; TS and EKS designed the research protocol with guidance from DO; TS and DR performed the literature review with guidance from DO; TS performed the analysis with guidance from DO, EKS, and JB; TS wrote the paper; DO and JB provided revisions which were written by TS. All authors read and approved the final manuscript.

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Figures

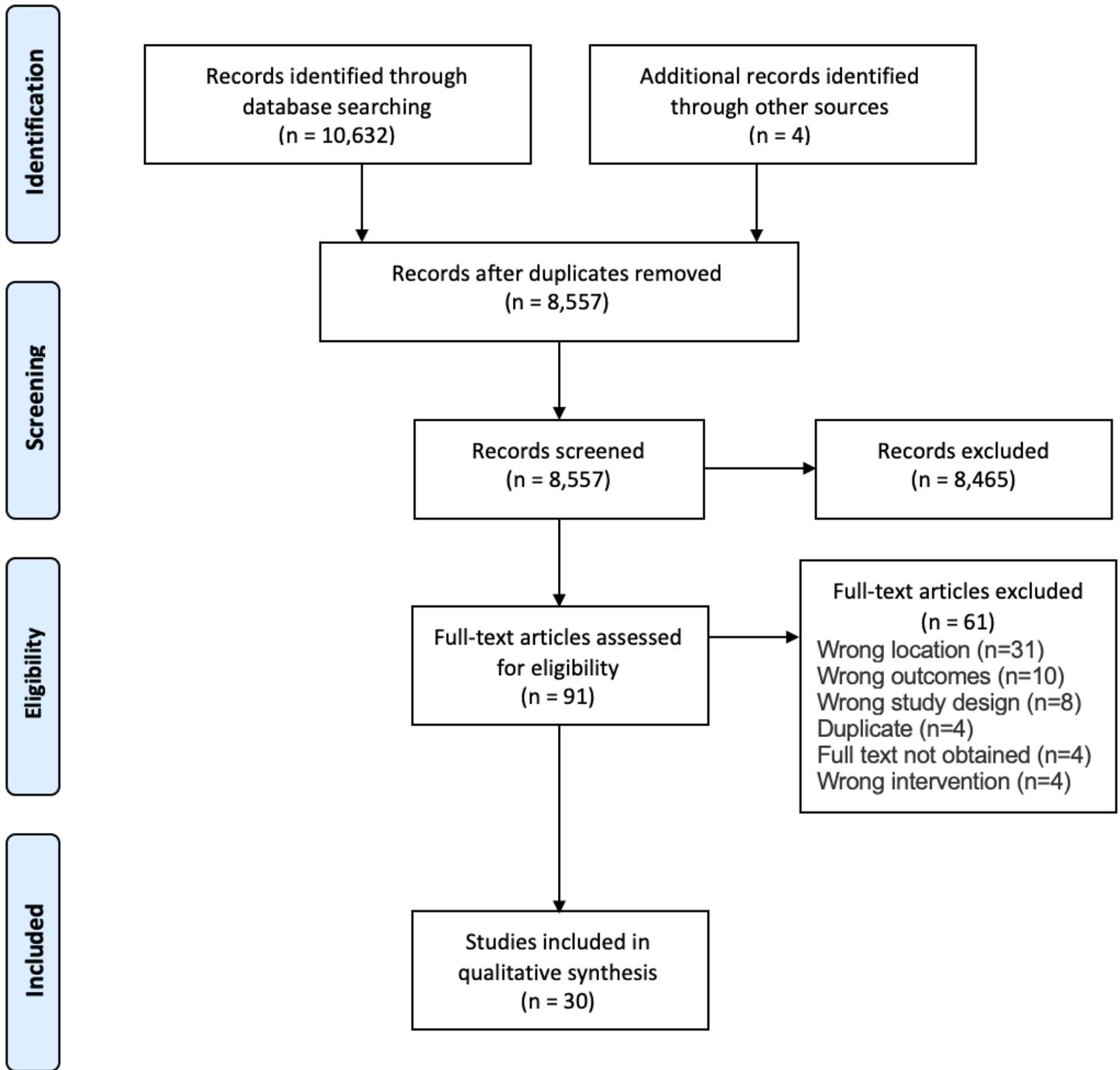


Figure 1

PRISMA Flow Diagram

Supplementary Files

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