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REVIEW ARTICLE

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Use of theories of health behavior in sleep promotion studies: A scoping review

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ABSTRACT

Background: Sleep deprivation forms a vicious cycle with chronic diseases. This can be prevented by promoting behaviors conducive to restorative sleep. Although theories of health behavior can inform issues of behavior change, their use in the context of sleep promotion has not been yet comprehensively reviewed.

Methods: A scoping review was conducted. Five electronic databases were searched: AgeLine, CINAHL, Embase, MEDLINE, and PsychINFO. Additional studies were identified through reference chaining. Studies were included if theories of health behavior were mentioned, referenced and applied in relation to a sleep behavior. Study characteristics and data on theoretical applications were collected using a charting form. Quantitative findings were analyzed through frequency count, while qualitative findings were thematically analyzed.

Results: Thirty-five studies with various method designs were included. Most studies targeted adults with obstructive sleep apnea (n=18) and students at risk of poor sleep hygiene (n=12). The application of twenty-two theories of health behavior was identified with three main ways of informing sleep promotion initiatives. Most of the evidence obtained from theoretical applications related to how personal beliefs, intentions to change and social influences can explain adherence to treatment for obstructive sleep apnea or the adoption of healthy sleep hygiene, and how these factors can be changed via theory-based interventions and program evaluations.

Conclusions: This study provides public health researchers and health promoters synthesized evidence to deploy theory-based interventions that address many factors shown to influence treatment adherence for obstructive sleep apnea and healthy sleep hygiene. Limited evidence is provided on sleep behaviors pertinent to individuals affected with insomnia.

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sleep; theories of health behavior; scoping review; health promotion; behavior change

Introduction

According to the National Health Interview Survey (NHIS), almost 33% of American adults reported sleeping less than six hours a night in 2017; an increase of 15% since 2004 [1]. In the short-term, insufficient and/or poor-quality sleep impairs affective, cognitive and behavioral functions [2-4]. In the long term, it can lead to chronic diseases, such as obesity, coronary artery disease, type 2 diabetes, hypertension, depression and anxiety [5-7]. Sleep plays an important role in regulating the immune system and inflammatory markers [8]. High levels of pain and stress due to chronic conditions can prevent one from obtaining adequate sleep [9]. Poor sleep quality, including difficulty falling asleep, waking up at night, having a hard time getting back to sleep, and waking up repeatedly during the night can lead to decreased quality of life [10]. Overall, sleep deprivation and poor-quality sleep form a vicious cycle with chronic disease.

Causes of sleep deprivation, interrupted sleep or poor quality sleep can be pathogenic (e.g., insomnia, sleep apnea), mental (e.g., anxiety, depression, stress), physical (e.g., pain), behavioral (e.g., bedtime procrastination, poor sleep hygiene, poor adherence to treatment), environmental (e.g., exposure to noise, light and other stimulants), and social (e.g., loneliness) [11-14]. Many of these causes can be modified and are therefore amenable to behavior change interventions. This paper focuses on behaviors that can be modified voluntarily to achieve restorative sleep, rather than pharmacological treatments of sleep disorders, as it is meant to inform a healthy lifestyles program from a health promotion and behavior change lens [15]. Various non-pharmacological interventions exist to improve sleep quality and duration. Some of these include physical activity, mindfulness based therapy, breathing exercises, music therapy, relaxation, laughter, acupuncture, foot reflexology, passive body heating, light therapy, amber lenses, herbal medicine, and diet [16-31]. For chronic insomnia, cognitive behavioral therapy (CBT), stimulus control, sleep restriction, sleep hygiene education, relaxation training and brief behavioral treatments are recommended [32,33]. For obstructive sleep apnea (OSA), optimal use of positive airway pressure (PAP) devices, oral appliances and obesity management interventions can help achieve restorative sleep [34]. While there are many effective interventions for improving sleep parameters, it is just as important to know how to support individuals in changing their habits to improve sleep and overall health.

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Theories are often used in public health to examine interventions requiring a change in behavior. It has been shown that interventions that use a theoretical base are more effective than those that do not have a theoretical base [35]. Many theories of health behavior (THBs) exist and have been developed and applied for a number of health behavior changes [35]. Examples include the Theory of Planned Behavior (TPB) [36], Health Belief Model (HBM) [37], Transtheoretical Model of Behavior Change (TTM) [38], Social-Cognitive Theory (SCT) [39], Self-Determination Theory (SDT) [40], and the Ecological Model of Health Behavior (EMHB) [41], among many others. These theories, models and frameworks seek to answer questions like, 'What factors influence health behaviors?' and, 'How can we use these factors to influence health behaviors in individuals, groups or populations?

The Theoretical Domains Framework (TDF) [42] can help analyze modifiable factors that influence behavior change and guide the development and implementation of interventions [42]. It classifies factors influencing behavior under 14 unique domains: 1) knowledge, 2) skills, 3) social role and identity, 4) beliefs about capabilities, 5) optimism, 6) beliefs about consequences, 7) reinforcement, 8) intentions, 9) goals, 10) memory, attention and decision processes, 11) environmental context and resources, 12) social influences, 13) emotion and 14) behavioral regulation. This framework was developed from experts in behavior change, incorporating 33 theories of health behavior.

In 2015, Davis and colleagues conducted a scoping review on the application of theories of health behavior across the social and behavioral sciences [43]. Of the behaviors reviewed by the study, none were specifically framed in the context of improving sleep [43]. To date, the authors of this paper are not aware of any comprehensive study that has used similar methodology to map theories of health behavior across multiple behaviors conducive to sleep improvement. Therefore, the purpose of this study was to provide a broad overview of the literature in relation to which theories of health behavior can inform the development and improvement of non-pharmacological sleep interventions, where a change in habit is required. The objectives were to:

1) Map the use of theories of health behavior across multiple behaviors relevant to sleep promotion, and populations of interest;
2) Identify gaps in the literature to inform future studies;
3) Inform a healthy lifestyles program [15].

Methods

Study design

A scoping review was conducted: a methodology that can identify main concepts underpinning a complex and unfamiliar research area [44]. The process generally consists of identifying and selecting relevant studies, charting data, and collating, summarizing and reporting results [44]. This methodology allows researchers to map main sources of information and types of analysis with the intention of obtaining a preliminary assessment of the scope and number of research activities available, including those in progress [44,45]. The breadth and depth of possible outcomes useful within the field of study can be determined by researchers during the process of identifying and collecting data [44]. No formal quality assessment is required as the focus is on getting a fulsome understanding of the field as opposed to determining the strength of cumulative evidence [45]. This methodology contrasts with systematic reviews, which utilize an exhaustive search strategy in a focused and well-defined area of research to appraise the quality and strength of available evidence, with the overall intention of providing recommendations for practice and future research [45].

Document identification

The search strategy was developed and pilot tested with the help of librarians and experts in systematic review methods. The final search strategy was conducted on August 3rd, 2017. Electronic databases searched included AgeLine, CINAHL, Embase, MEDLINE, and PsychINFO. The search string included keywords that related to theories of health behavior and sleep (see Appendix 1). Searches were limited to studies published between 2007 and 2017, and human subjects. A 10-year window period ensured that the selection process was more manageable and findings were more timely, given that some theories of health behavior have origins in the early-mid 1900's and these can evolve over time. Additional studies were identified through reference chaining.

Document selection

Identified studies were imported into Zotero® (Corporation for Digital Scholarship, Fairfax/ Virginia, 2017). Suggested duplicates were screened and merged into single items. The first 100 unique articles were screened by three investigators to help solidify inclusion criteria. Studies were excluded through title and abstract if they did not focus on a behavior relevant to sleep promotion that can be modified voluntarily. Remaining studies were screened through full-text and included if they mentioned a THB, provided a reference for the theory and applied the theory in relation to a behavior that can improve sleep. Studies that applied at least one construct of the theory were included. These inclusion criteria were inspired by a study conducted by Davis et al. (2015) who reviewed the use of theories of health behavior across multiple behaviors relevant to public health [43]. Articles with inaccessible full-texts or that did not meet inclusion criteria were excluded. Full-text eligibility of studies was confirmed by three investigators. Disagreements regarding study eligibility were discussed until consensus was met.

Data collection

A charting form was developed based on a preliminary literature review, and pilot tested by three investigators on five random studies [39]. Discussions from this process were used to create a final charting form (see Appendix 2), subsequently used on the remaining studies. Qualitative and quantitative data was collected regarding each article's title, author, year, country, study design, target population, target behavior, applied THB, theoretical constructs, purpose of theoretical application, and results derived from theoretical application. Data collection was completed in 2017.

Data analysis

Data collected in charting forms was summarized in a table. Frequency count analysis was performed on data related to

'year of publication', 'country of publication', 'study design', 'target population', 'examined behavior' and 'applied theory of health behavior' to assess the nature and extent of studies reviewed [39]. Content abstracted under the category 'purpose of theoretical application' was thematically analyzed until diverse, yet distinguished, categories of purposes were identified [41]. The Theoretical Domains Framework (TDF) was used to assess defined domains of behavioral influence receiving most attention in the field and to help structure the summary of results and discussion points linked to applied theoretical constructs [42]. Memos were made to guide data interpretation and gaps within the literature. Data analysis was completed in 2018.

Ethical consideration

The study relied on previously published data that is accessible to the public. As such, no ethical approval was required.

Results

Identified studies

A total of 1,296 unique articles were identified through database searching. Of these, 24 met full inclusion criteria, meanwhile reference chaining identified 11 additional studies. Thus, 35 studies were included in the scoping review (see Appendix 3). Figure 1 outlines the document identification, screening and selection process, following the PRISMA checklist for systematic reviews and meta-analyses [43].

Study characteristics

Most studies were published between 2010 and 2013 (n=13, 37%), conducted in the United States (n=16, 46%) or Australia (n=7, 20%), adopted a mixed methods study design (n=11, 31%), randomized controlled trial (n=8, 23%) or prospective cohort (n=7, 11%), and targeted patients with OSA (n=18, 51%) as well as students with poor sleeping habits (n=12, 34%). Behaviors described in studies fell under the categories of adherence to treatment for OSA (n=18, 51%), sleep hygiene practices (n=15, 43%), or adherence to treatment for chronic insomnia (n=2, 6%), including CBT and hypnotic tapering. Table 1 outlines descriptive information on reviewed articles.

Applied theories of health behavior

Twenty theories of health behavior were identified. The most commonly used theories of health behavior were the SCT (n=11, 31%), TTM (n=11, 31%), TPB (n=7, 20%) and HBM (n=5, 14%). The SCT was applied solely in the context of examining treatment adherence, while the TPB and EMHB were applied mostly to examine sleep hygiene practices. The TTM, HBM and Health Action Process Approach (HAPA) were applied in similar proportions amongst behaviors. Table 2 outlines all theories of health behavior that were identified along with their theoretical constructs and frequency of use.

Based on the TDF, most commonly applied theoretical constructs fell under the following domains of behavioral

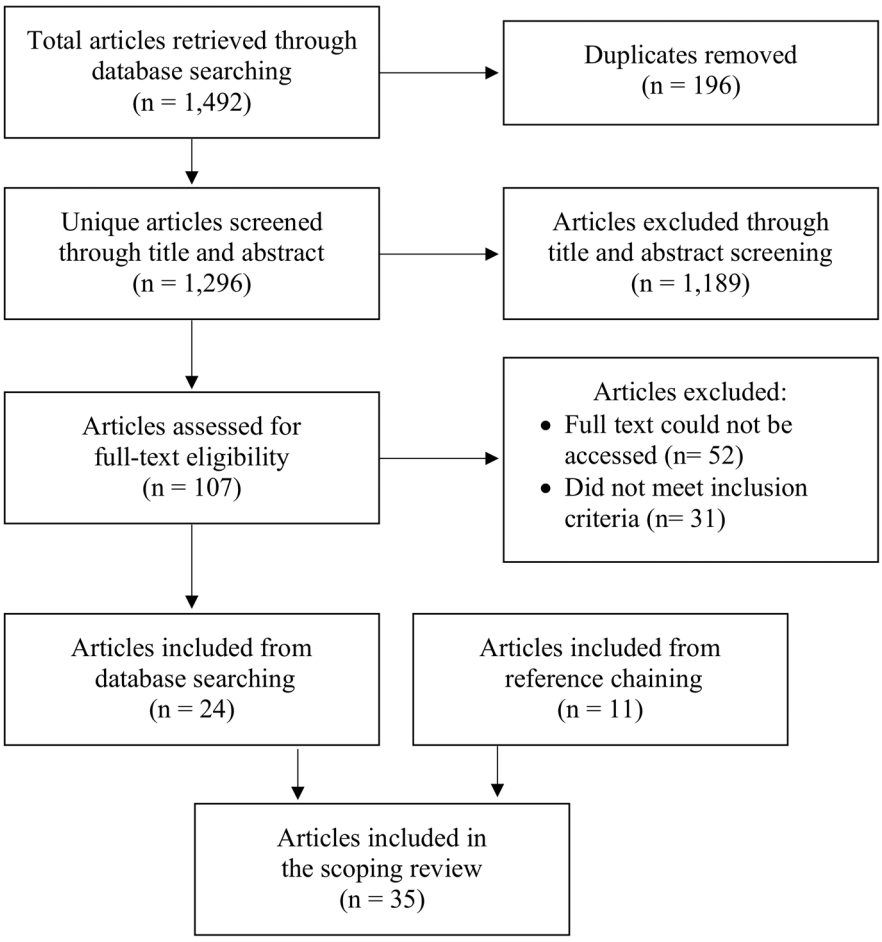

Figure 1: PRISMA flow diagram.

Table 1: Characteristics of studies reviewed

Code	Results	n (%)
Year	2014-2017	12(34)
	2010-2013	13(37)
	2006-2009	6(17)
	2002-2005	4(11)
Country	United States	16(46)
	Australia	7(20)
	Canada	3(9)
	China	2(6)
	Portugal	2(6)
	United Kingdom	2(6)
	France	1(3)
	Iran	1(3)
	New Zealand	1(3)
Study design	Mixed methods	11(31)
	RCT	8(23)
	Prospective cohort	7(11)
	Cross-sectional	4(11)
	Review	4(11)
	Secondary analysis of RCT data	1(3)
Target population	Patients diagnosed with sleep apnea	18(51)
	Students	12(34)
	Insomniacs	2(6)
	Other (i.e., workers, women, not specified)	3(9)
Modifiable behavior	Adherence to treatment for sleep apnea (APAP, CPAP, OAT, PAP)	18(51)
	Sleep hygiene practices (bedtime, wake-up time, before bed practices)	15(43)
	Adherence to treatment for chronic insomnia (hypnotic tapering, CBT)	2 (6)

Legend: APAP (auto-adjusting positive airway pressure); **CBT** (Cognitive Behavioral Therapy); **CPAP** (continuous positive airway pressure); **OAT** (oral appliance therapy); **PAP** (positive airway pressure).

Table 2: Applied theories of health behavior, associated constructs, and frequency of use

Applied theories of health behavior	Applied theoretical constructs (components)	n (%)
Social Cognitive Theory/ Value-Expectancy Theory [59,72-75,77-82]	Goals, outcome expectancy/perceived effectiveness, perceived barriers, perceived facilitators, risk perception, self-efficacy, social support	11(31)
Transtheoretical Model of Behavior Change [56,59,72,73,76,77,78,83-86]	Stages of change (behavioral intention, decisional balance, processes of change, readiness to change, self-efficacy)	11(31)
Theory of Planned Behavior/ Integrated Behavioral Model/ Reasoned Action Approach [54,65,67-70,83]	Attitudes (affective, cognitive, experiential, instrumental), behavioral intention, perceived behavioral control/personal agency, subjective norms (injunctive, descriptive)	7(20)
Health Belief Model [70,85,87-89]	Cues to action, knowledge, outcome expectancy (perceived barriers, perceived benefits), risk perception (perceived severity, perceived susceptibility), self-efficacy	5(14)
Ecological Models of Health Behavior [89,90]	Levels of health (individual, community/social, societal/environmental)	2(6)
Health Action Process Approach [58,91]	Motivational phase (intention, goals, outcome expectancy, risk awareness, self-efficacy), volitional phase (planning, implementation, self-efficacy, maintenance)	2(6)
Social Learning Theory/ Social Cognitive Model [92,93]	Cost-benefit equation, attitudes, beliefs, health value, locus of control (internality, powerful others, chance), self-efficacy	2(6)
I-change model (or Attitude-Social Influence-Self-Efficacy Model) [85]	Attitudes, self-efficacy, social influences (peers, parents)	1(3)
Multitheory Model of Health Behavior Change [71]	Initiation phase (behavioral confidence, participatory dialogue, physical environment), sustainability phase (emotional transformation, practice), social environment	1(3)
Control Theory along with Strength Model of Self-Control [55]	Self-monitoring, self-regulation	1(3)
Principles of Motivational Interviewing [76]	Ready, willing, able	1(3)
Self-Determination Theory [65]	Perceived autonomy support	1(3)
Self-Efficacy Theory [46]	Self-efficacy (emotional arousal, performance accomplishments, physical arousal, social persuasion, verbal persuasion, vicarious experiences, outcome expectancy)	1(3)
Self-Regulatory Model [78]	Family coping (social support, mobilizing help, passive appraisal, reframing, spiritual support) illness perception (emotional representations, illness comprehensibility, illness representations)	1(3)
Self-Regulation Theory [91]	Self-regulation, emotional arousal, preparation	1(3)

Note: Studies may have applied more than one theory.

influence: knowledge, beliefs about capabilities (e.g., self-efficacy, perceived behavioral control, internal locus of control), beliefs about consequences (e.g., outcome expectancy, risk perception, attitudes), intentions (e.g., stages of change, readiness to change, motivation), and social influences (e.g., subjective norms, social support). Few studies explored domains related to skills, reinforcement, goals, memory, attention and decision processes, environmental context and resources, emotions, and behavioral regulation. Optimism and social role and identify as domains of behavioral influence were not addressed. See appendix 3 for supplemental information on the categorization of applied theoretical constructs in respective domains of the TDF.

Purposes for using theories of health behaviors and linked findings

The main purposes for using a THB were to 1) explain sleep behaviors by testing their association with applied theoretical constructs, 2) suggest behavioral change techniques, components or interventions that can promote desired sleep behaviors and 3) evaluate the effects of sleep interventions on applied theoretical constructs and resulting sleep behavior change. Table 3 summarizes results linked to the application of identified theories of health behavior in each study. Supplemental information can be found in Appendix 3, where findings are organized by the TDF's domains, including suggested approaches within each domain.

Table 3: Summary of findings emerging from theoretical applications (N=35)

N=18 Adherence to treatment for sleep apnea (APAP, CPAP, OAT, PAP)						
Stepnowsky (2002)[72]	United States	Prospective cohort	Patients with OSA, new to CPAP treatment	TTM (decisional balance, stages of change and processes of change) & SCT (self-efficacy, outcome expectancy, social support and knowledge)	(1) Explain CPAP adherence by testing individual constructs and models	TTM and SCT models did not explain variance in CPAP adherence at baseline. At 1-week post CPAP fitting, TTM and SCT models explained 17% and 26% of the variance in CPAP adherence (decisional balance was the only significant individual predictor); at 1-month post CPAP fitting, TTM and SCT models explained 33% and 40% of the variance in CPAP adherence.
Engleman & Wild (2003)[93]	United Kingdom	Clinical review	Patients with OSA	SCM (cost-benefit equation modulated by health attitudes, beliefs, locus of control, health value and self-efficacy)	(2) Suggest a behavioral change technique, component or intervention	Cost-benefit equation can be improved through education. Partners can be present during the diagnosis phase to promote influence of powerful others. Locus of control and self-efficacy can be improved though CPAP demonstration and acclimatization. Patients at risk of poor CPAP adherence should be provided with extra support and education.
Weaver (2003) [79]	United States	Mixed methods	Patients with OSA	SCT (risk perception, outcome expectancy and self-efficacy)	(1) Explain CPAP adherence by identifying perceptions held by participants	More than 50% of patients did not perceive accidents, depression and problematic sexual drive as high risks of OSA. Feelings of claustrophobia and concern for disturbing bed partner's sleep were the two most important obstacles preventing patients from using CPAP.
Wild (2004)[92]	United Kingdom	Prospective cohort	Patients with OSA, prescribed CPAP treatment	SLT (health value, self-efficacy and locus of control; the latter depends on internality, powerful others and chance)	(1) Explain CPAP adherence by testing individual constructs and models	Higher CPAP adherence at 3 months was associated with stronger internal locus of control, less belief in powerful others and greater health value. Self-efficacy and chance were not associated with CPAP adherence. The SLT model explained an adjusted 6% of the variance in CPAP use; health value emerged as a significant predictor.

Tyrrell (2006)[87]	France	Mixed methods	Patients with OSA who had abandoned CPAP treatment	HBM (perceived susceptibility, perceived benefits and perceived barriers)	(1) Explain CPAP adherence by identifying perceptions held by participants & (2) Suggest a behavioral change technique, component or intervention	All participants were able to mention the negative consequence of sleep apnea. However, more than 50% did not view OSA as an illness. Some attributed fatigue to CPAP treatment rather than OSA. Few mentioned any benefits. Authors suggested prescribing CPAP to patients with high perceived susceptibility to OSA as they are more likely to adhere to the treatment.
Stepnowsky (2006)[73]	United States	Cross-sectional	Patients with OSA and experience using CPAP for 7 years	TTM (decisional balance) & SCT (self-efficacy, outcome expectancy, social support and knowledge)	(1) Explain CPAP adherence by testing individual constructs and models & (2) Suggest a behavioral change technique, component or intervention	Self-efficacy and decisional balance were the only variables to predict CPAP adherence. TTM explained an adjusted 16% of the variance in CPAP adherence. The SCT model explained an adjusted 11.5% of the variance in CPAP adherence. Authors suggested improving decisional balance by educating patients about the benefits of using CPAP on mood, energy level, productivity, social functioning and cardiovascular health.
Richards (2007) [74]	Australia	RCT	Patients with OSA, new to CPAP treatment	SCT (self-efficacy, outcome expectancy and social support)	(2) Develop a sleep intervention to improve CPAP adherence & (3) Evaluate a sleep intervention	A CBT intervention was developed to correct inaccurate beliefs about OSA and CPAP treatment. The intervention included educational components, CPAP acclimatization, relaxation techniques and role models. Compared to TAU, participants receiving CBT used CPAP for 2.9 hours per night longer and had significantly greater self-efficacy and social support. The proportion of participants that used CPAP for at least 4 hours per night was greater in the CBT group.
Olsen (2008)[88]	Australia	Prospective cohort	Patients with OSA, new to CPAP treatment	HBM (risk perception, outcome expectancies, self-efficacy)	(1) Explain CPAP adherence by testing individual constructs and models	Only risk perception and outcome expectancies were significant predictors of CPAP adherence at 4 months. The HBM model explained an adjusted 21.8% of the variance in CPAP adherence.
Sawyer (2010) [80]	United States	Mixed methods	Patients newly diagnosed with OSA	SCT (knowledge, outcome expectancy, self-efficacy, health goals, perceived barriers and perceived facilitators)	(1) Explain CPAP adherence by identifying perceptions held by participants	CPAP treatment adherers differed from nonadherers in their ability to define OSA risks, identify outcome expectancies, recognize symptoms of OSA, demonstrate self-efficacy, perceive facilitators to using CPAP, develop goals, demonstrate problem-solving skills and obtain social support.

Sawyer (2011) [75]	United States	Prospective cohort	Veterans considered at risk of severe OSA, new to CPAP treatment	SCT (risk perception, outcome expectancy and self-efficacy)	(1) Explain CPAP adherence by testing individual constructs and models & (2) Suggest a behavioral change technique, component or intervention	Baseline self-efficacy and African American race explained 14.9% of the variance in CPAP adherence; 19% of the variance post CPAP education; and 20.8% of the variance after 1 week of CPAP use. Authors suggested improving risk perceptions and outcome expectancies by educating patients on the symptoms and functional risks of sleep apnea as well as the benefits of CPAP treatment. Self-efficacy can be improved by sharing solutions to common treatment challenges.
Sampaio (2013) [77]	Portugal	Prospective cohort	Patients with OSA	TTM (decisional balance and processes of change) & SCT (self-efficacy, outcome expectancy and social support)	(1) Explain APAP adherence by testing individual constructs and models	Low baseline outcome expectancies predicted optimal APAP adherence. Low self-efficacy at 1-2 months FU and 3-6 months FU, predicted poor APAP adherence. There was no association found between APAP adherence and decisional balance, processes of change or social support.
Deng (2013)[58]	China	RCT	Patients newly diagnosed with OSA, new to CPAP treatment	HAPA (motivational phase characterized by intention, risk awareness and outcome expectancy; volitional phase characterized by action planning, self-efficacy, implementation and maintenance)	(2) Suggest a behavioral change technique, component or intervention & (3) Evaluate a sleep intervention	A stage-matched intervention can address risk awareness through guided reflection on the impact of OSA on patient's personal life; outcome expectancies through proper CPAP use guidance and education on associated benefits; self-efficacy through verbal encouragement, assistance in setting attainable goals, and reflections on past successes. Compared to TAU, the stage-matched intervention resulted in higher adherence to CPAP treatment, self-efficacy, outcome expectancy, but not risk awareness.
Aloia (2013)[59]	United States	RCT	Patients with OSA, new to CPAP treatment	TTM (readiness to change, decisional balance) & SCT (self-efficacy)	(2) Explain how an intervention can improve PAP adherence & (3) Evaluate a sleep intervention	MET helps patients reflect on their readiness to change, decisional balance and self-efficacy via tailored discussions. Compared to education and TAU, MET resulted in higher decisional balance and PAP use 12 months FU among moderate PAP users. Other differences in effect among groups were insignificant.
Dickerson (2013) [46]	United States	Mixed methods	Patients with OSA, new to CPAP treatment	SET (self-efficacy and outcome expectancy)	(2) Develop a sleep intervention to improve CPAP adherence	Authors presented a self-care management book containing self-monitoring tools, success stories and tips to get social support to improve patient's self-efficacy and outcome expectancies by obtaining objective and encouraging feedback of CPAP use.

Bartlett (2013) [81]	Australia	RCT	Patients with moderate to severe OSA, new to CPAP treatment	SCT (self-efficacy, social support and outcome expectancy)	(3) Evaluate a sleep intervention & (1) Explain CPAP adherence by testing individual constructs	There was no significant difference in CPAP adherence, social support, self-efficacy and outcome expectancy between the social interaction + BES intervention and the Social Cognitive Therapy + BES intervention. Both arms achieved comparable results, with CPAP uptake ranging between 82% and 88%, and CPAP adherence at 6 months ranging between 47% and 55%. Baseline self-efficacy was the only significant predictor of CPAP adherence at 6 months.
Sampaio (2014) [78]	Portugal	Prospective cohort	Patients with OSA, prescribed with APAP treatment	TTM (decisional balance and processes of change) & SCT (self-efficacy, outcome expectancy and social support) & SRM (family coping and illness representations)	(1) Explain APAP adherence by testing individual constructs	Greater self-efficacy, family coping and decisional balance, as well as lower illness cognitive representations, were associated with optimal APAP adherence at 6 months. Processes of change, social support and emotional representation were not associated with APAP adherence. Association with outcome expectancy was not reported, nor was the variance explained by the model.
Williams (2014) [84]	United States	Mixed methods (protocol)	African American study participants with metabolic syndrome at risk of OSA	TTM (stages of change)	(2) Explain how an intervention can improve CPAP adherence	Authors discussed a stage-matched phone intervention: ten phone calls are intended to address challenges, barriers and strategies for adhering to the recommended treatment plan. Motivation needs to be addressed before emphasizing knowledge, beliefs and health value.
Carballo (2016) [82]	United States	Cross-sectional	Individuals (+65 years) with OSA prescribed oral appliance therapy	VET (perceived effectiveness, self-efficacy and social support)	(1) Explain adherence to OAT by identifying perceptions held by participants & (2) Suggest a behavioral change technique, component or intervention	Few participants (36%) believed in the effectiveness of oral appliance therapy; felt that they would adhere to the treatment (39%); believed that they would receive social support on a regular basis from healthcare staff and significant others (38-41%). Specific perceptions included those related to technical issues, negative side effects, negative test results supporting treatment ineffectiveness, and inability to use the device. Authors suggested educating patients about sleep apnea and how oral appliance therapy can improve symptoms.
N=2 Adherence to treatment for chronic insomnia (hypnotic tapering, CBT)						

Belleville & Morin (2008)[86]	Canada	Secondary analysis of RCT	Chronic hypnotic users with symptoms of insomnia	TTM (self-efficacy, stages of change, decisional balance, and readiness to change)	(1) Explain adherence to hypnotic tapering by testing individual constructs	Compared to patients that did not reach drug free status, patients that ceased using hypnotics had higher self-efficacy. Those who maintained drug-free status had a steeper decrease in readiness to change as they implemented change throughout the intervention and had higher self-efficacy, compared to those that relapsed. Differences in other cognitive constructs were not significant.
Hebert (2010) [83]	Canada	RCT	Individuals with chronic insomnia	TTM (stages of change) & TPB (attitude, subjective norm, perceived behavioral control and behavioral intention)	(1) Explain adherence to online CBT by testing individual constructs and models	Greater intention, perceived behavioral control and contemplation were associated with frequent practice of sleep hygiene homework. Contemplation explained an adjusted 8% of the variance in intention to complete the program, while perceived behavioral control explained an additional 51.2% of variance. Actual adherence was not explained by TTM nor TPB models.
N=15 Sleep hygiene (bedtime, wake-up time, before bed practices)						
Moseley & Gradisar (2009) [56]	Australia	Mixed methods	High school students with and without delayed sleep timing	TTM (stages of change)	(3) Evaluate a sleep intervention	After receiving a brief education on sleep hygiene, 40.5% of students thought they needed to obtain 9 hours of sleep each night and 16.7% were willing; 34.2% of students did not plan to regularize their bedtime routine and 31.6% did not plan to get exposure to morning light in order to wake-up. Overall, students were not convinced by strategies to improve sleep.
Kor & Mullan (2011)[65]	Australia	Mixed methods	University students	TPB (behavioral intention, attitudes, subjective norm and perceived behavioral control) & SDT (perceived autonomy support)	(1) Explain sleep hygiene by testing individual constructs and models & (2) Suggest a behavioral change technique, component or intervention	Perceived behavioral control and subjective norms were significantly associated with intention to adopt healthy sleep hygiene. The TPB model explained 12.8% of the variance in intention, and 7.3% of the variance in sleep hygiene. SDT did not add significant variance in predicting intention. Authors suggested improving perceived behavioral control via self-regulation exercises.

Cain (2011)[76]	Australia	RCT	High school students with and without delayed sleep timing	PMI (willing, ready and able) & TTM (stages of change and processes of change)	(2) Explain how an intervention can improve sleep hygiene; suggest a behavioral change technique, component or intervention & (3) Evaluate a sleep intervention	A stage-matched educational intervention was evaluated: Pre-contemplation was targeted by providing students with accurate information and asking them to complete sleep diaries; contemplation and determination with decisional balance sheets and role-plays; action with relaxation and mindfulness exercises; and maintenance with relapse-preventative strategies. The intervention improved intention to regularize wake up time in all students and obtaining 9 hours of sleep amongst students with delayed sleep timing. Authors further suggested that monitoring past successes, brain storming activities, and social support could help raise students' sense of ability.
Knowlden (2012) [66]	United States	Mixed methods	University students, not residing with parent or legal guardian	TPB (behavioral intention, perceived behavioral control, subjective norms and attitudes)	(1) Explain sleep hygiene by testing individual constructs and models & (2) Suggest a behavioral change technique, component or intervention	Perceived behavioral control, attitudes and subjective norms were associated with intention to obtain adequate sleep (7-8 hours/night), while perceived behavioral control and behavioral intention were associated with sleep duration. The TPB model explained 36.2% of the variance in intention, and 34.5% in sleep duration. Authors suggested improving perceived behavioral control by addressing barriers such as poor time/financial management, inflexible class schedules and noisy dormitories, and goal-setting skills; subjective norms by training assertive communication techniques or delivering Rational Emotive Behavior Therapy; and attitudes through education.
Loft & Cameron (2013)[91]	New Zealand	RCT	Daytime adult workers wishing to improve their sleep	SRT (self-regulation, emotional arousal and preparation) & HAPA (motivational phase characterized by behavioral intention, goals and self-efficacy; volitional phase characterized by planning, implementation and maintenance)	(2) Explain how an intervention can improve sleep hygiene & (3) Evaluate a sleep intervention	Authors suggested improving self-regulation through an arousal reduction imagery which helps individuals direct their emotional thoughts towards mental images that are conducive to sleep; implementation intentions imagery was suggested to improve sleep planning skills. Compared to arousal reduction imagery and a control imagery, implementation intentions imagery was the most effective at improving and maintaining change in self-efficacy, sleep planning and engagement in healthy sleep hygiene practices of daytime workers.

Cassoff (2014) [85]	Canada	Mixed methods	High school students	TTM (behavioral intention and readiness to change) & ASE (attitudes, social influence and self-efficacy) & HBM (knowledge, risk perception and cues to action)	(1) Explain sleep hygiene by testing individual constructs & (2) Suggest a behavioral change technique, component or intervention	Cues to action, positive attitudes, and parents waking up the child were associated with intention to advance bedtime. An integrated model using cue to action, parents setting bedtime, parents waking up the child, positive attitudes toward sleep and peer social influences explained 49% of the variance in intention to advance bedtime. Authors suggested improving the influence of cues to action via mindfulness-based activities such as body scans.
Todd & Mullan (2013)[55]	Australia	RCT	University students	CT (self-monitoring) SMSC (self-regulation)	(2) Explain how an intervention can improve sleep hygiene & (3) Evaluate a sleep intervention	Authors suggested sleep diaries as a tool to self-monitor sleep hygiene practices and their associated consequences on individual's state of functioning and Go/NoGo response inhibition to improve self-regulation skills. Upon testing, participants receiving the Go/NoGo response inhibition training improved skills in this activity, but not other versions of response inhibition exercises. Sleep diaries only resulted in less stress-provoking activities before bed, compared to the control group.
Knowlden & Sharma (2014) [70]	USA	Mixed methods	University students who drive motor vehicles and are employed	HBM (risk perception, outcome expectancy, cues to action and self-efficacy)	(1) Explain sleep hygiene by testing individual constructs and models	Perceived severity, perceived barriers, cues to action and self-efficacy were associated with adequate sleep duration (7-8 hours/night). The HBM model explained 34% of the variance in obtaining adequate sleep.
Robbins & Niederdeppe (2015)[69]	United States	Mixed methods	University students	IBM (subjective norms, attitudes and perceived behavioral control)	(1) Explain sleep hygiene by testing individual constructs and models & (2) Suggest a behavioral change technique, component or intervention	Intention to obtain adequate sleep (8-9 hours/night) and actual sleep duration were associated with descriptive norms exerted by friends; attitudes that obtaining adequate sleep reduces time for socializing and academic success; having less stress/work and managing time effectively as facilitators to perceived behavioral control. The HBM model explained 49% of the variance in intention and 44% in sleep duration. Authors suggested improving attitudes by communicating the benefits of sleep (e.g., improved focus, efficiency and quality work); and perceived behavioral control through time/ project management, breathing exercises, physical activity, and meditation.

Lao (2016)[67]	China	Mixed methods	University students	TPB (behavioral intention, attitudes, perceived behavioral control, and subjective norms, including injunctive and descriptive norms)	(1) Explain sleep hygiene by testing individual constructs and models & (2) Suggest a behavioral change technique, component or intervention	Perceived behavioral control, intention, attitudes, and injunctive norms were positively associated with healthy sleep patterns. TPB explained 43% of the variance in intention to sleep healthily and 19% of the variance in healthy actual sleep hygiene (sleeping for 7-9 hours/night, going to bed early, waking up early). Perceived behavioral control can be influenced through psychoeducation (e.g., time management training); attitudes through communication on the benefits of sleep; subjective norms through supportive social environments.
Tagler (2017)[54]	United States	Critical review	University students	RAA (perceived behavioral control)	(2) Suggest a behavioral change technique, component or intervention	Time/stress management training was suggested to improve perceived behavioral control over sleep hygiene practices.
Strong (2017)[68]	Iran	Prospective cohort	High school students	TPB (behavioral intention attitudes, subjective norms and perceived behavioral control)	(1) Explain sleep hygiene by testing individual constructs and models	Attitudes were associated with intention only in students with poor sleep hygiene knowledge. Intention, perceived behavioral control and subjective norms were positively associated with sleep hygiene. The TPB model explained 49.9% of the variance in behavioral intention. Behavioral intention, along with coping and action planning, explained 60.2% of the variance in sleep hygiene.
Knowlden (2017) [71]	United States	Mixed methods	University students sleeping for less than 7 hours a night	MTM (initiation phase characterized by behavioral confidence, participatory dialogue and physical environment; sustainability phase characterized by emotional transformation, practice and social environment)	(1) Explain sleep hygiene by testing individual constructs and models & (2) Suggest a behavioral change technique, component or intervention	Behavioral confidence was associated with initiation to obtain adequate sleep (≥7 hours/night). Emotional transformation, practice for change and changes in social environments were associated with sustainability of adequate sleep. The MTM model explained 24.4% of the variance in initiating change and 34.2 % in maintaining change. Authors suggested improving behavioral confidence by helping students identify and overcome barriers; emotional transformation by addressing emotional receptivity and goal-setting; practice by using self-monitoring tools; supportive social environments by mobilizing students to seek support and advice.

Grandner (2017) [89]	United States	Literature review	Not specified	EM (individual, community and societal levels of influence) & IM (behavioral intention, attitudes, subjective norms) & HBM (risk perception, outcome expectancy, self-efficacy and cues to action)	(1) Explore the contextual factors that affect sleep hygiene & (2) Suggest a behavioral change technique, component or intervention	Sleep beliefs differ between cultures and races. Neighbourhoods affected by crime and poverty are more likely to experience poor sleep. Globalization and technology can induce a 24/7 society, causing longer working hours, shift work and desensitizing adequate sleep. However, healthy policies can be put in place to promote adequate sleep (e.g., regulations for work hours, screening procedures for sleep disorders, and noise and brightness regulation in neighbourhoods). Authors mentioned that educating the population on the severity of poor sleep was not enough; according to HBM there are many other perceptions that affect one's decision to obtain adequate sleep.
Vézina-Im (2017) [90]	United States	Systematic review and meta-analysis (protocol)	Adult women, including those that are pregnant or having a sleep disorder	EM (individual, social and environmental levels of influence)	(1) Explore the contextual factors that affect sleep hygiene	Factors that affect adequate sleep duration (7-9 hours/night) at the individual level will be searched (e.g., demographics, psychological and behavioral factors). At the social level, factors associated with the family environment will be searched. At the environmental level, physical factors and policies will be searched.

Legend: APAP (auto-adjusting positive airway pressure); **ASE** (Attitude-Social Influence-Self-Efficacy Model); **BES** (behavioral and education session); **CBT** (Cognitive Behavioral Therapy); **CPAP** (continuous positive airway pressure); **CT** (Control Theory); **EM** (Ecological Models of Health Behavior); **HAPA** (Health Action Process Approach); **HBM** (Health Belief Model); **IBM** (Integrated Behavioral Model); **MET** (Motivational Enhancement Therapy); **MTM** (Multitheory Model of Health Behavior Change); **OAT** (oral appliance therapy); **OSA** (obstructive sleep apnea); **PAP** (positive airway pressure); **PMI** (Principles of Motivational Interviewing); **RAA** (Reasoned Action Approach); **SCM** (Social Cognitive Model); **SCT** (Social Cognitive Theory); **SDT** (Self-Determination Theory); **SEMSA** (Self-Efficacy Measure for Sleep Apnea); **SET** (Self-Efficacy Theory); **SLT** (Social Learning Theory); **SMSC** (Strength Model of Self-Control); **SRM** (Self-Regulatory Model); **SRT** (Self-Regulation Theory); **TAU** (treatment as usual); **TPB** (Theory of Planned Behavior); **TTM** (Transtheoretical Model of Behavior Change); **VET** (Value-Expectancy Theory).

Discussion

This scoping review included 35 articles that described the use of a theory of health behavior to address non-pharmacological and habit-responsive approaches to improving sleep. Theoretical constructs were organized according to the Theoretical Domains Framework, providing an overview of how various behavioral influences can impact sleep. A large proportion of studies focused on improving CPAP adherence for the non-pharmacological treatment of sleep apnea, or sleep hygiene practices among students. Few studies applied a THB to inform the improvement of CBT for chronic insomnia. Although CBT may already be considered to have solid foundation in the behavioral and psychological sciences, [46] its theoretical base and effectiveness should continue to evolve [47].

The secondary objective of this paper was to identify gaps in the literature. Sleep and fatigue is a concern in emergency medical services workers [48]. Yet, no study has sought to apply a THB to support sleep interventions for this population group. In the contrary, one study used a THB to promote 'alertness' during shift-work, rather than adequate sleep [49]. Targeted behaviors included scheduled naps and stimulating activities, such as drinking caffeinated beverages, which are not recommended as part of healthy sleep hygiene practices [50]. Therefore, this study was excluded from this scoping review. Another population group that has been poorly examined is parents living with their children [51]. Parents are likely to experience chronic sleep deprivation due to stress, household chores, role overload and child misbehavior [52]. Only recently has a study applied the Social Cognitive Theory to describe both parents' and school-aged children's sleep-related cognitions and behaviors [53]. Since the study was conducted in 2018, it was not included formally in this scoping review.

Currently targeted behaviors in the field of sleep promotion have mostly focused on sleep parameters rather than concrete actions that can be changed voluntarily [54]. Todd and Mullan (2014) clearly underscored this challenge stating that "whilst many aspects of sleep quality such as sleep disturbances and depth of sleep are uncontrollable and difficult to measure, sleep hygiene behaviors are generally specific, modifiable and controllable" [55]. Limiting sleep promotion research to measures of sleep duration has pitfalls, especially for

individuals suffering from a physical or mental health condition preventing them from obtaining quality sleep despite efforts to maintaining regular sleep schedules. More appropriate measures of behavior change could consist of those aiming to address underlying causalities of poor sleep (e.g., alcohol abuse, lack of social interactions, limited physical activity, poor diet, noise, stress, extended exposure to screen light). Future research should expand on these limitations and include a wider variety of controllable behaviors known to improve sleep.

Many studies were excluded because they did not provide a reference to a THB, and if they did, the application of theory in the scope of sleep was not evident. Of those included, many did not use an entire theoretical model, but rather a portion of the constructs within the model. For example, in evaluating the impact of an educational program teaching students about healthy sleep habits, Moseley and Gradisar (2009) used the TTM to assess participants' stages of change [56]. Many other TTM constructs were left out, including self-efficacy, decisional balance, and processes of change [38]. Incomplete theoretical use limits the value of using a THB when designing and evaluating interventions, and explains why a given intervention may not be effective [47]. Future studies should explain theories in their entirety, with evidence on the predictive value of each construct and the model as a whole. They should also provide an explanation of how each construct informs the design and evaluation of the intervention, so that readers can understand the context in which the theories were chosen from, and continuous refinement of both theory and intervention is possible [47]. The Theory Coding Scheme can serve as guidance to ensure optimal theoretical application [47], meanwhile the TDF can be used to identify a wider variety of behavioral influences worth exploring [42].

Fit within the literature

Previously, Olsen et al. (2008) reviewed which theories of health behavior informed issues with CPAP adherence, summarizing the predictive correlation of many theoretical constructs [57]. Their literature review identified behavioral and cognitive interventions. However, only one had a theoretical-underpinning [57]. Olsen et al. (2008) explained the need to develop further educational interventions that shape early experience with CPAP, since this factor was found to be a significant predictor of long-term adherence [57]. Since 2008, additional studies have been published to inform this area of need, some of which have developed and evaluated educational interventions based on a THB. Findings are summarized in this paper and support the positive effect of staged-matched educational interventions and motivational enhancement therapy [58], [59].

In the realm of sleep hygiene, two reviews have been published to assess the theoretical underpinning of studies. Blunden et al. (2012) reviewed multiple educational programs addressing sleep duration among children and adolescents up to age of 19 [60]. Studies were published between 2002-2011, and not all were based on a THB. The main objective of the study was not to comprehensively review how theories of health behavior informed educational interventions. Recently, Mead and Irish (2019) conducted a literature review summarizing the correlation between theoretical constructs and measures of sleep duration and hygiene across studies published in 2011-2019 [61]. The review restricted its search strategy to few THBs, and missed many studies included in this paper. Overall, our scoping review utilized a more comprehensive search strategy with the objective of mapping as many different THBs as possible across the sleep promotion literature. Studies were not limited to a single way of using a THB; the summary provided in this paper includes results ranging from the predictive value of individual constructs and models, to interventions that have been developed and evaluated based on a THB.

Given the initial search for this paper was conducted in August 2017, the authors reran the original search strategy in PubMed from 2018-2020, identified and reviewed other current and relevant studies in PubMed. The overall assessment indicated that recent studies do not add substantive information other than that already included in this paper. Nonetheless, of note there are two qualitative studies that used the SCT to analyze factors influencing CPAP adherence in individuals with spinal cord injury and OSA [62], and sleep hygiene in parents and children [53]. Another qualitative study used the Common-Sense Model of Self-Regulation to explore experiences with sleep in patients with psoriasis [63]. In addition, a recent literature review applied the socioecological framework to discuss modifiable factors influencing sleep in the population [64]. The latter study made an important point regarding the need to further support sleep among prison inmates, homeless individuals, Native Americans, and hospitalized patients [64].

Implications for research

Although the purpose of this study was not to identify a THB that best informs sleep promotion, findings demonstrate that multiple studies inform this question. There is an opportunity to conduct a rigorous systematic review to assess the cumulative evidence regarding the correlation between similar theoretical constructs and measures of sleep (e.g., sleep duration, CPAP use). Other studies may wish to utilize theories of health behavior, via qualitative and mixed-methods approaches, to explore the influence of social roles, skills, living environment and emotions on sleep, especially among poorly examined population groups (e.g., parents, shift-workers, homeless individuals). Similar methodologies may be leveraged to better understand sleep promotion among individuals with chronic disease; this population can experience high levels of pain and stress, preventing them from obtaining adequate sleep [9]. Available THBs could guide researchers in evaluating the interconnections between cognitions, behaviors, sleep and measures of chronic disease. Additional studies should test the 'applicability' of THBs in explaining habits amenable to sleep improvement, other than CPAP adherence or sleep hygiene. For example, examined lifestyle changes could include mindfulness exercises, screen time reduction, sleep restriction, relaxation training, engagement in laughter-inducing activities. In this process, studies could compare the applicability of multiple theories of health behavior, to contribute to the refinement of a model that best supports change in a given habit. This will help eventually develop and evaluate effective theory-based interventions across various habits relevant to sleep.

Implications for policy and practice

Many THBs have been applied in the literature to inform improvements in CPAP adherence and sleep hygiene. These

theories provide evidence that both behaviors can be impacted by beliefs about capabilities, beliefs about consequences, intentions and social influences. Based on the summarized evidence in this scoping review, interventional designers may use the demonstrated predictive value of the Theory of Planned Behavior [65-68], Integrated Model of Behavior Change [69], Health Belief Model [70] or Multitheory Model of Health Behavior Change [71] to develop educational and behavioral interventions improving sleep hygiene among students. For CPAP adherence, the Social Cognitive Theory [72-75], Transtheoretical Model of Behavior Change [72,73] and Health Belief Model [57] can be used. Various behavioral change techniques are available to modify cognitive and behavioral factors impacting CPAP adherence and sleep hygiene. For example, self-regulation exercises and brain storming activities have been proposed as influencing perceived behavioral control [65,76]. Meanwhile, Motivational Enhancement Therapy can be used to improve decisional balance towards adhering to CPAP [59].

Aggregated findings in this paper provide information on factors associated with sleep, specific behavioral change techniques and their effectiveness, when available. This information can support health promoters in quickly identifying, developing and evaluating promising public health interventions that address sleep deprivation in individuals with OSA, chronic insomnia or poor sleep hygiene. For example, the cumulative evidence in this paper informed a new year-long healthy lifestyles program, that combines CBT and an ecological approach to behavior change [15]. In this program, sleep among many other health behaviors is promoted through acquisition of knowledge, self-efficacy, skill building, identification of barriers and facilitators, emotional and behavioural regulation, reinforcement, and action planning [15]. The program includes educational learning sessions, self-reflection, brain storming activities, and social events [15].

Strengths and limitations

Even though there are many reasons explaining sleep deprivation in the population, this paper used a population health lens especially focused on exploring modifiable behaviors, rather than clinical outcomes. The scoping review methodology allowed for a wider search of the literature than would have been possible through a traditional systematic review. Each phase of the scoping review was discussed between investigators, librarians, experts in systematic searching methods and theories of health behavior, allowing for refinement of research objectives, methodologies and tools. Inclusion and exclusion criteria were developed iteratively upon increasing familiarity with the field of research. This helped develop a transparent and robust selection strategy that resulted in a feasible amount of studies to review. Inductive thematic analysis helped identify purposes for using theories of health behavior, meanwhile the application of the Theoretical Domains Framework strengthened the synthesis process by categorizing findings into defined domains of behavioral influence.

Appraising the quality and strength of each individual study was not the main goal of this study, nor was assessing the cumulative evidence to provide recommendations on most effective sleep interventions or components. The search strategy was not exhaustive. Only English keywords were searched, limiting studies published in other languages. The grey literature was not searched, possibly leaving out relevant unpublished studies out. Thirty-one percent of studies were identified through reference chaining. Of those, more than half had not been identified through database searching as they were published before 2007. The remaining 45% could have been identified if additional keywords were searched within study titles or abstracts, such as 'motivation' and 'PAP'. The selection process was limited to studies explicitly mentioning theories of health behavior. Thus, studies that used theoretical constructs without mentioning use of theory were not assessed. Lastly, the scope of this review was not to assess the evolution of theories of health behavior from their original conception. This question may be of interest for future studies.

Conclusion

Sleep deprivation remains a significant public health issue that affects the mental and physical health of various population groups. Numerous theories of health behavior have been used to identify modifiable factors associated with sleep deprivation with the hope of designing and evaluating behavioral change techniques and intervention components that can remedy the root causes of this issue. Future studies should focus on applying theories of health behavior at their full capacity, informing behaviors that go beyond sleep duration and CPAP adherence. Mixed-methods and qualitative research should be conducted in areas yet poorly explored, meanwhile systematic reviews with meta-analyses assessing the quality and weight of constructs that predict CPAP adherence and sleep hygiene are warranted.

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