Benefits of Community-Based Approaches in Assessing and Addressing Sleep Health and Sleep-Related Cardiovascular Disease Risk: a Precision and Personalized Population Health Approach

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Abstract

Purpose of Review In this current review, we describe the benefits of community-based and "precision and personalized population health" (P3H) approaches to assessing and addressing sleep health problems and sleep-related cardiovascular diseases (CVD) among vulnerable populations such as racial/ethnic minorities, the elderly, and the socioeconomically disadvantaged.
Recent Findings Very few sleep health programs utilize a community-based or P3H approach, which may account for low estimates of sleep health problems, related CVD outcomes, and inadequate healthcare infrastructure to address sleep-related health outcomes at the community and population level. We describe community-based and P3H approaches and programs as solutions to accurately capture estimates of sleep health and reduce burden of sleep health problems and corollary CVD outcomes at the level of the community and population. Specifically, we describe seven critical steps needed to successfully implement a community-based and P3H approach to address sleep health problems.
Summary Community-based and P3H approaches are effective strategies to assessing and addressing sleep health problems and related health conditions.

Keywords Sleep · Sleep health · Community · Personalized · Health disparities · Cardiovascular disease

Introduction

Although cardiovascular disease (CVD) deaths have gradually declined over the past 10 years, CVD is still the leading cause of deaths globally. In the USA, 1 in 3 deaths have been linked to CVD and, in 2014–2015, CVD accounts for approximately 15% of total healthcare expenditures ($351.2 billion [direct cost, $213.8 billion and indirect cost, $137.4 billion in lost productivity/mortality]). Projections estimate that CVD-related healthcare expenditures will rise to approximately $750 billion by 2035, highlighting the need for urgent solutions to stem this deluge of CVD and its related health consequences [1]. Racial/ethnic minorities, the elderly, and low-income individuals appear to be the most burdened by CVD and thus need urgent and sustainable solutions to address disproportionate CVD burden among these populations [1, 2].

Ongoing attempts to halt, reverse, and improve the burden of CVD through prevention and management strategies, such as the American Heart Association's (AHA) Life's Simple 7 (no smoking, physical activity, diet, weight, cholesterol, blood pressure, and blood glucose), have yielded moderate results [3] with the prevalence of CVD and CVD mortality still high [4]. Although these modest results may be attributed to several behavioral, biological, clinical, environmental, psychosocial, and system-level barriers, CVD prevention and management

strategies, like the AHA's Life's Simple 7, lacks the inclusion of other significant behavioral CVD predictors, such as sleep. The omission of sleep health is glaring, especially since there is mounting epidemiological, basic research, and clinical evidence that sleep duration, quality, and sleep disorders predict CVD and increase the likelihood of CVD risk markers, such as hypertension, diabetes, obesity, dyslipidemia, and hypercholesteremia [2–5]. Despite overwhelming evidence that sleep health parameters are associated with CVD, most CVD prevention and management programs exclude sleep as a core feature.

The omission of sleep is quite consequential for provider knowledge and clinical practice, patient and community health literacy, and patient-centered healthcare delivery. First, inadequate knowledge and training about sleep as a significant predictor of CVD and cardiovascular health may lead to inadequate assessment of sleep in CVD prevention and management programs. Second, low patient health literacy about the impact of sleep on CVD, especially among those at elevated CVD risk and burden (e.g., racial/ethnic minority groups), may compromise patient-provider communication about sleep and related health conditions and disempower the patient's voice in treatment where they are unable to fully advocate for their health and well-being. Third, patient-centered healthcare delivery and experience, where patients are seldom asked about and informed about their sleep and how sleep problems might affect their risk for CVD and overall cardiovascular health [6–9]. To overcome these barriers, we argue for greater utilization of community-based and precision and personalized population health (P3H) approaches to combat sleep-related cardiovascular health among disadvantaged groups. To make this case, we first describe how a community-based approach and P3H framework can accurately assess and solve the burden of sleep health problems and sleep-related health outcomes, and then we describe steps and components needed to develop an effective community-based sleep health program and intervention.

Demystifying the Definition of Sleep Health

Sleep health within a disease-focused approach generally emphasizes the absence of disease such as a sleep disorder and thus in turn devalues less disease-focused parameters such as sleep duration, sleep quality, satisfaction with sleep, and daytime sleepiness [7]. The disease-focused conceptualization of sleep health limits the need and reach of sleep interventions, since the prevalence of non-diagnosable sleep disturbances exceeds the prevalence of sleep disorders [8, 9]. Viewing sleep health as the absence of sleep deprivation and sleep disorders narrowly defines sleep health and offers limited solutions as to how individuals and populations can obtain good sleep health. A disease-focused approach to sleep health also unhealthily tethers communities to be reliant on medical systems to be the only purveyors of sleep health knowledge and care. Overall, an exclusively disease-focused approach to sleep health does not fully capture all possible sleep issues and sleep-related chronic health conditions.

Therefore, researchers guided by a disease-focused view of sleep health often neglect the importance of sleep health when designing studies. The complex picture of sleep health is often difficult to operationalize versus easily measurable sleep parameters such as sleep duration or overall perceived sleep quality. But this practice fails to capture the full breadth of relevant dimensions of sleep health in the general population. The difficulty in defining sleep health more broadly is exacerbated by existing empirically validated measures to describe sleep disorders. The RU-SATED model was created as a research tool to define sleep health. RU-SATED measures six dimensions of sleep health: sleep regularity, subjective satisfaction, appropriate timing, adequate duration, high sleep efficiency, and sustained alertness during the day [10]. This heuristic has been translated into a basic scale and validated among English-speaking adults [10]. Although this is one way of conceptualizing sleep health, it advances thinking in the field because it makes sleep health a concept defined by the parameters of sleep health as they are experienced by the general population.

The Relationship Between Sleep Health Parameters and Cardiovascular Disease Risk

Several robust meta-analyses of clinical, epidemiological, and experimental findings indicate that individuals with poor sleep health, defined as (1) chronic sleep deprivation or habitual short sleep duration (average total sleep <7 h per 24 h period), (2) sleep disorder (e.g., sleep apnea or insomnia), (3) poor sleep quality, (4) irregular sleep patterns and timing, (5) dissatisfied with the quality of their sleep, (6) excessive sleepiness, and (7) poor sleep efficiency, are at increased risk of cardiovascular disease [11–13].

Insufficient sleep duration (either < 7-h sleep/24-h cycle in epidemiological data or < 6-h sleep/24-h cycle in clinical data) is associated with several CVD risk markers, such as elevated blood pressure/hypertension [13], elevated cholesterol [14], and elevated fasting blood glucose [15]. Epidemiological findings indicate that insufficient sleep increases risk of hypertension [16], while clinical and laboratory studies indicate that 24-h sleep restriction increases blood pressure levels [17]. Insufficient sleep may increase sympathetic nervous system activity and prohibits normal nocturnal blood pressure dipping, which may lead to elevated blood pressure and heart rate [18].

In addition to hypertension, insufficient sleep has been linked to elevated cholesterol levels [14]. Gangwisch et al. (2010) found that insufficient sleep increased the odds of having high cholesterol levels among women, and each additional

hour of sleep was associated with a lower risk of being diagnosed with hypercholesterolemia [19]. Experimental studies found that sleep restriction increased total cholesterol and specifically LDL cholesterol [19]. The long-term effects of high LDL cholesterol may lead to atherosclerosis, the hardening and subsequent blockage of blood vessels, which increases the risk of CVD events like a heart attack and stroke [20]. Insufficient sleep duration is also linked to unhealthy glucose levels in prospective and cross-sectional studies [15]. In a meta-analysis of seven prospective studies, individuals reporting insufficient sleep were 28% more likely to be at risk for type 2 diabetes [21]. Despite the overwhelming evidence supporting the relationship between insufficient sleep and elevated levels of glucose and insulin, Ford et al. found that the relationship was no longer significant when body mass index (BMI) was adjusted [22]. Their finding suggests the potential mediating role of BMI on the relationship between sleep and unhealthy glucose levels. It is likely that insufficient sleep may induce hunger and increase appetite, which may result in greater food intake and less energy expenditure, thus increasing likelihood for greater BMI. Similarly, high BMI levels have also been linked to an imbalance in glucose homeostasis and hyperglycemia.

Sleep Disorders and CVD

A systematic review showed that 6–17% of the adult US population has some form of sleep disorder (e.g., sleep apnea and insomnia being the most prevalent). Both sleep apnea and insomnia have been linked with increasing risk of cardiovascular disease. Although sleep apnea is common among the general population, almost half (49%) are in advanced age [6]. The prevalence of insomnia is also high with approximately 10–20% of the population experience at least one insomnia symptom: difficult with sleep onset and maintenance and involuntary early awakenings [12]. Several studies indicate that both sleep apnea and insomnia independently increase the risk of CVD outcomes such as coronary heart disease, ischemic heart disease, diabetes, hypertension, heart failure, stroke, and CVD mortality [23, 24].

Epidemiological and Community-Based Estimates of Sleep and Sleep-Related CVD Among Subgroups

Although epidemiological data indicate high burden of sleep disturbances and sleep-related CVD risk among minority, elderly, urban and low-income populations, estimates in community-based samples indicate much higher prevalence [25•]. Discrepancies between epidemiological and community-based estimates of sleep health as well as estimates of diagnosed and undiagnosed sleep disorders like sleep apnea among vulnerable subgroups highlight the limitation of crude sampling methods and the need for community-based

sampling approaches to estimate sleep health problems. For example, in epidemiological data, the prevalence of OSA among Blacks is 24% [6, 26]; however, in several community-based samples in New York City, 31–87% of Blacks were at moderate-high OSA risk [23, 27]. The discrepancy between how many Blacks are at risk for sleep apnea versus those with a physician diagnosis (only 5% of those at risk) highlights another poorly estimated sleep health burden. Discrepancies in sleep parameters underestimate sleep-related CVD burden among vulnerable groups such as racial/ethnic minorities, the elderly, and low-income groups [25•].

Burden of Poor Sleep Health Among Racial/Ethnic Minority Populations There is an abundance of evidence indicating that racial/ethnic minorities—African American/Black, American Indian/Alaska Native, Asian, Hispanic/Latino, or Hawaiian/Pacific Islander—experience on average poorer sleep health [28]. These groups, in general, often demonstrate shorter sleep duration, lower sleep quality, less slow wave sleep (deep sleep), and higher rates of symptoms of sleep disorders, including insomnia disorder, sleep apnea, and other sleep and circadian rhythm disorders. These include sleep maintenance problems, snoring, inconsistent sleep timing, and shortened free running circadian period (Tau) compared with their White counterparts [28–30]. Individuals who identified as either Black/African ancestry, Chinese, or Latino had shorter objectively measured total sleep time ($\approx 44\%$, $\approx 37\%$, 31%, respectively vs. $\approx 20\%$), higher prevalence of insufficient sleep (≤ 6 h), and poorer sleep quality (8.3%, 6.7%, and 6.6% vs. 5.0%) compared with their White counterparts. Although population-based studies indicate that racial/ethnic minorities (Blacks and Latinos) have a greater risk of having sleep apnea, community-based studies indicate that the risk may be much greater since population-based studies might reflect issues of underreporting, under-diagnosis, and under-treatment among racial/ethnic minority groups [31]. However, the prevalence of poor sleep health parameters is higher in community-based samples than in large-population-based samples primarily because the percentage of racial/ethnic minorities is generally much lower than Whites, which may not be fully adjusted even after statistical correction [32]. The discrepancy in the prevalence of sleep health problems between population- and community-based samples can have significant public health consequences, as underestimated burden may prevent or divert attention from seeing sleep health as a serious public health issue among racial/ethnic groups. The lack of attention given to sleep as a public health issue in racial/ethnic groups may obscure and limit full understanding of how poor sleep health may contribute to the burden of certain chronic health conditions, like cardiovascular and cardiometabolic diseases. It is possible that the high prevalence of poor sleep health may partially explain the burden of cardiovascular diseases and conditions, such as obesity,

hypertension, and diabetes among non-Hispanic Blacks and Latina[o]s [33–35]. However, inconsistent estimates of sleep health parameters and few clinical trials investigating the effect of poor sleep health parameters have on CVD burden among racial/ethnic minorities in robust clinical trials are lacking. A robust community-based approach is needed to establish more accurate estimates of sleep health problems in racial/ethnic minorities, understand predictors of poor sleep health, investigate clearer links between sleep health parameters and chronic health outcomes in that group, and provide evidence to influence policy and justify the need for resources to ameliorate health conditions for racial/ethnic minorities.

Burden of Poor Sleep Health Among Elderly Populations

Sleep health problems among the elderly are unique in prevalence, presentation, cause, and consequence and thus require unique set of treatments. Regarding prevalence, poor sleep health disproportionately affects the elderly, where it is estimated that around 50% of people 55 or older have some sort of sleep problem [36]. Sleep health problems that often plague the elderly include insomnia, irregular sleep-wake times, less slow wave sleep (deep sleep), rapid eye movement behavior problems, higher apnea-hypopnea index scores, less total sleep time (typically due to less consolidated sleep at night due to more naps), periodic limb movement, and restless legs syndrome [36–39].

Although the prevalence of sleep health problems among the elderly is high, it is believed that the rates are higher because older adults tend to underreport sleep problems [37, 38]. As a result, sleep health problems among the elderly go unrecognized, misdiagnosed, untreated, inappropriately treated, and underappreciated, which can have deleterious health consequences, like cardiovascular disease and mortality [39, 40]. The lack of robust approaches to estimate sleep health and sleep-related CVD outcomes among the elderly may be due to the dearth of community-based programs to appropriately ascertain the prevalence of sleep problems and its impact on health among the elderly, instead of seeing poor sleep exclusively as a consequence of old age. Community-based sampling and interventions are viable options to accurately capture the prevalence of sleep health problems and implement appropriate and group-tailored interventions to improve sleep health among the elderly. For example, Black and colleagues (2015) found that a mindfulness mediation exercise successfully improved sleep quality among older adults with sleep disturbances [41]. Similarly, other community-based programs use music, pilates training [42], acupuncture [43], and acupressure [44] to improve sleep among the elderly. These findings indicate that communal and activity-based interventions are successful strategies for improving sleep health among the elderly.

Burden of Poor Sleep Health Among Urban Communities

Urban and low-income communities are burdened by sleep health problems [45]. Specifically, stigma toward urban neighborhoods was negatively associated with sleep quality and duration [46]. For urban communities, environmental stimuli such as noise [47], light, and air pollution, highly prevalent in urban metropolitan communities, are significantly associated with poor sleep health and sleep-related health outcomes, like heart disease [50]. Noise-related annoyance impedes sleep and contributes to CVD outcomes [48, 49]. Low-income urban individuals are particularly at risk for poor sleep health [28] and would benefit most from tailored community-based interventions to improve sleep health. In one study that investigated the impact of improving living conditions via a community transition program, individuals who moved from impoverished urban neighborhoods to less urban and less-resourced neighborhoods demonstrated an increase in sleep quality and duration [50]. The high burden of poor sleep health among urban and low-income communities makes the compelling case for community-based programs that promote sleep health in these communities. Such programs are opportune avenues to address underexplored sleep health problems in urban and low-income communities [51].

Strategies and Interventions to Reduce Sleep and Sleep-Related CVD Burden

Despite the foregoing evidence that sleep health parameters (e.g., sleep deprivation, poor sleep quality, and sleep disorders) are linked to CVD risk, health systems and public health infrastructures are not fully prepared to handle the sleep health crisis in America, as the ratio between the US population and certified sleep specialists is 43,000 to 1 and only approximately 8000 certified sleep clinics [52]. Based on this, it is evident that the healthcare system is unable to adequately address the sleep health crisis in the USA. It is for this reason that community-based and population health approaches are needed, as they decentralize and expand testing and treatment of sleep health problems outside of the healthcare system, and instead include strategies that utilize several community resources and stakeholders to address sleep health issues.

Tailored community-based interventions may be effective strategies in addressing sleep and sleep-related CVD burden in niche subgroups, such as racial/ethnic minorities, the elderly, low-income, and urban populations [53–57]. Community-based interventions may be more effective to address the burden of poor sleep health in communities because population-based and medical interventions are unable to address determinants of poor sleep unique to a subgroup. For example, we have found that addressing dysfunctional attitudes about sleep health in Blacks significantly improved health-seeking behaviors and screening for sleep problems [54]. An added advantage of community-based programs in addressing sleep health

problems lies in their ability to use novel methods of delivering health information and providing medical support in addressing sleep health problems in niche communities. For example, peer-based education via community health workers to improve sleep health literacy among Blacks and thus increasing the likelihood of OSA assessment and treatment among Blacks at risk for sleep apnea [55] and insomnia in the form of computer-based CBT-I in community health centers [56]. Despite the promising results of community-based programs in addressing sleep health disparities among niche communities, it is unclear how to develop and assess successful community-based programs that address sleep health problems in niche and vulnerable communities.

Addressing the Gaps

Based on the aforementioned literature, it is evident that community-based sampling to estimate burden of sleep and sleep-related CVD, and community-based interventions to address these issues are needed. However, strategies to implement such an approach are limited, especially in sleep medicine. To address these gaps, we performed a systematic review of published papers and registered clinical trials to determine (1) sampling strategies used to detect community-specific prevalence of sleep and sleep-related CVD; (2) types of community-based interventions; and (3) strategies employed to develop community-based interventions that tackle the burden of sleep and sleep-related CVD. Our thesis is rooted in our belief that a community-based approach will better capture more accurate estimates of sleep and sleep-related CVD in vulnerable subgroups and thus allow for better development and scaling of tailored interventions that can solve these health burdens. After describing these three major areas, we will articulate a new vision of community-based research and interventions, one that uses a precision and personalized population health approach.

Methods

To address the gap highlighted above, we conducted a systematic review on the last 5 years of research on community-based clinical trial interventions that address sleep health problems and related CVD outcomes. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines were followed for this review. The databases PubMed/Medline, Embase, Cochrane Library, Web of Science Plus, PsychINFO, Ageline, and CINAHL were searched for clinical trial studies published between August 2014 and August 2019.

Search Strategy

The search strategy used the following terms: (Sleep) AND (community intervention) AND (clinical trial) AND (racial/ethnic minority) AND (elderly), AND (low income), (urban), AND (hypertension OR high blood pressure OR Cardiovascular Disease OR Cardiovascular OR CVD), as the primary outcome of the clinical trial. All articles were restricted to the last 5 years to be consistent with journal recommendations.

Inclusion and Exclusion Criteria

Inclusion criteria were all clinical trial full texts that used community intervention for sleep and CVD as primary or secondary outcomes. Exclusion criteria were review studies, letters to the editor, observational studies, case reports, qualitative studies, prospective studies, and pilot studies.

Data Extraction

One author (JM) screened the titles, abstracts, and full texts of the retrieved studies in Covidence. All retrieved articles were clinical trials. Subsequently, another author (AS) validated and reviewed screening and extraction of retrieved studies. A third author (GJL) served as the arbitrator to resolve conflicts about article inclusion. The included data were authors, type of community population, intervention method, intervention target, and outcomes.

Results

A total of 457 articles were retrieved from the searched databases based on primary extraction. The number of articles retrieved from each database broke down as follows: 325 from PubMed/Medline, no results from Embase, 53 from Cochrane Library, 78 from Web of Science Plus, 1 from PsychINFO, and no results from Ageline or CINAHL. A total of 448 articles were excluded after title and abstract review, and 4 were excluded after full-text review, resulting in 5 articles retrieved with a total of 738 participants (Table 1). Results indicate that only a few published clinical trials explicitly use a community-based approach to improve sleep health and sleep-related health outcomes, such as cardiovascular disease.

Discussion

Results of the systematic review revealed that majority of the reviewed studies (4 out of 5), published in the past 5 years, utilized community-based approaches to improve sleep health and sleep-related CVD risk markers and found them to be

Table 1 Results from the systematic review of clinical trials

Study	Authors	Year	Community population	Intervention target	Intervention	Outcome	Sample size
Treating Acute Insomnia: a Randomized Controlled Trial of a "Single-Shot" of Cognitive Behavioral Therapy for Insomnia	Ellis, J G; Cushing, T; Germain, A	2015	Community in Northeast UK with insomnia diagnosed with DSM-5	Sleep and reduced acute insomnia	A self-help pamphlet, outlining the principles of stimulus control, cognitive control and the use of imagery distraction techniques and single session of CBT-I	The intervention improved sleep outcome to the levels of natural remission seen in the control group (50–60% vs. 10–15%).	40
Cognitive Behavioral Therapy vs. Tai Chi for Late Life Insomnia and Inflammatory Risk: A Randomized Controlled Comparative Efficacy Trial	Irwin, Michael R; Olmstead, Richard; Carrillo, Carmen; Sadeghi, Nina; Breen, Elizabeth C; Witarama, Tuff; Yokomizo, Megumi; Lavretsky, Helen; Carroll, Jude E; Motivala, Sarosh J; Bootzin, Richard; Nicassio, Perry	2014	Los Angeles community older than 55 with insomnia diagnosed by DSM-4	Sleep, late life insomnia and inflammatory risk	CBT, Tai Chi, or control for 2-h group sessions weekly over 4 months with follow-up at 7 and 16 months	CBT performed better Tai Chi and control for treating insomnia. ($P < 0.01$), and also showed greater and more sustained improvement in sleep quality, sleep parameters, fatigue, and depressive symptoms (all P values < 0.01). As compared with control, CBT was associated with a reduced risk of high CRP levels (> 3.0 mg/L) at 16 months (odds ratio [OR], 0.26 [95% CI, 0.07–0.97] $P < 0.05$)	123
Effects of a health education intervention on hypertension-- related knowledge, prevention and self-care practices in Nigerian retirees: a quasi-experimental study	Ozoemena, Eyuche L; Iweama, Cylia N; Agbaje, Olaoluwa S; Umoke I, Prince C; Ene, Osmond C; Ofili, Perpetua C; Agu, Benedicta N; Orisa, Charity U; Agu, Michael; Anthony, Enejoh	2019	Participants enrolled from Southeast Nigeria	Hypertension risk	Health education session	Self-reported sleep quality, physical activity engagement, diet, substance use abstinence, medication adherence all improved at 1-month follow-up compared with control	400
Effects of a combined community exercise program in obstructive sleep apnea syndrome: a randomized clinical trial	Torres-Castro, R; Vilaro, J; Marti, J-D; Garmendia, O; Gimeno-Santos, E; Romano-Andrio- ni, B; Embid, C; Montserrat, J M	2019	Sleep unit patients in Barcelona, Spain	Sleep apnea	Combined physical and oropharyngeal exercise program on OSA in patients with moderate to severe obstructive sleep apnea	No significant difference in apnea outcomes. Intervention group participants improved pre- vs. post-intervention, in regard to body weight, BMI, and waist	27

Table 1 (continued)

Study	Authors	Year	Community population	Intervention target	Intervention	Outcome	Sample size
						circumference. However, when only including participants under 60 years old, participants did see a significant improvement in apnea scores ($p = .028$).	
Baduanjin exercise intervention for community adults at risk of ischemic stroke: A randomized controlled trial	Zheng, Guohua; Chen, Bai; Fang, Qianying; Lin, Qiu; Tao, Jing; Chen, Lidian	2019	Adults 50 to 75 at risk for ischemic stroke in three community centers in China (in Wufeng, Fengdanbailu, and Chuntian) recruited over 2 years Nov 2013–Oct 2015	Cerebrovascular function	Baduanjin-designed exercise program	Significant reduction in ischemic stroke risk including improved SBP, DBP, and anthropometric measurements	170

effective strategies in improving sleep health and sleep-related CVD among racial/ethnic minorities, the elderly, urban, and low-income communities. Ellis, Cushing, and Germain (2015) found that a single CBT-I (cognitive behavioral therapy for insomnia) session combined with educational pamphlet materials reduced acute insomnia symptoms and improved sleep in a northeast UK community [57]. In another community-based study, Irwin et al. (2014) found that a CBT-I intervention was more effective than Tai Chi or an education at reducing insomnia symptoms and C-reactive protein [58]. Ozoemena et al. (2019) found that a community health education intervention was successful in improving sleep outcomes and reducing cardiovascular risk [59]. Zheng et al. (2019) found that a traditional Chinese exercise intervention reduced stroke risk and improved CVD outcomes in three Chinese communities [60]. However, Torres-Castro and colleagues' (2019) community-based study did not show significant improvements in insomnia symptoms with a community exercise program in Barcelona, Spain. These mixed findings point to the important gap showing that not all community-based programs/interventions are built or conducted the same. This, therefore, raises the need for more standardization in the development, execution, and evaluation of community-based programs/interventions in sleep health and sleep-related health outcomes [61]. We therefore provide a description of how to develop, execute, and evaluate a community-based program/intervention in sleep health and sleep-related health outcomes for vulnerable communities and populations based on our track record of successfully completing several community-based trials and studies on sleep health [53, 55, 62].

Building Successful Community-Based Interventions for Sleep Health

Although health-related community-based programs are complex to implement in the current healthcare landscape, especially in specialty areas like sleep medicine, our roadmap to establishing community-based programs will make this process less arduous and more likely to achieve the intended goals of the program for the community and members of the healthcare ecosystem. Our roadmap, which is steeped in a precision and personalized population health framework, consists of seven important phases: phase 1, determining if a community-based approach is needed; phase 2, defining, identifying, and measuring the community; phase 3, needs assessment and community engagement; phase 4, translational approach; phase 5, identify the active ingredient for the intervention; phase 6, intervention delivery method (e.g., community program, health worker, and shifting approach [community health workers]); and phase 7, treatment optimization from group tailoring to personalization.

The precision and personalized population health framework attempts to understand, manage, and treat health conditions along a continuum from discovery to treatment adherence using personalized and population-level data. Ideally, the precision and personalized population health approaches use machine learning and big data to make new discoveries (etiologies of disease that may be specific to an individual or to a phenotype of people); it then uses these findings to disseminate and implement the value-based healthcare continuum—which we call "D 6As" which include Discovery, Awareness, Avoidance, Access, Assessment, Acceptance, and Adherence.

Precision and personalized population health through highly dimensional data and analyses yields insights from the population which informs tailored and individual treatments to determine which treatments are appropriate for which individual and then monitors and learns how that individual responds to that treatment over time to make modifications on how to optimize treatment effects for the individual.

Process in Developing Community-Based Program Within a Precision and Personalized Population Health Framework

In this section, we describe the necessary activities for each phase and quality measures and tools to ensure that the implementation process is being executed correctly. There is a fundamental difference between doing the research or establishing the program in a community versus using a community-based framework to solve the population or public health issue. The former means that individuals who benefit from the program are in the community and are not in a clinical or institutionalized setting. Conversely, a community-based approach uses principles of community-based participatory research which include (1) seeing the community as the primary unit to be reached and treated; (2) enhancing and building existing community assets; (3) fostering collaborative relationships between the community and stakeholders in the healthcare ecosystem throughout the research and intervention process; and (4) gaining and generating knowledge through the community partnership and translating these into specific actions [63, 64] that can improve the health of the community (e.g., sleep health) and the healthcare continuum (see Fig. 1).

Phase 1. Determining if a Community-Based Approach Is Needed

Phase 1 entails determining if a community-based approach is needed. Throughout several years of developing and conducting community-based programs, we have learned that this is a forgotten and ignored yet important step. A community-based approach is just one method and if it is not the correct method then no matter how accurately the

program is set up, it will not succeed because there the method of delivery and population/public health need will be misaligned. In Table 2, we describe a list of questions and an adjudicatory rubric we have used to assess whether a community-based approach is needed to solve a community/public/population health issue.

Phase 2. Defining, Identifying, and Measuring the Community

After it is established that a community-based approach can be helpful or needed, then the next step is to define, identify, and measure the community of interest. In our community-based programs, we identify community as a group of people who either share a common identifier such as race/ethnicity, age group, geographical local, and psychosocial factor (e.g., socioeconomic status) or a psychological sense of community and belonging among themselves [63]. It is important to distinguish between the two approaches because the former is generally an assigned grouping (e.g., dark-skinned individuals are considered Black), while the latter is an embraced relational grouping (e.g., not all dark-skinned individuals embrace being called African American because they may not share that culture). Understanding this distinction is key, because patients and research participants are more likely to respond positively to their relational community grouping, as opposed to their assigned grouping. For example, some participants insist and prefer that they be identified by their cultural background (Caribbean or Afro-Caribbean) as opposed to ancestral background (Black or African American), while others prefer the opposite. To reconcile these two views, in our community-based research programs, we list "Black" as the header and then describe what "Black" entails (e.g., African America, African, Afro-Caribbean, African ancestry).

Community Measurement Toolbox After identifying and defining the community, it is imperative to determine membership in the community. There are two standard approaches to determine inclusion into a community. The first approach is based on the self-reported inclusion by the individual, where an individual identifies and reports they belong to a certain

Fig. 1 Value-based healthcare continuum of Discovery Science, Dissemination, and Implementation using the "D 6As" framework
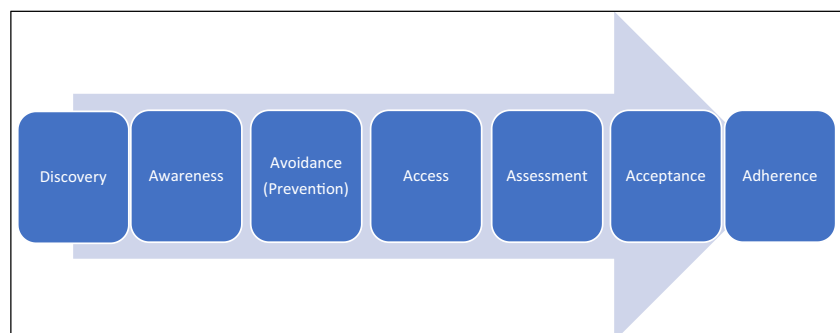

Discovery | Awareness | Avoidance (Prevention) | Access | Assessment | Acceptance | Adherence

Table 2   Assessment to determine if community-based approaches are needed

Question	
1 Evidence of public health issue in the community via qualitative (the issue is not widely studied but community members state it is an issue) or quantitative (public health data) evidence	Yes or No Note: If Yes, then a community-based approach is a good fit
2 Does the public health issue affect a community of people?	Yes or No Note: If Yes, then a community-based approach is a good fit
3 Analyze how this public health issue is being addressed via a supply chain model or workforce framework. Is there broad and deeper coverage?	Yes or No Note: If No, then a community-based approach is a good fit
4 Are current methods to address the public health issue successful?	Yes or No Note: If No, then a community-based approach is a good fit
5 Can the public health issue be addressed by offering or expanding the range of health services that is currently offered?	Yes or No Note: If Yes, then a community-based approach is a good fit
6 Can the current health infrastructure meet or address the public health issue?	Yes or No Note: If No, then a community-based approach is a good fit
7 Is the governmental or health services in the community under-resourced to provide adequate support for the public health issue?	Yes or No Note: If Yes, then a community-based approach is a good fit

race/ethnicity, sex, or age group. The second approach is based on a quasi-objective method, where an individual's sense of community is evaluated via a validated survey called the Sense of Community Index (SCI) or by a process called community mapping, where a randomly selected group of individuals from the community in question is asked through guided focus group to identify a criteria list for inclusion and exclusion. To avoid contentious experiences of being the gate-keeper to determine inclusion to a group, we highly recommend using the former, the self-reported method, as the default and chosen approach.

Phase 3. Needs Assessment and Community Engagement

The third phase of developing a community-based approach entails conducting some form of needs assessment and community engagement. Though the two processes are different, in our practice over the years, we have combined the two. Conducting a needs assessment, where we ascertain the strengths, assets, needs, and challenges of a specified community, is a crucial method of engaging the community. Previous studies have been successful in creating community-based interventions for sleep. Healthy Children, Strong Families 2 is a healthy lifestyle intervention for a range of health behaviors, including sleep as a secondary outcome [65]. These types of intervention usually involve needs assessment and community engagement through focus groups.

Needs Assessment Needs assessment is defined as appraisal of public health needs of the community, key players, and stakeholders in the community, strengths and gaps the community possess to address the public health issue. There are four types of community needs: perceived needs, expressed needs, absolute needs, and relative needs. Perceived needs are based on what individuals feel their needs are. The standard may change based on each individual's point of view. The purpose of the needs assessment is to establish a community's assets and capacity [66]. Community assets typically refer to the people (skills and abilities of people in the community, specifically key stakeholders and leaders), governmental (e.g., local representatives, policies, services, and tax base), institutional (educational, healthcare), business, financial, and environmental resources in a community. Over the years, we have utilized several methods of conducting needs assessment which include focus group interviews, surveys, listening sessions, and direct or participatory engagement (visiting community settings such as schools, faith-based organizations, barbershops, beauty salons).

NYU Sleep Health Disparities Summit The NYU Sleep Health Disparities Summit, which consisted of several DELPHI focus groups and conferences, brought together experts from sleep and health equity research to address important questions regarding the causes of sleep health disparities, challenges in accessing sleep services, and methods to manage sleep disorders. Stakeholder engagement provided unique

insights into sleep health problems and ways to implement solutions to improve sleep health and to using credible venues to disseminate health messages to reduce disparities in minority communities. This established the NYU community-academic partnership, which allows us to develop future sleep health community-based programs.

Example of Needs Assessment for Sleep Health Using DELPHI Framework Community engagement is important in health disparity and community-based research, as it allows us to establish shared research scope [65], refine our strategies, delineate barriers and increase community participation [66], improve intervention effectiveness [66], and enhance sustainability [67]. We have established strong partnerships with Black and Latino/a community stakeholders in NYC. Previous work supports community engagement as a successful strategy as it increases participation, recruitment, retention, and uptake of clinical trials [68, 69]. Stakeholders in the Community Steering Committee (CSC), another form of community engagement, can guide sleep research and education protocol development and study implementation [68–72]. Addressing sleep disparities by engaging our CSC stakeholders is critical. Stakeholder engagement benefits the proposal by providing knowledge of contextual factors promoting or hindering uptake of messages. Engagement ensures findings lead to improvements in sleep care and health policies promoting health equity for community members [73–76, 77•, 78, 79]. Summarized results of our Delphi Survey and NY Sleep Health Disparity Summit are described elsewhere [80–83].

Determining Community Health Concerns In 2010 and 2017, we conducted a series of lectures and DELPHI focus groups with community-based organizations (CBOs) that serve Black and Latino communities. From this emerged a "Shared Sleep Research Agenda" to eliminate sleep apnea health disparities. They identified sleep health as one of the highest health priorities. Results contributed to our decision to focus on sleep health problems because of its significant burden among Black and Latinos in the NYC catchment area.

## Phase 4. Translation: From Dissemination to Implementation

After the needs assessment, the findings must be developed into a mission and vision for the research or health program, followed by an action plan which includes activity, timeline, person responsible, and markers of success. It is imperative that the drafting process of the mission and vision statement be collaborative with researchers, providers, payers, Community Steering Committee (which consist of 5–7 members in the community), and other stakeholders in the community ecosystem.

Research Mission Statement and Action Plan The mission and vision statements should describe the agreed-upon purpose and goals of the research or health program. While, the action plan must describe what the public health need is, solution-focused activities, timeline to develop, implement, and assess success of community-based research program, who is responsible for executing and assessing the solution (we recommend that these are two different people or groups to maintain objectivity), and clear markers of success. From our NYU Sleep Health Disparities Summit, our mission was "to improve sleep health for all by informing, engaging, and mobilizing communities and eliminating sleep and health disparities that burden underserved communities through science and outreach," while our vision was to "have a world that was free of sleep and health inequities."

To achieve this mission and vision, we engaged in several solution-focused activities that span the healthcare continuum from discovery to adherence (Fig. 1). Discovery within a community-based and precision and personalized population health approach entails a continuum of insights from description to optimization (Fig. 2). Each stage represents a progression to unearth a deeper understanding and insight into a particular phenomenon, such as sleep health. Description represents the first level of insight, while optimization represents the zenith of insight where there is deep understanding about which treatments work for whom, when, in what context, and why. Achieving this deep level of insight is difficult in a typical community-based approach as it relies on traditional research design and data analytical methods. These limitations have led us to incorporate machine learning, causal inference, just-in-time adaptive research design, and simulation modeling approaches to achieve better attributional, classification, prediction, explanation, personalization, and optimization insights.

Discovery within a community-based approach also allows us to explore and find new relationships and etiologies (even biological and basic science findings through mechanistic studies) of sleep health outcomes. Unlike large population-based studies, a community-based research program has the flexibility to assess and investigate novel predictors of sleep health. For example, in our observational studies, we are able to look at different levels and sources of noise pollution and how they impact several objective and subjective sleep health parameters and whether the noise-sleep relationship impacts adverse health outcomes such as 24-h ambulatory blood pressure profile of participants. The advantage of these nuance data collection methods and analyses is that they allow us to ask more nuanced and sophisticated questions that affect communities most, which in our example we wanted to ask does chronic and cumulative noise pollution exposure throughout the day affect sleep health and blood pressure for urban dwellers.

Fig. 2 Precision and personalized population health approaches to discovery
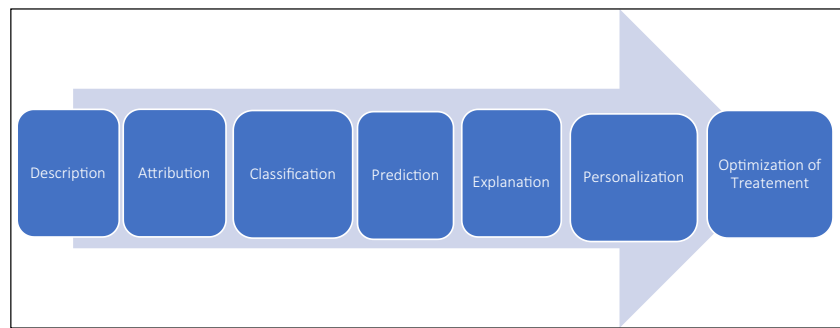
In addition to discovery, a hybrid community-based and precision and personalized population health approach allows us to implement and disseminate novel ways of improving awareness about sleep health, how to avoid and prevent poor sleep health, assessing sleep health problems at the individual and community level, how access services to address sleep health issues, methods to increase acceptance/uptake, and adherence of treatments for sleep health problems.

Lastly, in order to successfully complete the translation phase, it is imperative to establish a timeline to develop, implement, and assess success of community-based research program, which is responsible for implementing, assessing success of program, and disseminating findings to the community.

Phase 5. Identify the Active Ingredient for the Intervention

Although a community-based approach is an important method in solving sleep health problems (Fig. 3), it must be paired with an active intervention that aims to solve individual-, provider-, and system-level barriers and facilitators in behavior change and adherence to sleep treatments. To address barriers and facilitators to care, we have created the pantheoretical approach (which is explained in another publication), an

approach that investigates a wide range of modifiable and non-modifiable factors as active ingredients that can optimally effect behavior change, such as good sleep health [77•]. This pantheoretical approach conducts studies that aim to personalize treatments, based on an individual's idiographic profile (a constellation of behavioral/lifestyle, sociodemographic, environmental, and psychosocial factors that serve as a data portrait of the individual that captures strengths and weaknesses in achieving behavior modification) to spur optimal behavior change. The pantheoretical approach allows us to identify a parsimonious but deep understanding of what are the most active ingredients that will likely cause behavior change for the individual. Several categories of factors have been identified as potential active ingredients in community-based programs that range from biological to system-level factors.

Active Ingredient in Sleep Apnea

Determinants of OSA care include health literacy (Fig. 4), social support, trust in healthcare, readiness to change, risk perception, outcome expectations, OSA severity, acculturation, and sleepiness [84, 85]. For Latinos, acculturation is a critical determinant as highly acculturated Latinos have more severe sleep difficulties and CVD, [86–89] and are more

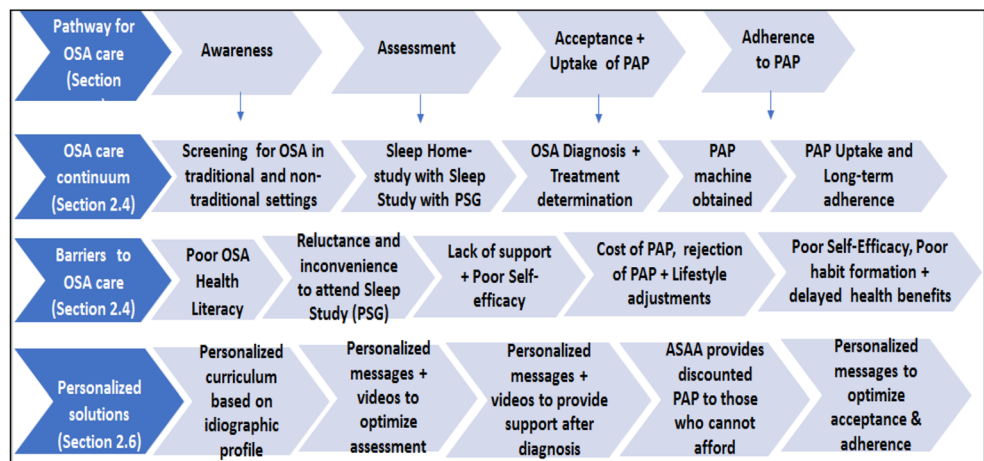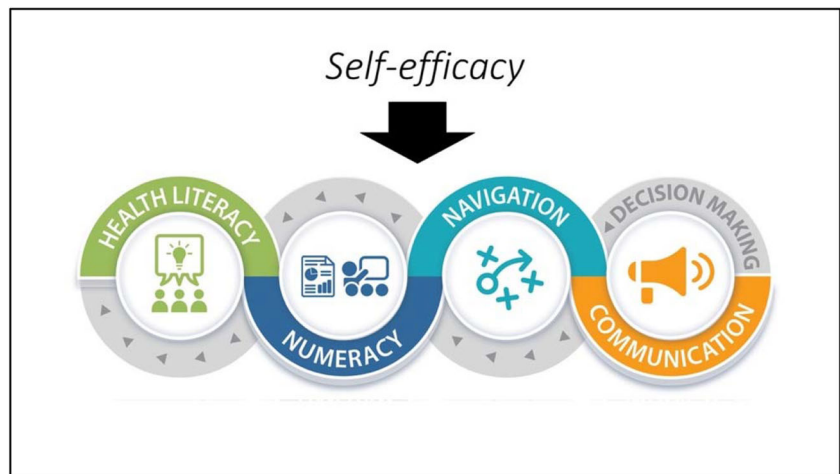Fig. 3 Obstructive sleep apnea behavioral pathway

Fig. 4 The role of self-efficacy and health literacy in health behavior change. Source: Improving health literacy in patients with chronic conditions: a call to action Dunn, Patrick et al. *International Journal of Cardiology*, volume 273, 249–251

willing to seek treatment. Outside of acculturation, OSA self-efficacy (belief and ability to seek assessment and use PAP effectively in a variety of circumstances) (Fig. 5) is the most proximal determinant to successfully navigate the OSA care continuum which includes awareness and screening for OSA risk, home- or laboratory-based assessment and treatment determination (PAP, dental device, or surgery), PAP delivery and setup, and PAP uptake and adherence (Fig. 3).

In our community-based programs, we utilize two methods to affect positive behavior change. First, we use a culturally and linguistically tailored educational program/curriculum intended to teach knowledge and skills about (1) OSA and health, (2) how to overcome barriers and engender facilitators of OSA care, and (3) real-time support on how to navigate resiliently the complex healthcare system that may prevent adherence to OSA care. Second, we employ a digital platform to deliver the culturally and linguistically tailored curriculum based on an individual's idiographic profile (using demographic, behavioral, psychological, and clinical data).

Phase 6. Method of Delivery Intervention

After you have decided what the active ingredients are to be modified in the community-based program, it is imperative to assess the method by which the intervention will be delivered. Over the years, we have implemented several methods which include health information campaigns, educational programs (by healthcare providers and lay paraprofessionals), support programs, marketing strategies, and health fairs, just to name a few. The method of delivery must be matched with the active ingredient and component of the healthcare continuum (D 6As listed above) the program is intended to address. For example, in a few of our community-based programs, we identified that awareness and health literacy about sleep health problems were the most pressing issues and as such we developed programs around to address those two areas. We developed health literacy programs that aimed to improve health literacy about sleep health among urban Black communities in New York City. Initially, we trained healthcare providers to

Fig. 5 Types of self-efficacy and the relationship with effectiveness of treatment
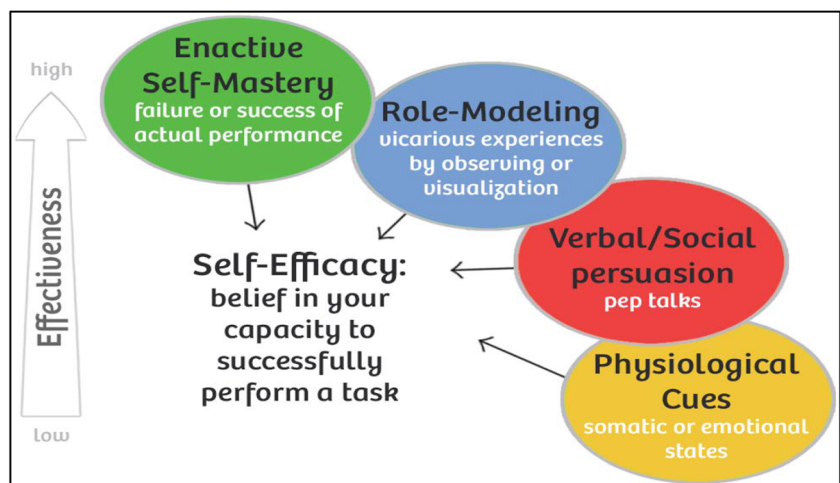
provide health information via telephone about sleep health problems (specifically sleep apnea) to increase literacy, screening, assessment, and treatment of sleep apnea because we were guided by work that showed that members of racial/ethnic minority communities had deference for healthcare providers and saw them as credible messengers of health information. Although our program was successful, we found that the rate of screening, assessment, and treatment was muted by several individual-, provider-, and system-level barriers. Specifically, participants' felt uncomfortable sharing private information about their sleep patterns with healthcare providers. They also felt that healthcare professionals were unable to provide the level of support and education needed to navigate the complex healthcare system. To address this, participants suggested that peers from the community would be better messengers and supportive figures in helping them navigate through the complex healthcare system to get the appropriate assessment and treatment if they were at the risk for sleep apnea [90]. For this study, we employed a widely used framework called task shifting. In task shifting, health education and navigation responsibilities of providers are given to peer health educators.

Phase 7. Treatment Optimization: From Group Targeting and Tailoring to Precision and Personalization

Although, community-based approaches are successful at reaching hard-to-reach communities, these communities are not homogeneous and as these programs may lack the specificity needed to reach most or all members of the community versus just the aggregate. Sleep health interventions and programs, therefore, must match within and between group heterogeneity. To accommodate the heterogeneity within and between groups, community-based programs must provide a gradient of messages and programming on sleep health that spans a continuum of group targeting and tailoring, and precision and personalized approaches.

Targeting entails providing sleep health programing to a specific subgroup of people. While, tailoring entails customizing sleep health programs to a specific community or group of people. Tailored approaches are considered more effective than targeting because they are customized to fit the needs and characteristics of a community [91]. Although tailoring is a marked improvement from targeting, it too has limitations as it assumes communities are the same because they share some commonality. For example, no two communities are the same and not all members of a community are alike. Reductionistic approaches imbued in tailored strategies may lead to misaligned programing (e.g., having a day program for a predominantly working class community), superimposition of priorities and values on a community (e.g., forcing communities to give up personal and cultural priorities and values in the

service achieving sleep health), and exclusion of certain segments in the community. To avoid or address these potential mistakes, we propose the use of a precision and personalized population health approaches.

Precision and personalized population health (P3H)—the use of genomic, environmental, and lifestyle individual differences to understand the etiology of health conditions and develop targeted health interventions—can positively impact healthcare, specifically sleep health and medicine in the following ways: (1) determine which treatments work for whom; (2) understand complex mechanisms underlying health and disease; (3) emphasize prevention and treatment of sleep health problems; (4) minimize adverse treatment (e.g., drug) reactions and side effects; (5) optimize patient adherence to treatment; (6) minimize high-risk invasive medical procedures; and (7) controlling the overall cost of healthcare. Precision and personalized population health (P3H) is a growing treatment modality that provides individualized, stratified, and tailored medical treatment based on an individual's genomic, lifestyle, and environmental profiles. P3H has revolutionized healthcare, specifically in the treatment of cancer, cardiovascular disease, and dementia. For example, in cancer precision treatment, an individual's genome is sequenced and an appropriate cancer treatment is given to the individual if it matches the individual's genetic profile. In cardiovascular disease, P3H is used to develop individualized diets for individuals with diabetes who have difficulties controlling their glucose levels with medication, and in dementia P3H is used to develop personalized cognitive exercises that can prevent early memory loss.

Although P3H has significantly increased our understanding of how we prevent, diagnose, and treat disease in certain diseases states and health conditions, its use in sleep medicine is nascent and thus has a far way to go to reach its full potential. Despite being in a sophomoric phase, the use of P3H in sleep medicine has evolved and shown promising signs of being fully integration in traditional care workflows. For example, (1) the deep phenotyping of community-based samples to find profiles of sleep apnea and insomnia via machine learning to find customized treatments, (2) the integration of sleep health in omni-channel community treatment programs (programs that address multi-level causes of poor health through various sources in the healthcare ecosystem), and (3) the use of machine learning and artificial intelligence to improve delivery of healthcare services and adherence to treatments suggest that sleep medicine is poised to fulfill its promise of providing value-based care for all if it embraces community-based and precision and personalized population health (P3H) approaches.

In fact, if implemented and executed correctly, the P3H approach should have a community-based approach at its core, whereby any attempt to understand the health of a population must require deep investigation and understanding of,

as well as partnerships with, communities. The vision of P3H in sleep medicine would entail finding new etiologies of disease that may be unique or shared across individuals, communities, and populations (e.g., sleep health problems), and optimizing delivery, dissemination, and implementation of the healthcare continuum (Discovery, Awareness, Avoidance, Access, Assessment, Acceptance, and Adherence) of healthcare services to all individuals, communities, and populations regardless of biological-, individual-, familial-, community-, and society-level barriers.

Obtaining Value-Based Care Through Community-Based and Precision and Personalized Population Health Approaches: From Discovery to Adherence

We argue that in order to provide value-based healthcare—healthcare that is affordable, accessible, high quality, and with multiple choices—the healthcare continuum (Discovery, Awareness, Avoidance, Access, Assessment, Acceptance, and Adherence, otherwise known as D 6As model) must be reliable, valid, efficient, and beneficial for all. The D 6As model (which we coined) refers to the promotion of Discovery, Awareness, Avoidance, Access, Assessment, Acceptance, and Adherence in population health treatments and research. Each component is equally important, as practitioners and scientists generally utilize one or more in treatment, interventions, or research programs.

Evidence of successful programs that utilize community-based and P3H approaches is typically seen in programs that utilize multi-level interventions to address systemic influences and challenges in providing value-based healthcare in sleep health. For example, the SENSE study utilized community education and awareness intervention to improve cardiac health by improving awareness of sleep health and how it impacts heart health [92]. Similar programs have used school-based education and parental education to improve awareness of sleep health, while also incorporating baked-in adherence strategies [93]. Programs that have used community-based and P3H approaches to optimize seamless navigation of patients along the continuum of care, by improving awareness, and assessment of sleep disorders and poor sleep health, as well as acceptance and adherence to treatment, have also proved successful [55, 62, 94]. Each of these programs incorporates two or more 6A methods as one of their guiding principles, and many intervention studies incorporate all of them. Although previous research has addressed the 6As as effective tools for intervention, only community-based intervention can inherently and authentically incorporate Discovery, Awareness, Avoidance, Access, Assessment,

Acceptance, and Adherence to address sleep health disparities.

Limitations

Findings from our review may be subject to several limitations and as such results should be interpreted cautiously. For example, the keyword search narrowly focused on published clinical trials that have investigated the role of sleep health parameters on cardiovascular outcomes as primary outcomes using a community-based approach. Our inability to find more qualifying studies may be due to the preponderance of trials being conducted as clinical studies as opposed to community-based studies. Additionally, it is likely that community-based trials may focus on other lifestyle behaviors other than sleep health, especially since the American Heart Association's Life's Simple 7 does not include sleep as clinically indicative target to reduce CVD risk or manage CVD. Despite these limitations, our findings are still significant because they highlight glaring methodological, scientific, clinical, and population health gaps.

Conclusion

In sum, both community-based and precision and personalized population health (P3H) approach are useful in addressing the burden of sleep health problems in vulnerable groups for a variety of reasons that includes but not limited to the following: (1) providing evidence and proof that sleep is important to patients and communities, beyond epidemiological and aggregate data, which are limited in capturing risk and burden in hard-to-reach communities; (2) providing more patient-centered care; (3) improving alliance between provider and patients; and (4) improving the delivery of value-based sleep healthcare from discovery to adherence, at the level of the individual, group, community, and population.

Compliance with Ethical Standards

Conflict of Interest   The authors declare no conflicts of interest relevant to this manuscript.

Human and Animal Rights and Informed Consent   This article does not contain any studies with human or animal subjects performed by any of the authors.

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