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REVIEW

Sleep, health behaviors, and behavioral interventions: Reducing the risk of cardiovascular disease in adults

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Abstract

Numerous health behaviors, including physical activity, diet, smoking, and sleep, play a major role in preventing the development and progression of cardiovascular disease (CVD). Among these behaviors, sleep may play a pivotal role, yet it has been studied somewhat less than other behaviors and there have been few well-designed sleep intervention studies targeting CVD. Furthermore, despite the fact that these behaviors are often inter-related, interventions tend to focus on changing one health behavior rather than concurrently intervening on multiple behaviors. Psychological constructs from depression to positive affect may also have a major effect on these health behaviors and ultimately on CVD. In this review, we summarize the existing literature on the impact of sleep and other cardiac health behaviors on CVD onset and prognosis. We also describe interventions that may promote these behaviors, from established interventions such as motivational interviewing and cognitive behavioral therapy, to more novel approaches focused on mindfulness and other positive psychological constructs. Finally, we outline population-health-level care management approaches for patients with psychiatric conditions (*e.g.*, depression) that may impact cardiac health, and discuss their potential utility in improving mental health, promoting health behaviors, and reducing CVD-related risk. Much work is still needed to better understand how sleep and other health behaviors may uniquely contribute to CVD risk, and additional high-quality studies of interventions designed to modify cardiac health behaviors are required to improve cardiovascular health in individuals and the population at large.

Key words: Sleep; Diet; Physical activity; Cardiovascular disease; Care management

Core tip: This manuscript discusses the link between modifiable health behaviors; including sleep, diet, activity, and their relationship to adult risk for cardiovascular disease. Despite knowing that these behaviors are

often interrelated, interventions to date have primarily focused on changing one health behavior *vs* intervening on multiple behaviors simultaneously. Population health level care management approaches are outlined to aide providers in counseling their patients.

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INTRODUCTION

Recent guidelines for adequate sleep duration from the American Academy of Sleep Medicine and Sleep Research Society state that a typical adult needs at least 7 h of sleep each night to maintain optimal health[1,2]. Population-based studies estimate that one in three adults in the United States report sleeping fewer than 7 h per night[3,4]. This statistic is alarming as research has shown that individuals with insufficient sleep are at a significantly greater risk for many chronic diseases, including cardiovascular disease (CVD)[5-8], which is responsible for one in four deaths in the United States[9]. Additional health behaviors beyond sleep, including poor diet, low levels of physical activity, and prolonged sedentary time, are also major risk factors for the development of CVD[6]. This review will discuss the current literature linking these modifiable health behaviors to an increased risk of CVD, and the evidence-based interventions that can modify them, in order to guide future intervention targets and strategies aimed at reducing CVD risk in adults.

IMPORTANCE OF SLEEP IN REDUCING CVD RISK

In recent literature, both insufficient sleep duration (most often defined as fewer than 7 h) and long sleep duration (more than 9 h) have been associated with poor health outcomes and increased mortality risk[6,10]. In one such large, population-based study, individuals who reported fewer than 6 h of sleep had a 15% higher incidence of CVD compared to those who reported sleeping between 7-8 h[8].

Many biomarkers related to CVD risk have been examined in relation to insufficient sleep duration. The relationship between short sleep duration and hypertension is well documented, extending from experimental studies to longitudinal epidemiological studies and intervention studies[11-13]. Short sleep duration (collected *via* self-report questionnaire) has been associated with higher blood pressure in cross-sectional studies and greater overall incidence of hypertension in population studies. Studies tend to vary in their definition of short sleep duration, but overall conclude that 5 or fewer hours of sleep each night is related to the worst blood pressure outcomes. These poor blood pressure outcomes are reported to be most common in women and adults who are less than 65 years old. Racial/ethnic differences have been found showing that relationships between short sleep duration (fewer than six hours per night) and hypertension are strongest in non-Hispanic whites, blacks, and Hispanics/Latinos populations[5].

Insufficient sleep has also been associated with other conditions linked with CVD, such as obesity and type 2 diabetes mellitus (T2DM). Short sleep duration has been strongly linked to an increased risk of obesity across all populations[14], and, conversely, for each additional hour of sleep an individual's body mass index (BMI) decreases by 0.35 units[14]. Racial/ethnic differences have been found, with the strongest relationship of very short sleep (less than five hours per night) and obesity in individuals who identify as African American/black[5]. Further research has shown that women who reported sleeping less than 6 h per night over the course of 16 years gained significantly more weight compared to women that slept at least 7 h[15]. Individuals with short sleep duration (fewer than 6 h per night) have also been shown to have an increased risk of T2DM[16,17]. It remains unclear whether this increased risk is mediated by obesity or if there are other mechanisms, including glucose metabolism, that may explain the increased risk of T2DM.

There is less data on the connection between short sleep duration and other biological markers of health[6]. Regarding inflammatory markers, when sleep is experimentally restricted to fewer than four hours per night, increases in C-reactive protein and interleukin-1 receptor have resulted[18,19]. Studies examining the effects of short sleep duration and insulin resistance are also rare. Self-report of fewer than 6 h of sleep per night has been associated with increased insulin and hemoglobin A1C (HbA1c), but this result was attenuated when BMI was added to the model[20]. Studies of sleep restriction (fewer than 6 h in bed) have found an increase in insulin resistance[21,22]; however, these studies were limited to healthy, young males. Therefore, the relevance of these associations to the general population remain unclear.

Importance of other health behaviors in reducing CVD risk

Dietary intake, physical activity, and sedentary time have also been associated with CVD risk in adults. The effects of numerous dietary components on CVD risk have been examined[23]. For example, adherence to a Mediterranean diet, consisting of a high intake of fruits and vegetables, fish, olive oils, and dairy, has been associated with a lower risk of CVD events including myocardial infarction and stroke as well as lower cardiovascular mortality[24]. A similar dietary eating pattern, the DASH eating plan, consisting of fruits and vegetables, low-fat dairy, whole grains, poultry, fish, and nuts, has also been found to lower incidence of adverse cardiovascular events[25]. Specific dietary components have also been associated

with a reduced risk of CVD. Diets high in polyunsaturated fatty acids and low in sodium have are linked to fewer cardiovascular events[23]. Increasing physical activity levels, at any intensity level, has been shown to lower CVD risk. Individuals with higher daily overall physical activity (measured *via* accelerometer) and moderate-vigorous physical activity have been shown to have lower CVD mortality[26]. Although reducing sedentary time appears important to overall health, sedentary time has generally not been associated with CVD mortality[26].

POTENTIAL RELATIONSHIPS BETWEEN MULTIPLE HEALTH BEHAVIORS IN REDUCING CVD RISK

Despite the strong evidence of increased CVD risk associated with each of the above behaviors on poor health outcomes, an important issue in this line of research is detangling the effects of these health behaviors from one another, as they tend to be strongly correlated within individuals. Due to this, it can be difficult to discern which health behaviors independently contribute to improved health outcomes. For example, there is limited data regarding how sleep combines with the other behaviors. Additional evidence is needed to define how these behaviors may cluster or pattern together resulting in an increased risk of disease; such knowledge can help to inform future public health intervention guidelines and policy in this area. Intervention and policy strategies to date have focused on changing individual behaviors, with very few strategies attempting to target multiple lifestyle behaviors simultaneously[27]. A study in over 500000 United Kingdom adults aged 37-63 years found that individuals with CVD were more likely to report low levels of physical activity, more than 3 h of TV viewing per day, and fewer than 7 h of sleep per night, compared to individuals without CVD[27]. The clustering of these behaviors was termed a "unhealthy phenotype" and individuals with this unhealthy phenotype had poorer disease outcomes.

Multiple health behavior interventions have been shown to have improved health outcomes, such as blood pressure, cholesterol, and glucose, when changes to both diet and activity are changed simutanously[28]. However, there is very limited evidence to date that these types of interventions directly impact CVD events or mortality[28].

STANDARD HEALTH BEHAVIOR INTERVENTIONS AND THEIR IMPACT IN CVD RISK POPULATIONS

Cognitive-behavioral therapy

Cognitive-behavioral therapy (CBT) is an evidence-based intervention for improving cardiac health behaviors and outcomes. It is a short-term skills-based psychotherapy that teaches cognitive (*e.g.*, cognitive restructuring, probability estimation) and behavioral strategies (*e.g.*, behavioral exposures, behavioral activation) to reduce emotional distress, improve well-being, and promote healthy behavioral choices. Originally developed for treating emotional problems, CBT is often most useful for improving health behaviors among patients with or at risk for chronic medical conditions who may be more motivated for change, and psychiatric symptoms among individuals with mental health disorders who have the greatest room for symptom improvement. For example, in a study of CBT for improving sleep in healthy college students, only those with poor sleep at baseline showed significant improvement (Trockel *et al*, 2011). Thus, much of the work on CBT and cardiac risk factors has been aimed at improving sleep and other health behaviors and psychiatric symptoms in patients with insomnia, mental health problems, or those with or at risk for CVD. Table 1 shows representative studies examining the effects of standard health behavior interventions on health outcomes.

CBT is useful for improving sleep and other health behaviors in patients with or at risk for CVD. A recent review of CBT for insomnia (CBT-I) in CVD patients found that there is limited but promising evidence for CBT-I to improve sleep characteristics (*e.g.*, sleep efficiency and quality), CVD biomarkers, symptom burden, functional impairment, and quality of life[29,30]. CBT has also been shown to improve health behaviors including diet (*e.g.*, reduced sugar, increased fruits/vegetables), physical activity, and smoking cessation in some studies of healthy adults and those with or at risk for CVD[31-35].

In line with the original aim of CBT, much of the research on CBT and cardiac health has focused on the efficacy of CBT in improving psychosocial problems in CVD patients given that these problems have a significant negative impact on cardiac morbidity and mortality[36,37]. The results of several randomized clinical trials (RCT) support the efficacy of CBT in improving depression, anxiety, and quality of life in CVD patients, patients suffering an acute coronary syndrome (ACS), heart surgery patients, and heart failure patients[38-44]. A systematic review and meta-analysis of psychological interventions for depression in CVD found that CBT had the strongest effects[45], and the American Heart Association specifically recommends CBT for treating depression in CVD patients[46]. CBT is also associated with improved psychosocial outcomes among individuals at risk for CVD including those with type 2 diabetes, hypertension, and overweight and obesity[31,34,47].

Evidence for direct effects of CBT on physical health outcomes is less consistent. A Cochrane review of 64 RCTs found that psychological interventions produced small-moderate improvements in depression and anxiety and a small effect on cardiac mortality in CVD patients, but no effect on total death or cardiac events[44]. Another systematic review found improvements in depression symptoms but no effect on all-cause mortality, cardiac mortality, or cardiac events[43]. In the Enhancing Recovery in Coronary Heart Disease Patients trial, a randomized trial of 2481 post-ACS patients, CBT was asso-

Table 1 Representative studies examining the effects of cognitive behavioral therapy and motivational interviewing on health-related outcomes

Ref.	Population	Intervention	Outcome
Tsiros *et al*[33], 2008	*n* = 47 adolescents with overweight or obesity	CBT *vs* no-treatment	Greater improvements in weight, BMI, body fat, sugar intake (soft drinks) in CBT group at 20-wk follow-up
Welschen *et al*[34], 2013	*n* = 154 diabetes patients	CBT *vs* managed care	Greater improvement in physical activity, quality of life, and depression in CBT group at 6-mo follow-up; no group differences at 12-mo follow-up
Freedland *et al*[39], 2009	*n* = 123 CABG patients with depression	CBT *vs* supportive stress management	Greater depression remission in CBT than supportive stress management group at 3-mo and 9-mo follow-up
Berkman *et al*[48], 2003	*n* = 2481 MI patients	CBT *vs* usual care	Greater improvement in depression and social support in CBT group at 6-mo follow-up; no group differences in survival at 29-mo follow-up
Woollard *et al*[55], 1995	*n* = 166 patients with hypertension	MI low dose *vs* MI high dose *vs* usual care	Greater improvements in alcohol and salt intake in low-MI *vs* usual care; greater improvements in weight and blood pressure in high-MI *vs* usual care at 18-wk follow-up
Ma *et al*[59], 2014	*n* = 120 Chinese patients with hypertension	MI *vs* usual care	Greater improvements in treatment adherence and blood pressure in MI group
Ogedegbe *et al*[60], 2008	*n* = 190 African American patients with hypertension	MI *vs* usual care	Greater improvements in medication adherence and blood pressure in the MI group at 12-mo follow-up
Cain *et al*[68], 2011	*n* = 104 adolescents	MI and sleep education *vs* no intervention	Greater improvements in sleep knowledge and out-of-bed time in MI group; improvements in sleep and daytime functioning in both groups

BMI: Body mass index; CABG: Coronary artery bypass graft; CBT: Cognitive behavioral therapy; MI: Motivational interviewing.

ciated with improvements in depression symptoms, but did not affect survival or cardiac events at 6-mo follow-up[48]. It is possible that longer-term follow-up is needed to identify physical health benefits of CBT, which may take time to develop and require continued use of CBT skills[49,50].

Recent studies have explored telephone-based and web-based CBT interventions for improving psychosocial outcomes in patients with CVD. These studies have shown mixed but promising results. For example, a RCT of telephone-delivered CBT for post-ACS patients with depression found greater improvements in depression symptoms following CBT as compared to usual care, with effects maintained up to one year later[42]. A pilot study of web-based CBT for heart failure patients also found improvements in depression symptoms though there were no significant between-group differences[51]. In a study of post-transplant patients, however, telephone-delivered CBT was not found to be acceptable, and while patients who did participate showed significant reductions in anxiety and depression symptoms, most (67%) continued to show elevated scores[52]. Given that there is evidence of potential feasibility and efficacy, and mobile health interventions have the potential to improve access to mental health care for CVD patients[53], further controlled studies should explore virtual CBT interventions

MI based interventions and their impact in CVD risk population

An even more traditional approach to health behavior change is motivational interviewing (MI). Over 30 years of research have established MI, a patient-centered method for identifying and enhancing intrinsic motivation, as an effective and straightforward technique for promoting behavioral change[54,55]. MI is effective and can be delivered remotely by different avenues with good fidelity[56,57]. MI interventions have led to improved health behaviors in patients with cardiac risk factors, including increased physical activity in patients with diabetes[58] and hypertension[59]. Additional studies have demonstrated improved medication adherence and significant reductions in systolic blood pressure in patients with hypertension[60-62]. Furthermore, a Cochrane review of MI for smoking cessation showed a modest but significant increase in quitting compared to usual care[63]. There are several ongoing trials assessing the potential of different MI-based interventions to improve other health behaviors and cardiac risk factors, including improving statin adherence in patients with hypercholesterolemia[64], optimizing risk factors in patients undergoing cardiovascular procedures[65], and comparing group-based to individual MI interventions in patients at high risk for CVD[66]. Although few interventions have used MI to modify sleep behaviors[67,68], MI may be well-suited to address sleep in a manner similar to that used for other health behaviors. Further, despite MIs extensive use in research studies and clinical care, the effects of solely MI-based interventions for activity promotion in patients with T2D[58] and other major cardiac risk factors may not be significant enough to prevent CVD or major cardiac events, raising the possibility that additional interventions may be necessary in these patients.

NOVEL INTERVENTIONS TO TARGET HEALTH BEHAVIORS AND CARDIAC OUTCOMES

Mindfulness and mind-body interventions

Mindfulness and other mind-body interventions have

received increased attention for improving cardiac health behaviors and outcomes. Mind-body interventions encompass a range of techniques that aim to unite the body and mind to promote well-being, such as progressive muscle relaxation, meditation, yoga, and tai chi. Mindfulness is a specific approach that involves paying attention to present moment experiences with an attitude of openness, non-judgment, and curiosity[69]. A large body of research supports the efficacy of mind-body interventions, particularly mindfulness-based interventions that incorporate elements of CBT (*e.g.*, mindfulness-based stress reduction, mindfulness-based cognitive therapy) for improving a range of physical and mental health outcomes (*e.g.*, Hofmann *et al*[70], 2010).

Mindfulness-based interventions may improve cardiac health behaviors. Recent systematic reviews have concluded that mindfulness interventions promote smoking cessation[71] and healthy eating[72]. Evidence for improvements in sleep are somewhat limited, with a systematic review finding few randomized controlled trials and no significant between-group differences in sleep outcomes, but a significant correlation between amount of mindfulness meditation practice and improved sleep[73]. Subsequent RCTs, however, have found significant effects of mindfulness training on insomnia[74]. There has been less research using mindfulness-based interventions to promote physical activity, though there is some evidence to suggest that mindfulness training can increase physical activity in healthy young adults[75] and CVD patients[76], and that the ability to be mindful during daily life in general (*i.e.*, trait mindfulness) might increase physical activity levels by making activity seem more satisfying[77].

Mindfulness-based interventions have also been associated with improved health outcomes in patients with and at risk for CVD. Research suggests that mindfulness training can promote weight loss among patients with obesity[78]; improve disease management and HbA1c levels among patients with diabetes[79]; and improve coping and blood pressure in patients with hypertension[80]. A systematic review among individuals with CVD or other risk factors (*e.g.*, hypertension and diabetes patients) found significant improvements in stress, depression, anxiety, and quality of life following mindfulness interventions; however, similar to studies of CBT, effects on physical health outcomes were less consistent[49]. Among CVD patients specifically, a systematic review of 11 RCTs of mind-body practices found significant improvements in depression, anxiety, and QoL, though these studies were found to be of overall low quality[81]. Mindfulness-based interventions have also been integrated into cardiac rehabilitation programs[82], and several studies suggest that meditation, tai chi, and yoga may be useful for improving health outcomes in heart failure patients[83-85]. Indeed, a systematic review of 29 trials (9 RCTs) found that tai chi is associated with reduced blood pressure and exercise capacity in patients with CVD and risk factors[86]. Further research on mind-body interventions for CVD risk behaviors and outcomes is needed, though providers should be aware that existing mind-body approaches may be useful for cardiovascular outcomes.

Positive psychological interventions for health behavior and cardiac outcome improvement

There has been increasing interest in the use of positive psychology (PP) interventions that aim to boost positive emotional experiences and cognitive processes through the use of simple tasks focusing on positive psychological constructs, such as optimism and positive affect. These positive constructs have been shown to correlate with improved adherence to cardiac health behaviors, such as physical activity[87,88], diet[89,90], and medication adherence[91]. They have further been associated with improved rates of heart disease and cardiac mortality[92-94]. Specific PP exercises found effective in medically healthy persons include recalling and discussing positive events, identifying and deliberately using personal strengths, and planning and performing acts of kindness[95,96].

PP interventions are simple for patients and do not require extensive provider training, raising the attractive possibility of a cost-effective and efficient means of improving mood and cardiac health behaviors. Despite this, there has been limited study of PP-based interventions to promote health behaviors, improve sleep, or reduce cardiac events or mortality. PP interventions have been applied in studies of T2D[97] and immunodeficiency virus[98], and a meta analysis has shown that their successful implementation leads to improvements in psychological outcomes[99]. Positive psychology interventions focused on gratitude have also promoted improvement in sleep hours and quality in patients with neuromuscular disease[100].

Among patients with existing CVD, there is a small literature on PP interventions[101-103], generally finding that such interventions are well-accepted and have beneficial effects on both positive and negative psychological states[101-106]. Additionally, randomized controlled trials of positive affect interventions have shown increased medication adherence in hypertensive patients[104] and improved physical activity in patients post-percutaneous coronary intervention[105]. Furthermore, combining PP with established health behavior interventions could provide additional benefit, building on the literature showing that PP exercises lead to increases in self-efficacy, confidence, and interpersonal connectedness[106-108] and findings that these same characteristics can improve engagement in health behavior interventions[109,110].

Management of mental health conditions/care management

Additional novel approaches to modifying health behaviors *via* mental health-related interventions may include care management programs for patients with psychiatric conditions. Depression and other psychiatric syndromes are common in patients with, or at risk for,

CVD[111,112], and they can be identified *via* systematic screening in clinical cardiology settings[113]. Patients with depression and related conditions are at substantially elevated risk for nonadherence, including nonadherence to cardiac health behaviors[114-116]. Given the high prevalence and substantial impact of these psychiatric conditions, utilizing population-based interventions to efficiently manage these conditions is a promising approach to improving psychiatric symptoms, health behavior adherence, and overall cardiac risk in the greatest number of patients. For example, "collaborative care" interventions utilize a non-physician care manager (often a nurse) to assess and longitudinally monitor psychiatric conditions for patients in inpatient and outpatient medical settings[117,118]. The care manager can also provide psychotherapeutic interventions and support to patients, and receives psychiatric medication recommendations when indicated from a team psychiatrist. These medication recommendations are conveyed to primary care physicians, who then prescribe all medications. This allows a large number of patients to receive ongoing and expert management of psychiatric care, while maintaining such care within their existing medical home.

Collaborative care interventions have been found to be effective in improving psychiatric symptoms in over 90 prior trials[117]. This includes several prior trials in patients with CVD or cardiac risk factors (*e.g.*, diabetes)[118-124], with beneficial effects on depression and/or anxiety symptoms. They have not typically included specific interventions to improve sleep or other health behaviors, and they have had more mixed effects on adherence, with some trials finding improvement in adherence to health behaviors (*e.g.*, diet, exercise, and medication adherence)[120,125], while others have not measured effects on adherence or found no significant change. Effects on cardiovascular outcomes have similarly been mixed, though an analysis of the large IMPACT trial of collaborative care found that the intervention was associated with lower risk of cardiovascular events among those participants with no CVD at the outset of the trial[126].

One promising approach to improving behavioral and cardiovascular outcomes is a "blended" collaborative care management approach that utilizes a nurse care manager to address depression, health behaviors, and medical targets (*e.g.*, blood pressure) in patients with medical illness. The TEAMCare randomized trial tested such an approach in patients with diabetes or coronary artery disease, and found that such an intervention lead to improved medical outcomes, including hemoglobin A1c and blood pressure, using this combined psychiatric, behavioral, and medical approach[127]. The COMPASS project then implemented this intervention in 172 real-world clinics among 3609 patients[128,129]. Overall 40% had depression remission or response, one-quarter met criteria for control of blood glucose, and nearly 60% met criteria for blood pressure control, impressive findings for real-world implementation in a complex population.

CONCLUSION

The importance of sleep as a health behavior to lower the risk of CVD in adults has not been widely studied. With recent guidelines shedding light on the importance of adults maintaining adequate sleep (defined as at least seven hours) for optimal health and the growing number of Americans not meeting this recommendation, future research needs to include sleep when assessing CVD risk factors and intervention targets. Research to date has primarily focused on other health behaviors including diet, physical activity, and sedentary time. Many of these interventions have focused on one health behavior, rather than changing multiple behaviors, despite the fact that these behaviors tend to be interrelated. The same theories and intervention strategies used to change individual health behaviors, including CBT, MI, mindfulness and mind-body interventions, and PP-based interventions, could be adapted to promote all relevant health behaviors as we have outlined in this review. Further, moving toward blended collaborative care models may be a promising approach to improve health behaviors in those with psychiatric conditions. Such interventions that focus on psychological status, health behaviors, and medical targets may indeed hold substantial promise to modify sleep and other health behaviors to reduce cardiac risk.

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