Sleep Health in Indigenous Australians

A review on the state of Indigenous Sleep Health in Australia on behalf of:
The Australasian Sleep Association
Indigenous Sleep Health Working Party

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1 Abbreviations

Advanced Sleep Phase Disorder (**ASPD**)
Australian Institute of Health & Welfare (**AIHW**)
Australasian Sleep Association (**ASA**)
Better Risk Stratification for Cardiac Health (**BIRCH**)
Confidence interval (**CI**)
Delayed Sleep Phase Disorder (**DSPD**)
Epworth Sleepiness Scale (**ESS**)
Longitudinal study in Indigenous children (**LSIC**)
National Sleep Foundation (**NSF**)
Obstructive sleep apnoea (**OSA**)
Odds ratio (**OR**)
Preferred Reporting Items for Systematic Reviewand Meta-Analyses (**PRISMA**)
Respiratory Disturbance Index (**RDI**)
Sleep disordered breathing (**SDB**)
The International Classification of Sleep Disorders (**ICSD**)
World Health Organisation (**WHO**)

2 Executive summary

The health and well-being of Indigenous Australians have long been an issue of concern, especially within the context of the ongoing impact of colonisation and the subsequent significant and unacceptable social and health disadvantage.

Similar to other Indigenous populations in New Zealand [3], Canada and the United States [4], there is evidence to suggest that Indigenous Australians experience a higher incidence of sleep problems compared to non- Indigenous Australians [5]. However, to date there is a lack of attention to sleep health (particularly education and appropriate health service availability) in Indigenous Australians. Sleep is a key foundation of health [6-9]. When sleep is problematic and unhealthy (defined here as problems with initiating and maintaining sleep, disrupted/restless sleep or excessive sleepiness), whether this is from a physiological, psychosocial or psychological aetiology, all other domains of health can be adversely affected. Conversely, when sleep is healthy and optimal, improvements in general physical and mental health ensue [9]. Thus, improving sleep health may contribute to better overall health and well-being in Indigenous Australians and, in line with recommendations from the 2019 Federal Government Report on the Inquiry into Sleep Health Awareness, should be a primary focus of health policy in Australia. However, to establish sleep as a potential target for improvement of health and well-being, research into Indigenous sleep health and its role/impact on other health disparities is necessary. The present review aimed to evaluate the prevalence of sleep problems in Indigenous Australians to provide up-to-date information on the status of sleep health for community, health and research professionals and policy makers. Findings from this report will inform decisions on prevention and treatment leading to better sleep health services and outcomes for Indigenous Australians.

Indigenous Australians

Aboriginal and Torres Strait Islanders are the first people of Australia. The culture of Aboriginal and Torres Strait Islander peoples is dynamic and continues to evolve and develop in response to historical and contemporary circumstances [10]. Aboriginal and Torres Strait Islander people have a special physical and spiritual connection to Country/Place with their own unique knowledge and belief systems. Aboriginal and Torres Strait Islander people are culturally diverse with over 250 language groups, differing kinship structures, gender, age, backgrounds, sexual orientations, religious beliefs, family responsibilities, marriage status, life and work experiences, and educational levels all expressed through varying historical, social and political lenses [10]. Indigenous Australians share to varying degrees the on-going impact of historical trauma, discrimination and racism and demonstrate resilience in responding to historic and contemporary impacts of colonisation. Importantly, through cultural strength and resilience, Aboriginal and Torres Strait Islander people have contributed to better outcomes for their people with governments now recognising that working in partnership with Aboriginal and Torres Strait Islander people is critical to improving health outcomes for First Australians.

For clarification of terminology in this report, the term Indigenous Australian defines a person of Aboriginal or Torres Strait Islander descent who identifies as Aboriginal or Torres Strait Islander and is accepted as such by the community in which he or she lives. Studies undertaken in Aboriginal and Torres Strait Islanders people will be referred to as

Indigenous Australian studies. The term 'non-Indigenous Australian" refers to members of the Australian population who do not identify as Aboriginal or from the Torres Strait islands.

Method

A systematic search using the keywords: "sleep problems"; "sleep disturbances"; "sleep quality"," "sleep disorder"; "sleep apnoea"; "obstructive sleep apnoea"; "OSA"; and "sleep- disordered breathing" AND "Indigenous Australians"; "Aboriginal"; "Torres Strait Islander"; was conducted to retrieve relevant peer-reviewed and grey literature published until August 2020. The databases searched included: PubMed; Informit Indigenous Collection Scopus and CINAHL; "LIt.search tool" from the Lowitja Institute; *Indigenous HealthInfoNet,* Google Scholar (advanced), government agencies were used for effective and relevant literature retrieval [11]. Twenty-two studies ([12-33] between the years 1998 and 2020, fitted the criteria for inclusion in this review.

Results

To August 2020, 22 studies focusing on sleep issues in Indigenous Australians were conducted in Australia [12-33]. Out of these 22 studies 14 studies were community based (11 focused on paediatric populations) [12, 14-21, 27, 29-31, 33] and the remaining eight were based on diagnostic sleep studies in clinical management or hospital settings (two focused on paediatric populations) [13, 22-26, 28, 32]. Only three studies were longitudinal [14, 16, 21] and all others were cross-sectional. In the community-based studies most studies used parental reports or self-reports with only two studies using actigraphy [17, 33], one study used the Epworth Sleepiness Scale to assess daytime sleepiness [33], but importantly, this has not been validated in Indigenous Australian populations.

The majority of community-based studies explored problems with initiating and maintaining sleep [12, 14, 15, 29-31], five studies examined sleep duration [17-20, 27, 33], two studies explored sleep patterns [16, 21], two studies explored daytime sleepiness [15, 33] and only one study explored the prevalence of sleep disordered breathing (SDB) (e.g., snoring) [31].

The evidence from diagnostic and management studies mostly focused on the prevalence and severity of OSA in Indigenous people, with some studies also focusing on gender difference in OSA prevalence [28] and utilisation of OSA diagnostic and management services in rural remote and Indigenous communities [24, 32].

Broadly the evidence from community-based studies and sleep laboratories can be covered under the following three types of sleep disorders/symptoms: insomnia symptoms (e.g., short sleep duration, trouble falling or staying asleep) [12, 14, 15, 17-20, 27, 29-31], sleep-related breathing disorders (e.g., OSA, snoring) [13, 22-26, 28, 31, 32] and sleep pattern/timing issues [16, 21].

The prevalence of sleep initiation and maintenance problems in children varied from 15% to 34.7% [12, 29], whereas in the adult population up to 22% reported a high number of objectively measured awakenings/night (>3) [33]. Up to 20% and 27% of severe daytime sleepiness (ESS score > 10) was reported in Indigenous children and adults, respectively [15, 33]. The studies in the adult population reported 15-35% prevalence of short sleep (<7 hours/night) and 29-41% prevalence of long sleep (>9 hours/night) [18, 33]. In children while the prevalence of long sleep varied between 4.5-12.3% [16, 21], up to 10.9% reported short sleep [16] and up to 50% were found to be late sleepers (bedtime after 9 pm) [21]. While in children up to 14.2% reported snoring [31], in adults up to 58% reported snoring [33].

The results from sleep laboratory-based studies suggest that the 39-46% of adults had severe OSA (AHI > 30) [24, 26], in children up to 51% were diagnosed to have OSA [22]. There was consistent evidence across studies suggesting that compared with non-Indigenous people, Indigenous people are significantly more likely to experience short and unhealthy sleep with a higher prevalence in the symptoms of OSA [19, 24, 27].

Discussion and conclusions

This review was undertaken to understand the state of sleep health for all Indigenous Australians. The necessity of undertaking this task lies in the significant and consequential impact of poor sleep on health and well-being. Importantly, it is noted that treating sleep disorders can reverse health outcomes both in the short and long term. Therefore, given the significant historical and ongoing inequities experienced by Indigenous Australians across a range of health outcomes, understanding the state of their sleep health offers opportunities to improve their overall health. Indeed, not only an enormous opportunity but potentially an imperative. Prevalence rates of respiratory sleep disorders for example, are significantly higher in Indigenous populations (apnoea up to 49% and up to 85% in sleep laboratory samples) compared to Australian populations norms (11.9% and 20.2% [34, 35]). We conclude that Indigenous Australians were more likely to report a higher prevalence of unhealthy sleep compared to non-Indigenous Australians [27]. Working and conferring with Indigenous communities is likely to improve future capacity for Indigenous and sleep medicine communities to engage in partnerships to improve sleep health and subsequently general health. Considering the bio-psychosocial model and determinants of sleep health offers a broader perspective with which to address sleep health in these populations.
Co- designed research and development projects are necessary to establish a national approach to assess sleep disorders amongst Indigenous Australians to improve sleep health and secondary outcomes and related services for Indigenous populations.

3 Objectives

The primary objective of this report was to review the current status of sleep health in Indigenous Australians. Specifically, we aimed to:

- Perform a systematic review to evaluate 1) The reported burden and determinants of sleep problems and 2) The quality of sleep health research undertaken and the Indigenous involvement and leadership in research studies to date.
- To compare sleep health broadly between Indigenous and non-Indigenous Australians
- To identify key gaps in our current understanding of the burden of sleep problems, the determinants of sleep problems and the prevention and treatment of physiological and non-physiological sleep disorders in these populations
- Provide key recommendations to inform an overarching strategic framework for the improvement of sleep health in Indigenous Australians, with the objective to engage and initiate conversation with key Indigenous-led community controlled services and peak-bodies, health-service delivery and policy makers at local, state and federal levels on the advocacy of sleep health.

4 Background

The context of Indigenous Australian health

Indigenous Australians are the first nations people of Australia and represent approximately 3% of the Australian population (25.4 million) [36]. Australia's Indigenous peoples comprise two similar but distinct traditional cultural groups — Aboriginal and Torres Strait Islander peoples comprising over 250 language groups, with unique laws and customs which identify membership of each group. Indigenous Australians share strong spiritual beliefs that connect them to land, sea and country with diverse cultural traditions across Australia. Similar to Indigenous populations across the globe [37], dispossession from their land, sea and country, historical colonisation, interruption of culture and intergenerational trauma coupled with ongoing racism and disadvantage have significantly impacted the health and well-being of our first nations populations [38].

In addition to these historical factors, this inequity has been further perpetuated with Indigenous people having little power to influence public policy decisions that affect their lives and health. Ongoing racism within the health system and externally continues to contribute to this trauma representing key drivers of health inequity [40].

Hence, in this review, it is important to consider the state of health in Indigenous Australians (and therefore sleep health) within the context of this complex interplay of factors [39].

Ongoing health inequity in Indigenous Australians

Despite efforts to improve aspects of health inequity made by successive Australian governments over time [41, 42], targets have not been met. In the modern era, the ongoing impact of colonisation and disadvantage these issues are major drivers of health inequity with impacts on employment, housing, education, income and differential access to health care services. Indigenous Australians experience a burden of disease that is 2.3 times the rate of non-Indigenous Australians and the major contributor to this burden is chronic disease [40]. Cardiovascular diseases, mental and substance use disorders, cancer, chronic kidney disease, diabetes, vision and hearing loss and selected musculoskeletal, respiratory, neurological and congenital disorders are the leading specific diseases contributing to chronic disease burden in Indigenous Australians [40]. Life expectancy is subsequently 7-8 years lower than non-Indigenous Australians and death rates are almost threefold higher [41]. An AIHW report showed Indigenous Australians experience significantly poorer mental health compared to non-Indigenous Australians, with 1 in 3 Indigenous youth experiencing psychological distress compared to 1 in 8 non-Indigenous youth [42]. Recognition, understanding and respect of the cultural determinants of health as well as policy and funding decisions continue to contribute to health service delivery in Indigenous Australians [38].

The contribution of sleep to general health in Indigenous Australians is unknown based on the current available evidence.

Sleep health in Indigenous Australians

Sleep is essential for health and well-being. Obtaining adequate sleep (a sufficient amount of sleep of acceptable quality) is imperative to sustaining optimal daytime functioning and health [43]. Both experimental and observational studies show that poor sleep is associated with

mental health, physiologic, cardiovascular and

endocrine changes [44]. All these health domains are notably problematic in Indigenous Australian populations [45]. Large epidemiological studies consistently show an association between sleep duration and quality and chronic health conditions. However, poor sleep quality and quantity is common in modern society and insufficient and/or suboptimal sleep is an emerging public health issue [46-48]. It is recommended that 7-9 hours of sleep per night is required to support optimal health in adults [49]. The most recent report by the Australian Sleep Health Foundation found that 12% of Australian adults experience very short sleep duration of <5.5 hours sleep/night [34] and another study of 14,900 adults reported that 20% experience short sleep duration <6 hours/night [8].

Understanding, assessing and measuring sleep in Indigenous Australians requires a different approach compared to non-Indigenous Australians, taking into account inter and intracultural differences in definitions, manifestations, and conceptualisations of sleep and health among Indigenous Australians. Indeed, in efforts to address these differences, recent, as yet unpublished works [50, 51] have begun to investigate, the biological and spiritual value and function of sleep, from Indigenous perspectives through Indigenous focus groups with a view to identifying poor sleep and how this is perceived to impact health and well-being. Importantly, Indigenous communities identify "poor sleep" as a major impact on their health. Through "sleep stories" sourced directly from a selection of Indigenous Yolŋu Elders, Arnhem Land Northern Territory, the important views and understanding of sleep health within Indigenous Australian communities were expressed. Below is an excerpt from one of the stories told by a Yolŋu Elder:

"Sleep is good for our HEARTS, our MIND and our SOUL. Sleep is important for HEALTH of our BODY. Our body needs to have rest.

Sleep is to RESTORE the body, build spiritual HEALTH and give inspiration to the MIND."

Yolŋu Elder, Yakurrpuy Dhäwu, The Sleep stories study, unpublished data.

Adapted from the Sleep Stories Study [51]

Indigenous Australians from these communities conveyed that sleep is viewed as important for health and well-being, spiritually and connection to land and country and kinship. When sleep is "bad" it can affect all these dimensions.

The current burden of sleep problems in Indigenous Australians in both urban and remote communities is unknown, with a lack of contemporary, nationwide data. However, studies in Indigenous populations, consistent across the United States, Canada, Australia and New Zealand, indicate increased risk of sleep disorders compared to non-Indigenous populations [3, 52-54]. For example, in New Zealand, Māori (Indigenous New Zealanders, 15% of the population) suffer disproportionately from poor sleep with higher incidence of insomnia and OSA [53-55]. To date, one previous comprehensive report by the Thoracic Society of Australia and New Zealand, the Australasian Sleep Association and Australian Lung Foundation in 2006, led by Dr Rob Pierce [5], detailed the state of respiratory sleep disorders in Indigenous adults but also contained some data on non-respiratory and non-physiological sleep disorders. The document reported that the prevalence of sleep-disordered breathing was thought to be approximately 5% in Indigenous Australians although there was little empirical data to confirm this at a population health level. Care and treatment related to sleep issues are seriously under-resourced, and awareness of sleep health is poorly managed and understood, particularly in remote communities and regional areas [5]. Importantly, this latest report only included information on sleep disordered breathing in Indigenous Australians. Currently, there has been no systematic review of the burden of sleep problems in Indigenous Australians that includes both physiological and non-physiological sleep problems.

Categorisation of poor sleep and sleep disorders

For this review, we will use the ICSD classification to document the current data available on the status of sleep health and sleep disorders in Indigenous Australians. Though we do acknowledge there are inter and intracultural differences in definitions, manifestations, and conceptualisations of sleep and health among Indigenous Australians. Poor sleep

health can be the result of insufficient sleep duration, or poor sleep quality as defined [9]. For simplicity in this report, we have focused on poor sleep according to the ICSD and as defined above (sleep duration, fragmented sleep, delayed sleep onset, problematic wake after sleep onset, excessive sleepiness and irregular or disturbed circadian rhythm problems and sleep disordered breathing). Sleep problems can be categorised broadly into physiological sleep disorders and non-physiological sleep disorders and are similar for adults and children. The International Classification of Sleep Disorders (ICSD) [56], includes seven major categories of sleep disorders which are presented below in **Table 1**.

Table 1. Major Diagnostic Sections of the International Classification of Sleep Disorders (ICSD) (3rd edition) [56]

Insomnia
Sleep-related breathing disorders
Central disorders of hypersomnolence
Circadian rhythm sleep-wake disorders
Parasomnias
Sleep-related movement disorders
Other sleep disorders Including non-physiological sleep disorders)

Determinants of sleep health in Indigenous Australians

According to the WHO, social and psychosocial factors that determine the health of Indigenous populations, include conditions of daily living, growth, education, food security, housing and living conditions, poverty, employment, health care, and factors including socioeconomic policy and resources [57]. For Indigenous populations inequities in the social determinants are created and maintained via the process of colonisation and may not meet the needs of Indigenous peoples across their life course [58].

As mentioned above, the health of Indigenous Australians is determined by a complex interaction of environmental factors, behaviours, biological factors and the social and cultural context that shapes their lives including but not restricted to those already cited. More comprehensive discussions of this can be found at Australian HealthInfoNet [59]

In regard to sleep health, there is no published model on the determinants of poor sleep in Indigenous Australians. It has been suggested that the high risk of sleep disorders among international Indigenous populations in high income countries may be related to the high prevalence of risk factors for sleep disorders such as obesity, chronic diseases, poorer living conditions and lower socioeconomic status [35] exacerbated by remote residence [14, 32, 60] lack of awareness of sleep health, environmental factors, such as a crowded sleeping spaces to name a few [14, 61]. As a collective, an understanding of determinants of sleep health will aid in informing the development of strategies that may improve prevention, treatment and management of sleep problems in Indigenous Australians. We suspect that all of the above determinants of health in Indigenous Australians will impact sleep health, forming a bio-psychosocial model for the determinants of poor sleep. This model considers sleep health to be interwoven with the biological, psychosocial, and contextual factors. We also acknowledge that recognising the cultural determinants of health will have a significant impact on reframing better health outcomes. For Indigenous Australians, good health is more than just the absence of disease or illness; it is a holistic concept that includes physical, social, emotional, cultural, spiritual and ecological well-being, for both the individual and the community [62]. This concept of health emphasises the connectedness between these factors and recognises the impact that social and cultural determinants have on health [62]. The Close the Gap 2020 report by Lowitja Institute [38] neatly illustrates a model of cultural determinants of overall health and well-being that may be adapted to future models of sleep health determinants. This model describes determinants of overall health and well-being with culture embedded within its centre and interconnected with physical, social, emotional, spiritual and ecological well-being, for both the individual and the community [38].

Therefore, we propose that cultural, social, psychosocial, contextual and biological determinants may impact sleep health. Importantly, identifying the reported determinants and knowledge gaps of poor sleep in Indigenous Australians in this review will provide the building blocks to engage with community to co-design a model that is appropriate for Indigenous Australians.

The impact of poor sleep in Indigenous populations

The body of literature on this issue provides very clear evidence that sleep problems (whether they have a physiological or non-physiological cause) have strong and causal associations with secondary deficits in daytime performance, sleepiness levels, academic performance, attention and learning, emotional regulation, behaviour and mood regulation, with increased likelihood of obesity, diabetes, high blood, pressure, somatic health, cardiovascular disease and general psychological health [9, 63, 64].

However, the number of studies on the sleep of Australian Indigenous populations and possible secondary performance measures, is limited to only a few studies mainly in children [14-17], despite evidence known inequities in academic performance, [15-17] emotional regulation and behavioural outcomes [30].

Mental health

Despite the higher rates of mental health problems [61] and suicide in Indigenous Australians [65], few studies have investigated the relationship between mental health and sleep in this population (particularly in adults). To our knowledge only one study has explored this relationship in Indigenous Australian Children. Data from a longitudinal study in 1,239 Indigenous children (the LSIC study), revealed that a high amount of racial discrimination was associated with poor child mental health status, sleep difficulties and obesity [30].

Academic performance and behaviour

A limited number of studies in Indigenous Australian children have investigated the effects of poor sleep on school performance and behavior [15]. In a sample of 25 Indigenous and 25 non- Indigenous children aged 7-11 years, sleep, and behavioral problems were assessed by questionnaire. Significant associations between behavior and sleep problems emerged among Indigenous children. Sleep problems (including total sleep problems, arousal problems and excessive daytime sleepiness) were associated with daytime problematic behaviours (including aggression, hyperactivity, withdrawal) in general and withdrawn behaviours specifically [15]. Using objective measures of sleep via actigraphy, Cooper et al. performed studies to investigate the association between sleep and school achievement in 21 Indigenous Australian children living in a remote community [17]. Actigraphy results revealed poor sleep quantity and quality in Indigenous Australian children in addition to a reduction in academic performance and auditory performance compared to population-based norms. Sleep fragmentation was associated with reduced reading and numerical skills [17]. However, sleep quantity showed no significant associations with academic performance. Notably, these studies performed to date have been limited due to the small sample size and the validity and robustness of the data require further investigation via larger multi-site studies across urban, regional and remote communities.

Chronic disease and cardiometabolic health

To date in Australia, few studies have investigated the relationship between sleep, chronic disease and cardio-metabolic risk in Indigenous Australian adults. In regard to sleep disordered breathing, a recent study revealed that Indigenous Australians referred for polysomnography testing had higher rates of chronic disease including class III obesity (27 vs. 15%), hypertension (26 vs. 14%), cardiac disease (34 vs. 23%), and diabetes (37 vs. 17%) compared to non-Indigenous Australians [24]. Furthermore, the severity of sleep disordered breathing appeared greater in Indigenous Australians, with the median total apnoea hypopnea index value being higher in

Indigenous Australians (25, interquartile range [IQR]: 11–58) compared to non-Indigenous (17, IQR: 7–36) Australians [24]

The association between sleep and cardio-metabolic risk factors has been explored briefly in both adults and children. One study, the BIRCH (Better Risk Stratification for Cardiac Health) study [33] has identified from 198 Indigenous adults a large proportion (34% and 41% assessed by self-report and actigraphy, respectively) had well below the recommended amount of sleep (7-9h/night) with a significant amount of sleep disruption (averaging 7 nocturnal awakenings/night assessed by actigraphy). Furthermore 22% of that population reported daytime sleepiness, defined by an Epworth Sleepiness Scale score >10. Poor sleep quantity and quality measures were associated with higher levels of low density lipoprotein and lower high density lipoprotein levels, which may in part, contribute to cardio-metabolic risk in this population [33]. In Indigenous Australian children, data from the Longitudinal Study of Indigenous Children (LSIC) survey of 1253 children aged 7-12 years has revealed that short sleep duration (assessed via primary carer report) was associated with unhealthy weight and increased BMI gain independent of age, socio-economic disadvantage, and level of remoteness [20, 21].

The economic costs of poor sleep

The costs of poor sleep health or sleep disorders, either direct or indirect, have not been studied specifically in Indigenous Australian adults or children. In 2017, the Australian Sleep Health Foundation published a commissioned report entitled "Asleep on the job: Costs of inadequate sleep in Australia," into the economic consequences of inadequate sleep in the overall Australian population (i.e. not differentiating between Indigenous Australians and non-Indigenous Australians) [34].

In that report, the total cost of inadequate sleep in Australia was estimated to be $66.3 billion in 2016 – 17. This total is made up of $26.2 billion in financial costs and $40.1 billion in the loss of well-being. The only available data regarding the cost of sleep problems in Australian children was in 2013 [66], which presented data on behavioural sleep disorders (e.g. Behavioural Insomnia of Childhood) [56] and did not include respiratory or other physiological sleep disorders in children. Quach et al estimated $27.5 million per annum in health care costs related to behavioural sleep disorders in children [66]. In addition to the direct cost, there is significant hidden indirect cost related to the parents of sleep disturbed children reported as illness-related morbidity and mortality, absenteeism, disability, reduction or loss of productivity, industrial and motor vehicle accidents [55].

The costs of sleep disorders and poor sleep health in Indigenous Australians are unknown, however if sleep problems occur at a higher prevalence in Indigenous Australians, as previously reported [5], and identified in other Indigenous populations in New Zealand, Canada, and the United States – we anticipate that costs of poor sleep in Indigenous Australians would arguably be similar if not greater compared to non-Indigenous Australians.

Summary

Evidence suggests that Indigenous people from other western countries (e.g. New Zealand, Canada, and United States) who have endured colonisation experience a higher incidence of sleep problems, yet access to sleep health care and health care that is culturally appropriate and respectful is lacking. This is of major concern. The inextricable link between sleep and overall health and well-being provides an evidence-base that improving sleep health should be a primary focus of health policy.

In line with the recent Australian Federal Recommendations for Sleep Health [83], sleep health represents a fundamental issue to target for the improvement of overall health and well-being in Indigenous people. We propose that poor sleep health may be a significant and, to date, poorly addressed factor that should be considered within the discourse around closing the gap in the health of Indigenous Australians.

5 Systematic review

To address aim one, the following systematic review and analysis aimed to document the current status of sleep health in Indigenous people in community based and clinic-based settings in Australia up to January August 2020.

Introduction and aims

There is a gap in health equity among Indigenous and non-Indigenous Australians, with Indigenous Australians having shorter life expectancy, higher rates of chronic disease and mental health problems [40]. In regard to sleep health, the last comprehensive report in 2006, suggested that respiratory-related sleep problems were higher in Indigenous compared to non-Indigenous Australians, however this was not based on any empirical data, but rather extrapolation of data [5]. This suggestion is consistent with other Indigenous populations in New Zealand, Canada and the United State who experience higher prevalence of sleep problems compared to non-Indigenous populations [3, 52-54]. Poor sleep at night can have a significant impact on daytime functioning, mental health, cardio-metabolic health and in children school attendance and academic performance [1, 2, 67] Currently there is a lack of health services that attend to sleep health in Indigenous populations, representing the current inequity within health systems [3]. Advocacy for improvement, increased funding, and education in sleep health for Indigenous Australians will be essential to bridge the gap. In 2020, while small independent studies have been performed, we have no contemporary, national data on the type, prevalence, and determinants of sleep problems in Indigenous Australians. Furthermore, at the heart of the proposed framework committed to improving health and well-being in Indigenous Australians is community control and shared decision-making [41]. Reporting and understanding these factors will be essential to inform co-designed prevention and treatment strategies for sleep problems to improve overall health and well-being. In this systematic review we ask 1) What type of sleep problems are reported by Indigenous Australians, 2) What is the prevalence of sleep problems in Indigenous Australians, 3) What are the known determinants of sleep problems and 4) What is the quality of Indigenous sleep research and level of community engagement and involvement in the research.

Method

Literature search

A systematic search using the keywords: "sleep problems"; "sleep disturbances"; "sleep quality"," "sleep disorder"; "sleep apnoea"; "obstructive sleep apnoea"; "OSA"; and "sleep- disordered breathing" AND "Indigenous Australians"; "Aboriginal"; and "Torres Strait Islander" was conducted to retrieve relevant peer-reviewed and grey literature published until August 2020.

Studies were included if they were:

(1) Original research articles

(2) Specifically explored and presented data on behavioural sleep problems or sleep disorders in Indigenous Australians

(3) Studies which provided subgroup prevalence data for these populations

(4) Conference abstracts were included if the study was a part of a bigger study, and methodological features of the study could be retrieved.

Studies were excluded if:

(1) Published in languages other than English

(2) Descriptive discussing the factors associated with poor sleep, without providing population data

(3) Duplicate data, i.e., conference abstract later published as journal articles

(4) Were review articles, editorials

(5) The study sample did not present separate information on poor sleep in the Indigenous subgroup.

In the case of duplicate studies, the one with the largest sample size and with more detailed results was included. The following databases were searched using appropriate specific search strings: PubMed, PsychINFO, Informit Indigenous Collection Scopus and CINAHL. "LIt.search tool" from the Lowitja Institute was used for relevant literature retrieval [11].

A grey literature search was conducted to retrieve government reports, theses, and conference presentations. Using generic search terms, we searched *Indigenous HealthInfoNet*, Google Scholar (advanced), government agencies, e.g., Australian Institute of Health & Welfare (AIHW) and Lowitja Institute websites. Along with this, reference lists of relevant articles and related reviews were checked for any missing studies.

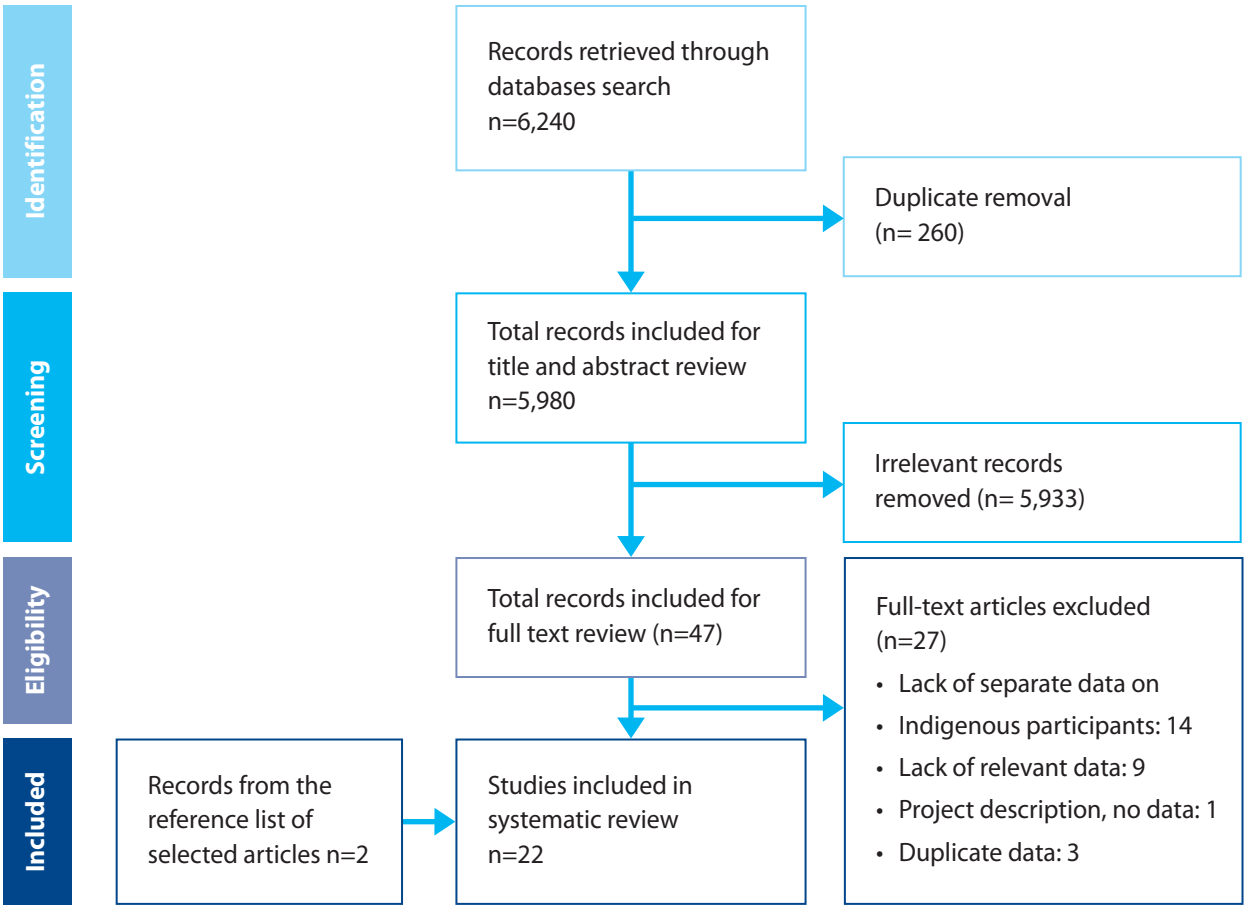

Figure 1: Flow diagram illustrating the selection process for articles included in the systematic review.

PubMed Search string: PubMed Search string: (sleep [Title/Abstract]) OR "sleep duration" [Title/Abstract]) OR "short sleep"[Title/Abstract]) OR "insomnia" [Title/Abstract]) OR "sleep quality"[Title/Abstract]) OR "quality of sleep"[Title/Abstract]) OR "sleep* problem*"[Title/Abstract]) OR "trouble sleep*"[Title/Abstract]) OR "OSA"[Title/Abstract]) OR "sleep apnoea"[Title/Abstract]) OR "snoring"Title/Abstract]) OR "nightmare*"[Title/Abstract]) OR "sleep* disturbance*"[Title/Abstract]) OR "sleep disorder*"[Title/Abstract]) OR "restless leg" "[Title/Abstract]) OR "sleepwalk*" "[Title/Abstract]) AND "Indigenous Australians"[Title/Abstract]) OR "Australian Aboriginal"[Title/Abstract]) OR "Torres strait Islander"[Title/Abstract]) OR ("Aboriginal and Torres Strait Islander"[Title/Abstract])) OR "First Australian*"[Title/Abstract]

Database Search

The search results were imported into an Endnote database (Thomson Reuters). After duplicate removal, title and abstract of the remaining records were then screened by two reviewers (YF and SY) for eligibility against the inclusion criteria. Finally, the full texts of potentially relevant papers were read, and studies meeting the inclusion criteria were selected. A Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart diagram shows the number of articles retrieved, screened, excluded, and selected during the literature review process (Fig. 1) [68].

Two investigators independently evaluated the selected studies to extract the following data:

(i) general information (author's name, publication, and data collection year),

(ii) study site and design (iii) study sample characteristics (size, sampling method, and age group),

(iii) sleep

problem/disorder assessment method, and (v) results. The final articles included in the review are summarised in **Table 1**.

Risk of bias assessment

We used the critical appraisal by Hoys et al. to independently assess the risk of bias in community-based studies included in the review [69]. The tool by Hoys et al. is a valid measure for appraising the quality of prevalence studies. The quality appraisal tool comprises nine items plus a summary item for bias assessment. Items 1 to 4 assess selection and non-response bias (external validity), and items 5 to 9 assess measurement bias and item 10 evaluates analysis bias (internal validity).

Individual items are deemed to be at either low (scored zero) or high risk (scored one) of bias. The risk of bias for a particular item was recorded to be uncertain when there was insufficient information in the article to permit a judgment for the item [70]. These points are then summed together into (a possible maximum of nine points) to categorise the risk of bias for each study. Scores are categorised into three groups: "low risk (scores 0-3)", "moderate risk (scores 4-6)" and "high risk (scores 7-9)" of bias, respectively (**Supplementary Table-S1**).

Community engagement and involvement in research

Since this review exclusively focused on Indigenous populations, we decided to evaluate the included studies on the level of Indigenous involvement in community-based studies. In Indigenous research there has been much debate regarding the need for research that explicitly involves Indigenous populations input, collaboration, and ownership to gain a truly Indigenous perspective on Indigenous health and health inequities [71]. We used the Cultural Identity Interventions Systematic Review Proforma to Indigenous involvement and leadership in sleep health research [72]. This is a recently developed 21 item tool which assesses studies regarding scientific rigour and also about meeting ethical and methodological standards that are specific to Indigenous health research in Australia [72]. We utilised selected questions from the Proforma to gain a general understating of Indigenous input and collaboration as not all questions were applicable to studies included in this review Questions selected were guided by the eight categories identified in a recent analysis for strengthening reporting of health research involving Indigenous Peoples (Governance, Prioritisation, Relationships, Methodologies, Participation, Capacity, Interpretation and Dissemination) [71]. For this review, we utilised questions 1, 2, 3, 4, 12, 16, 19 and 20 of the Proforma (Six items with a "yes," "no," or "not clear" response option, and the remaining two as open-ended responses) (See **Supplementary Table-S2 and S3**). Disagreements regarding quality items to use in evaluation were discussed and resolved through co-author consensus.

Results

Characteristics of Studies included in the Review.

A total of 22 studies focusing on sleep issues in Indigenous Australian were conducted in Australia [12-33]. Out of these 22 studies 14 studies were community based (11 focused on paediatric population) [12, 14-21, 27, 29-31, 33] and the

remaining eight were based on diagnostic sleep studies (two focused on paediatric population) [13, 22-26, 28, 32]. Only three studies were longitudinal [14, 16, 21] and all others were cross-sectional. In the community- based studies total sample size ranged from 21 to 1,671 participants [12, 17]. Whereas in the sleep clinic-based studies the sample size ranged from 91 to 403 participants [24, 26].

In the community-based studies most studies used parental reports or self-reports with only two studies using actigraphy [17, 33], one study used Epworth Sleepiness Scale to assess daytime sleepiness [33], but importantly, this has not been validated in Indigenous Australian populations. The majority of community-based studies explored problems with initiating and maintaining sleep [12, 14, 15, 29-31], five studies examined sleep duration [17-20, 27, 33], two studies explored sleep patterns [16, 21], two studies explored daytime sleepiness [15, 33] and only one study explored the prevalence of sleep disordered breathing (SDB) (e.g., snoring) [31].

The evidence from diagnostic and management studies mostly focused on the prevalence and severity of OSA in Indigenous people, some studies also focused on gender difference in OSA prevalence [28] and utilisation of OSA diagnostic and management services in rural remote and Indigenous communities [24, 32]. Characteristics of the included studies are shown in **Table 1**.

Table-1: Characteristics of studies included in the systematic review of poor sleep in Indigenous communities in Australia (based on references [12-33]).

Author (Year)	Study sample	Age-group	Study design & recruitment	Study tools (Reporter)	Outcome measures	Findings
Results from community-based studies						
Deacon-Crouch et al. (2020)	5204 non-Indigenous (48.1% male) and 646 Indigenous (41.8% male) adult participants in National Nutrition and Physical Activity Survey and the National Aboriginal and Torres Strait Islander Nutrition and Physical Activity Survey 2011–2013	Non-Indigenous group: 49 ± 16.2 y Indigenous group: 42 ±15.5 y	Cross sectional data from nationally representative Health Survey	Self-report	Sleep duration in Indigenous adults its association with body mass index (BMI)	15% Indigenous people reported sleeping for short duration (<7 h/night), while 41% reported sleeping for long duration (> 9 h/night). The association between sleep duration and BMI was not significant but a possible dose-response relationship was evident
Priest et al (2020)	4,664 participants (4.7% Indigenous, 55% male) of the Speak Out Against Racism student survey of school students in years 5–9 in New South Wales and Victoria over a 10- week period in 2017	10-15 y	Population representative cross-sectional Study involving 23 schools in metropolitan and regional areas	Self-report	Prevalence of direct and vicarious racial discrimination experiences from peer, school, and societal sources, and examine associations between these experiences and socioemotional and sleep outcomes	34.7% Indigenous participants reported high prevalence (mostly/all the time) of sleep disruption and had the highest prevalence (20.2%) of sleep latency >60 min across all ethnic groups. Racial discrimination across sources on sleep duration, sleep latency >60 min and sleep disruption

Author (Year)	Study sample	Age-group	Study design & recruitment	Study tools (Reporter)	Outcome measures	Findings
Fatima et al (2020)	1,258 Participants (50.7% males) of the wave 5-8 of the Longitudinal Study of Indigenous children (LSIC) cohort.	6.32 ± 1.52 y	Longitudinal, Cluster sampling covering 11 remote, regional and urban locations in Australia	Non-validated questionnaire (Primary caregivers)	Sleep phenotypes in Indigenous children and associations between sleep duration and BMI gain	Five classes of sleep patterns: early/long sleepers (4.5%), normative sleepers (25.5%), late sleepers (49.9%), consistent late sleepers (11.1%) and early risers (9%) emerged from the data. Compared with early sleepers, consistent late sleepers experienced 1.03 unit gain in BMI at follow-up (95% CI: 0.001-2.05, P = .05).
Yiallourou et al. (2020)	245 Indigenous (43% male) Participants of the Better Indigenous Risk stratification for Cardiac Health (BIRCH) cohort.	45 ± 13 y	Cross-sectional, convenience sample recruited from Aboriginal communities in the Northern Territory and Queensland	Actigraphy (n=46) and a validated questionnaire to assess daytime sleepiness measured through Epworth Sleepiness Scale (ESS)	Prevalence of short sleep and sleep problems in Indigenous Australians, and their association with cardio-metabolic Risk	Over one-third of participants obtained sleep < 7 hr/night and experienced poor-quality sleep, with 27% reporting severe daytime sleepiness (ESS score > 10) and a high number of objectively measured awakenings/night (6 ± 4). Short sleep duration was an independent predictor of diastolic (β = 5.37, p = .038) and systolic blood pressure (β = 14.30, p = .048), night-time awakenings were associated with increased glycated haemoglobin levels (β = 0.07, p = .020) and greater sleep fragmentation was associated with lower high-density lipoprotein levels (β = −0.01, p = .025).
Deacon-Crouch et al. (2019)	716 non-Indigenous (49.9% male) and 186 Indigenous (53.2% male) children in the National Nutrition and Physical Activity Survey and the National Aboriginal and Torres Strait Islander Nutrition and Physical Activity Survey 2011–2013.	5–12 y	Cross sectional data from nationally representative Health Survey	Non-validated questionnaire (Primary caregivers)	Sleep duration in Indigenous children and associations between sleep duration and body mass index (BMI)	Indigenous children experienced less sleep on average compared with non-Indigenous children, F (1, 900) = 6.05, P = 0.014. sleep was also significantly predictive of increased BMI, R2 = 0.214, β = − 0.007, P < 0.001.

Author (Year)	Study sample	Age-group	Study design & recruitment	Study tools (Reporter)	Outcome measures	Findings
Deacon-Crouch et al. (2018)	1.253 participants (43% males) of the wave 7 of the LSIC cohort.	7-12 y	Cross-sectional, Cluster sampling covering 11 remote, regional, and urban locations in Australia	Non-validated questionnaire (Primary caregivers)	Sleep duration in Indigenous children and associations between sleep duration and BMI	Children in older age group (12 y) had shorter sleep duration than children in the younger age group (6y). Sleep duration was negatively correlated with age-standardised BMI (r:−0.124, $P < 0.001$).
Blunden et al. (2018)	513 participants (52% males) of the Wave-3 (baseline) and wave 8 (follow up) of the LSIC cohort.	7-9 y	Longitudinal, Cluster sampling covering 11 remote, regional and urban locations in Australia	Non-validated questionnaire (Primary caregivers)	Sleep duration categories and their association with academic performance in Indigenous children	Five distinct groups of children were identified based on their sleep schedules, i.e., early risers (15%), long sleep (12.3%), normative sleep (49.7%), variable bedtimes (11.7%) and short sleep (10.9%). Short sleep at baseline was significantly linked with reduced spelling and writing performance at the follow-up.
Attard et al. (2017)	Participants (~50% males) of the Waves 1-5 of the LSIC cohort. Wave-1: n=1671, wave 2: n=1523, wave 3: n=1404, wave 4: n=1283, wave 5: n=1258	Wave 1: 0.5-5 y Wave 2: 1.5-3 y Wave 3: 2.5-7 y Wave 4: 3.5-8 y Wave 5: 4.5-9 y	Longitudinal, Cluster sampling covering 11 remote, regional and urban locations in Australia	Non-validated questionnaire (Primary caregivers)	Sleep pattern and sleep problems in Indigenous children	17.8% of children had difficulty sleeping. There was a small but significant effect of age on time in bed, $F(5, 1199): 4.48$, $p < 0.001$. across the waves, on average.
Shepherd et al. (2017)	1,239 participants (50% males) of the wave 6 of the LSIC cohort.	5-10 y	Cross-sectional, Cluster sampling covering 11 remote, regional, and urban locations in Australia	Non-validated questionnaire (Primary caregivers)	Impact of early exposure to racism on child health	Exposure to racism accounted for 19.1% of the population attributed risk for sleep difficulties in Aboriginal children, children exposed to racism had a higher likelihood of sleep difficulties.
Macniven et al. (2016)	59,489 participants (0.6% Aboriginal, 43.4% males) of the baseline cohort of the 45 and up study.	≥45 y	Cross-sectional, random sample identified through Medicare database	Self-reported sleep duration (Self)	Prevalence of short sleep and factors associated with unhealthy sleep (5-7/9+ hours)	Compared with non- indigenous people, Indigenous people had a higher prevalence of unhealthy sleep (OR: 2.03; 95% CI: 1.60-2.59).
Amarasena et al. (2015)	1,671 participants (~50% males) of the Wave-1 of the LSIC cohort.	≤ 2 y	Cross-sectional, Cluster sampling covering 11 remote, regional, and urban locations in Australia	Non-validated questionnaire (Primary caregivers)	Sleep problems in children and factors associated with sleep problems	15% of children had difficulty sleeping. 42% of caregivers cited teething as a reason for sleep difficulties.

Author (Year)	Study sample	Age-group	Study design & recruitment	Study tools (Reporter)	Outcome measures	Findings
Cooper et al. (2012)	21 Indigenous children (71% males) from a remote Indigenous community.	6-13 y	Cross-sectional, purposive community sample from a school in the remote Indigenous community in the Northern Territory	Actigraphy	Sleep duration, efficiency, and latency in Indigenous children and their association with academic performance and executive function.	Actigraphy data indicates a total sleep time of 8.78 h (SD±49.6 min) in children. Sleep fragmentation was significantly linked with reduced reading and numeracy skills.
Blunden et al. (2010)	50 school kids (50% Indigenous, 54% males) from metropolitan and urban areas.	Non-Indigenous children: 7-11 y Indigenous children: 7-12 y	Cross-sectional, Non-random sample from six schools in metropolitan and urban areas in the Northern Territory	Sleep disturbance scale for children (Primary caregivers)	Sleep initiation and maintenance problems in Indigenous children	32% of Indigenous children had behavioural sleep problems. 20% had sleep-wake transition problems, and 20% reported excessive daytime sleepiness.
Valery et al. (2004)	1,650 Indigenous children and adolescents living in Torres Strait and the Northern Peninsula Area.	0-17 y	Cross-sectional, Random sampling from five Indigenous communities in the Torres Strait region	Non-validated questionnaire (Primary caregiver (0-13 y group) and self-report) (14-17 y)	Prevalence of snoring in Indigenous children	Snoring, snorting and restless sleep was prevalent in 14.2%, 3.6% and 6% of the children, respectively.
Results from sleep clinic-based studies						
Mehra et al (2020)	337 Aboriginal adults (50.1% male) who underwent a diagnostic PSG	Mean age 47.8 y	Patients referred to the specialist sleep service based at the Royal Darwin Hospital and Darwin Private Hospital disorders, in particular OSA.	Polysomnography (PSG)	Obstructive Sleep Apnoea (OSA) diagnosis in Aboriginal adults and gender difference in OSA	Compared with females, males had higher prevalence (37% vs 63%) of severe OSA (Apnoea Hypopnea Index (AHI>30/hour).
Gentin et al* (2020)	284 patients (18.7% Indigenous, 37% male) referred for a diagnostic PSG	1-11 y	Retrospective study reviewing all paediatric patients referred for sleep assessment and underwent a diagnostic sleep study between 2016 and 2018 in the NT	PSG	OSA prevalence in paediatric patients	85% presented with snoring. 42% had significant daytime symptoms. 51% had PSG confirmed OSA
Heraganahally et al (2020)	3078 patients (13% Indigenous, 61% male) who underwent for a diagnostic sleep study	Non-Indigenous group: 51.5 y Indigenous group: 47.8 y	All adult patients who underwent a diagnostic PSG at the Respiratory and Sleep Service, Royal Darwin Hospital, between 2011 and 2015	PSG	Comparison of PSG characteristics of Indigenous and non-Indigenous adult patients	Among the Indigenous patients, 46% had severe OSA. The median total AHI value was higher in the Indigenous population (25, interquartile range [IQR]: 11–58) compared to the non-Indigenous (17, IQR: 7–36), and in rural/remote population (19, IQR: 8–42) compared to urban (17, IQR: 7–37)

Author (Year)	Study sample	Age-group	Study design & recruitment	Study tools (Reporter)	Outcome measures	Findings
Heraganahally et al (2019)	348 Adult Aboriginal (51% male) who underwent a diagnostic PSG	Mean age 47 years	Retrospective study reviewing patients referred for sleep assessment and underwent a diagnostic sleep study between 2011 and 2015	PSG	OSA and cardiovascular disease in Aboriginal Australians from the NT	According to AHI 78/348 (22%), 69/348 (20%) and 158/348 (45%) were noted to have mild, moderate, and severe OSA respectively
Atos et al* (2019)	156 Aboriginal (50% male) patients from the regional and remote communities	Mean age 47 years	Adult Aboriginal patients living in the remote and regional communities underwent a diagnostic PSG over a 5-year period	PSG	OSA prevalence in Aboriginal patients from the regional and remote communities	Mean AHI was 40/hr and 77 (49%) patients had an AHI of more than 30/hr.
Kassim et al (2016)	272 children referred to a weight management clinic (KOALA clinic) out of which 54 (11% Indigenous, % male) were also seen in the Sleep clinic between 2008 and 2013	3–14 y	A retrospective chart review of children with obesity seen in the KOALA weight management clinic and Sleep clinic	PSG	OSA prevalence in paediatric patients	There were six Indigenous children in the cohort and all had OSA
Wood et al (2015)	200 adults (50% Indigenous, 67% males) with a with a confirmed sleep related breathing disorder diagnosed prior to September 2011	Non-Indigenous group: 50.6 (±12.6) y Indigenous group: 47.3 (±12.6) y	A retrospective audit (conducted in 2012–2013) to assess the utilisation of OSA diagnosis and management at Alice Springs Hospital and Cairns Hospital	PSG	Sleep disorders in Aboriginal and Torres Strait islander people and residents of regional and remote Australia	87% of Indigenous patients reported snoring 58% Witnessed apnoea and 97% ha ESS score> 10. All regional and remote residents accessed diagnostic sleep studies at a rate less than Australia overall (31/100,000/y vs 575/100,000/y)
Lee et al (2009)	91 Indigenous patients from Far North Queensland (FNQ) who underwent for a diagnostic sleep study	Mean age was 54.3 years (range of 23 to 78)	Audit of formal sleep study and portable studies of Indigenous patients from July 2003 to March 2009 in FNQ	PSG and home-based sleep study	Prevalence and severity of sleep disordered breathing in indigenous populations in FNQ	35 patients (39%) had severe OSA (AHI - 30), 20 (22%) had moderate OSA (AHI 15–30) and 21 (23%) had mild OSA

OR: Odds Ratio, **CI:** Confidence Interval

Study quality

Each study included in the systematic review was evaluated for the risk of bias and the involvement of Indigenous people in research. For the risk of bias assessment, the highest scoring study received four points while the lowest scoring study received one point out of a possible 10 points. In total there were six studies deemed to be at low risk of bias [18, 19, 27, 29, 31, 33] and eight studies deemed to be at moderate risk of bias [12, 14-17, 20, 21, 30]. Most of the studies suffered from varied diagnostic classifications, selection bias, and limited generalisability. Based on the assessment tool, the studies rated of highest quality were mostly based on existing longitudinal cohort studies, e.g., Longitudinal Study of Indigenous Children (LSIC), Better Indigenous Risk stratification for Cardiac Health study (BIRCH).

Community engagement and involvement in research

For evaluating all Indigenous communities' involvement in the research, the use of the existing Proforma was helpful but inadequate. Using a shortened version of the Proforma we found that six studies [12, 14, 16, 20, 21, 30] had high level and the others had moderate levels of communities' involvement in the research [15, 17, 19, 20, 27, 29, 31, 33]. However, it is worth mentioning that based on the limited information provided in the papers, it was difficult to accurately assess the level of involvement of Indigenous communities in the research. While we attempted to retrieve as much information as possible for each paper, for some studies it was difficult to gauge the level of community engagement based on the information shared in the paper. It is possible that the research team engaged well with the community, but due to lack of reporting guidelines, word limit constraints etc. the information on community engagement was not adequately presented in the paper. Therefore, there may be reporting issues rather than any issues with study design or conduct. Noticeably, there was lack of information on Indigenous leadership in research. Whilst co-authors of this review were able to inform our analysis of indigenous involvement presented here with personal knowledge, omitting this information from original manuscripts makes evaluation of Indigenous input problematic. Findings are presented in **Table S1**.

Burden of poor sleep in all Indigenous populations

Based on the existing literature, the following three types of sleep disorders/symptoms are reported in community and sleep clinic-based studies on Indigenous Australian populations.

1. **Insomnia Symptoms** (e.g., short sleep duration, trouble falling or staying asleep)
2. **Sleep Related Breathing Disorders** (e.g., OSA, snoring)
3. **Sleep pattern/timing issues** (e.g., irregular sleep pattern)

Insomnia symptoms

The prevalence of sleep initiation and maintenance problems in children varied from 15% to 34.7% [12, 29], whereas in the adult population up to 22% reported a high number of objectively measured awakenings/night (>3) [33]. Up to 20% and 27% of severe daytime sleepiness (ESS score > 10) was reported in Indigenous children and adults, respectively [15, 33]. The studies in the adult population reported 15-35% prevalence of short sleep (<7 hours/night) and 29-41% prevalence of long sleep (>9 hours/night) [18, 33]. In children while the prevalence of long sleep varied between 4.5-12.3% [16, 21], up to 10.9% reported short sleep [16]. The studies focusing on the prevalence of short sleep in the adult population defined short sleep as <7 hours/night, which is in line with the National Sleep Foundation (NSF) recommendations. Compared with non-Indigenous people, Indigenous Australians were more likely to report a higher prevalence of unhealthy sleep (OR: 2.03; 95% CI: 1.60-2.59) [27] Some studies explored the association between sleep duration and other factors such as academic performance and executive function [15, 16], body mass index [18-21], cardiometabolic functions [33] and physical and mental health [29, 31, 73]. Overall, inadequate sleep

was significantly associated with poor health and functioning in all Indigenous people.

Sleep-related breathing disorders

There were only two community-based studies that that assessed SDB symptoms in Indigenous children and adults [31] While in children up to 14.2% reported snoring [31], in adults up to 58% reported snoring [33]. The results from sleep laboratory-based studies suggest that the 39- 46% of adults had severe OSA (AHI > 30) [24, 26], in children up to 51% were diagnosed to have OSA [22]. It is noted that these are highly biased and selective samples, but still present a high prevalence of significant disease in those presenting for sleep disordered breathing. There was consistent evidence across studies suggesting that compared with non-indigenous people, Indigenous people are significantly more likely to experience short and unhealthy sleep and higher prevalence of OSA [19, 24, 27]. There was some evidence of gender difference in snoring as Indigenous males were found to report a higher prevalence of OSA than Indigenous females [28].

The data from sleep clinic-based studies suggest that despite high burden of severe OSA in Indigenous patients and rural and remote communities [24], service utilisation is at a rate less than Australia overall (31/100,000/y vs 575/100,000/y) [32] which shows remarkable inequality. Although timely access and availability of services and follow-up are major barriers to treatment, when appropriate services are available a significant proportion of Indigenous patients are found to be compliant with treatment plans and have derived significant benefits from treatment [26].

Sleep pattern/timing issues

Only two studies discussed sleep pattern/timing issues in Indigenous children [16, 21]. Both the studies utilised the LSIC data, while Blunden et al found that around 12% of children reported variable bedtimes, Fatima et al reported that around ~50% of Indigenous children are going to bed after 9 pm [16, 21].

Determinants of sleep

Thirteen [12, 14, 18, 19-22, 24, 30-33] of the 22 studies explored potential determinants of sleep issues in adults and children. Male gender was associated with increased severity of OSA in adults [24] and in children higher prevalence of snoring and snorting during sleep compared to females [31]. Older age was associated with poorer sleep quality and sleep disruption in adults [33] and in children reduced time in bed [14] and sleep duration [19, 20]. Higher BMI in adults was associated with shorter sleep duration [18], confirmed diagnosis [32] and increased severity of OSA [24]. In children higher BMI was associated with shorter sleep duration [20], later bedtimes [21] and almost half of children referred for a diagnostic clinical PSG for suspected OSA were overweight/ obese [22]. Chronic conditions such as diabetes and kidney disease were associated OSA diagnosis [32] and sleep disruption [33] in adults. Respiratory problems (difficulty breathing) were reported as a major determinants of sleep disruption in infants and toddlers up to 2 years of age [12] and asthma symptoms (e.g. wheezing) were associated with increased risk of snoring [31] in children. Racial discrimination was associated with difficulties in initiating and maintaining sleep in children aged 5-10 years [30]. A higher level of remoteness was related to OSA diagnosis in adults [32] shorter time in bed [14] and shorter sleep duration [20]. More people living in the household was associated with longer time in bed [14]. Lower socio-economic status was related to shorter sleep duration [20] and children who attended school had later bedtimes and less time in bed [14].

Discussion

This review was undertaken to understand the state of Indigenous sleep health in Australia. The necessity of undertaking this task lies in the significant and consequential impact of poor sleep on health and well-being. Importantly, it is noted that treating sleep disorders can improve some health outcomes both in the short and long term. As Indigenous populations in Australia experience health inequities that are significant and consequential, understanding the state of their sleep health and,

from that, understanding what opportunities there are to improve these health disparities provides not only an enormous opportunity but should be considered an imperative. This review highlights the importance of understanding where inequities exist therefore alerting policy makers and health care systems to these. Previous documents have reported on specific sleep disorders such as sleep disordered breathing [5] in Australia Indigenous populations and these are mainly in adults. This review includes all sleep disorders and children, young people, and adults. As such, this review is the most comprehensive to date.

Main findings

In all studies reported here, prevalence of sleep disorders was higher for Indigenous compared to published prevalence rates for non-Indigenous populations, with Indigenous Australians reporting a higher incidence of unhealthy sleep [27]. Prevalence in children and adolescents from a pool of over 12,000 children and young people was approximately 18%. Similarly, in adults, with a comparable sample pool, prevalence rates were similar (19%).

However, whilst it is the first time we have such figures for Indigenous populations overall, the percentages are no doubt sensitive to age differences (e.g. junior vs senior school children) and different types of sleep disorders (e.g. short sleep vs difficulty falling asleep). Also, most of the studies suffered from varied diagnostic classifications, selection bias, and limited generalisability.

As presented in **Table 1**, the prevalence of short sleepers, reached approximately 35% in more than one study [33] with just over 10% of children also reporting short sleep. Importantly sleep disordered breathing was disproportionally represented in Indigenous populations, in both adults [24, 28] and children [22] with more than one study showing over 50% of adults presenting with OSA [13, 23, 32] and 80% of children presenting with consequential snoring [22]. Overall, inadequate sleep was significantly associated with poor health and functioning in Indigenous people.

The quality of the studies, as noted, has been variable with those studies rated of the highest quality mostly based on longitudinal data. These are dependent not only on significant government financial support but on the continued participation of Indigenous communities such as those in the Longitudinal Study of Australian Children (LSIC).

Similarly, despite some efforts, the evaluation tool utilized, showed that there is still significant work to be done to improve Indigenous participation at the policy, institutional and research levels. Findings suggest that either Indigenous participation has not been sufficiently maximized, or it has not been reported. Efforts to improve Indigenous participation in research across Australia should remain a priority. But further, it should be an aim to further increase indigenous leadership in sleep health studies, with the objective to engage and initiate conversation with key Indigenous-led community-controlled services and peak-bodies.

Types of sleep disorders

Twenty years ago, research into sleep disorders in Indigenous populations was largely focused on those with a physiological aetiology, such as sleep-disordered breathing [74].

Data has confirmed that Indigenous Australian have significantly higher rates of sleep disordered breathing compared to their non- Indigenous peers with studies showing rates of self-reported apnea (20%) and snoring at night (58%), much higher than populations norms estimated in Australian adults (11.9% and 20.2% for apnoea and snoring and at night, respectively) [34]. Woods et al [35] have demonstrated that Indigenous Australians are 1.8 times more likely to have a positive diagnostic sleep study and access diagnostic sleep studies at a lower rate compared to non-Indigenous Australians, but more recent work from clinical populations has reported similarly concerning figures of the prevalence of sleep disordered breathing in Indigenous Australians at approximately 50% of presenting cases [23, 24].

In the last twenty years, research has expanded to other non-physiological sleep disorders, notably insomnia. Insomnia is less common than sleep

disordered breathing. Available data suggest that Indigenous Australians experience higher rates of short sleep compared to non- Indigenous Australians [5]. Prevalence rates of up to 18% [34] have been reported in Australian adults experiencing short sleep duration of less that the recommended 7-9 hours per night [56]. For comparative purposes, analysis of the BIRCH Indigenous cohort revealed that 16% reported <5.5 hours of sleep and 20% reported <6 hours/sleep night. In that study, large degrees of sleep disruption were experienced by Indigenous participants, (3 or more objectively measured awakenings) lasting >30 minutes. Both of these symptoms are predictors of clinical insomnia [75, 76], indicating that Indigenous Australians may experience fragmented sleep at a level commensurate with clinically significant sleep disorders. Research suggests that insomnia can generally be amenable to change through lifestyle choices and improving sleep health behaviours which may offer opportunities for sleep health amelioration [9]. However, the initiation and maintenance of healthy sleep practices are constantly at risk of negative impacts from systems beyond the individual adult, the child or the community as can be seen through bio-psychosocial models such as Bronfenbrenner's model [77] and encompassed in the before-mentioned social determinants of heath from the WHO. These would plausibly include many of the contributors to poor sleep health in these populations that have contributed to poorer health outcomes for both Indigenous Australians. It is necessary to make the case here that it is both possible and critical to intervene at both community and policy levels to reduce inequities in sleep health.

Other sleep problems with non-physiological aetiologies have investigated sleep pattern/timing issues in two studies and these have both been in children [16, 21]. Variability in bedtimes and /or later bedtimes with subsequent sleep duration variations have been shown to be detrimental to sleep health due to disruptions to circadian sleep/wake systems [78]. Both studies utilized the LSIC longitudinal data. While Blunden et al., found that around 12% of children reported variable bedtimes, Fatima et al., reported that around ~50% of Indigenous children are going to bed after 9 pm [16, 21]. Variable sleep patterns and timing were related to downstream variables such as BMI [21] school performance and school attendance [16]. There is evidence that Indigenous families have noisier [79], and overcrowded houses [80] which would plausibly disrupt bedtime routines, and both have been associated with poor sleep [14]. This is further exacerbated by isolation with many Indigenous children living in regional or remote locations [14] where it has been reported that the more isolated the family, the worse the sleep [14]. Indeed, when the potential determinants of sleep were examined in the study, factors such as racial discrimination, higher level of remoteness, more people living in the household and lower socio-economic status were all associated with sleep patterning/timing and durations.

Regarding the potential determinants of sleep health, largely biological factors have been investigated including age, gender, BMI, and chronic illness [19, 24, 32, 33]. Older age, male gender higher BMI and presence of chronic illness all negatively impacted sleep health in both children and adult studies. There were some data available on social determinants such as level of remoteness, racism, socio-economic status, and housing which was represented in children's studies [14, 30], rather than adult. In terms of cultural determinants of sleep health, no studies to date have attempted to specifically explore this domain. Accordingly, more studies are needed to determine the potential determinants of sleep health including biological, social and cultural factors in Indigenous Australians.

Overall, this review highlights that poor sleep health in Indigenous adults and children is impacted by many Indigenous specific issues and impacts in turn many aspects of their physiological, psychosocial, and psychological health.

Limitations

Although we found a total of 14 community-based studies exploring the magnitude of sleep problems in Indigenous Australians, there remains a paucity of data across all ages and demographically diverse Indigenous subgroups in the literature and for a wide range of sleep disorders. Most of the studies suffered from information and selection bias and

offered limited reliability. It is common and acceptable to use large scale surveys, with self-reported questionnaires, if the purpose of the research is to describe the scope and scale of the health issue. Objective assessment of sleep problems and disorders is important but difficult given limited resources and location of services. In this review we have included those clinical studies that have reported prevalence rates of sleep disorders from clinical populations (specifically sleep disordered breathing). Whilst these are not indications of community prevalence rates, in terms of understanding Indigenous sleep and the urgency of treatment, including clinical population studies was deemed important.

Other limitations of the existing literature and reliance on large scale surveys, lies in the inconsistent definitions, assessment methods and reliance on self-reported estimations to study poor sleep and poor sleep health in general. Self-reported prevalence alone, whether it be of short sleep duration or disrupted/fragmented sleep, is an unreliable measure to assess the burden of the problem [81, 82]. Moreover, relying on only a single item to assess sleep quantity or quality would plausibly introduce bias as it fails to consider the complexity and severity of symptoms. Although some studies used validated measures such as ESS to assess daytime sleepiness, this tool (and most of the others) have only been validated in non-Indigenous settings. Subjective experiences of sleep and sleep health are extremely important facets of understanding sleep health from an Indigenous perspective as seen in the pilot studies by Turvey [51] and Fatima [50]. Although objective measures are important for aligning with clinical definitions, it is also difficult to understand prevalence and/or get necessary resourcing to enable marginalised populations if only objective tools are used. There is an urgent need to develop Indigenous specific sleep evaluation tools that will measure sleep in the context of Indigenous people's understanding and interpretation of poor sleep and gather data from community samples given the difficulty in achieving objective measures. We must utilise culturally specific and sensitive approaches to develop and validate tools led by Indigenous Australians.

Finally, Indigenous contribution and participation was difficult to assess. Utilising frameworks such as that recently presented by Huria et al [71] could guide this and raise awareness of the need to include this data in future studies.

Conclusions

Historical and sociocultural factors and subsequent ongoing disadvantage and inequities have contributed to poorer health for Indigenous populations. Subsequently, Indigenous health has been the focus of numerous national partnerships, action plans and government policies across Australia [60].

There are relatively few studies undertaken on the sleep health of Indigenous populations suggesting that their sleep health is not seen as a research priority. Sleep health is a cornerstone of general health and importantly, sleep health represents a marker of health inequity between Indigenous and non-Indigenous people. Identifying, and modifying sleep behaviours might result in some short-term improvements in sleep, but for sustainable change it is necessary to attend to sleep within the broader social determinants of health. It is vital therefore to consider the ongoing effects of colonisation and social determinants of sleep health. Sleep may represent a modifiable target for the improvement of overall health in these populations. Addressing these issues alongside development of programs, informed by, guided by, and led by Indigenous Australians may represent a strategic pathway to improve sleep health of these populations.

We propose that poor sleep health may be a significant and, to date, poorly addressed factor that should be considered within the discourse around inequity in the health of Indigenous populations [37].

6 Recommendations

The following recommendations have been developed by the authors in extensive consultation with Professor Alex Brown and Associate Prof Ching Li Chai-Coetzer.

The Australasian Sleep Association recognises the rights of Indigenous peoples to high quality health care and specifically good sleep health care and increased sleep health awareness. Sleep health has causal and bi-directional relationships with physical and mental health and well-being. To reverse the impact of poor sleep on physical and mental health and well-being of all Indigenous populations we urgently recommend that an overarching strategic framework be developed to improve sleep health involving several key areas:

1. Sleep health care – free of racism

1.1 A fundamental factor in improving sleep health services needs to take into account the systemic racism evident in Australia's health care system. The National Aboriginal and Torres Strait Islander Health Plan 2013–2023 [10] has recognized that racism experienced by Indigenous Australians is evident at an interpersonal, institutional, and systemic level [10]. We recommend therefore establishing sleep health services which are free from racism, and which allow Indigenous Australians access to health services that are effective, high quality, culturally appropriate and affordable.

2. A holistic approach to improving sleep health and culturally appropriate treatment

2.1 A comprehensive approach. An approach that combines public health measures to prevent disease with a broad clinical service to manage established poor sleep health is required to address sleep health issues across three levels of implementation.

a) Primary: Prevention of poor sleep practices including early education.

b) Secondary: Community education and public health messaging. Increasing awareness and upskilling of health professionals in sleep health.

c) Tertiary: Adequate diagnostic and follow up services and availability and equitable access to secondary and tertiary care when required.

2.2 To facilitate a comprehensive approach, integration of sleep health into broader health messages and management is required. Sleep is a modifiable risk factor for poor physical and mental health and as such offers therapeutic pathways to improve well-being. A better approach would be a focus on incorporating sleep health initiatives into primary care with integration into chronic diseases management approaches (e.g. metabolic syndrome, cardiovascular disease, depression). Thus, evaluation for, and management of, sleep health should be better integrated with chronic disease management in primary, allied and specialist health care provision.

2.3 Responses to sleep health problems should maximise access and uptake among Indigenous Australians. Innovative and tailored,

multilayered approaches to sleep health should consider the determinants of health specific to Indigenous Australians. This should include (1) embedding culturally safe sleep health support to ensure access to and provision of comprehensive sleep services to Indigenous infants, children, families, and communities; (2) incorporating preventative measures within the context of Indigenous lived experience and (3) the development, deployment and evaluation of innovative measures and strategies specific to and developed by Indigenous people and communities.

2.4 Access to appropriate healthcare services for prevention, treatment and awareness of sleep health needs to be improved as care and treatment are seriously under-resourced, particularly in many remote communities and regional areas. Integration, co-ordination and planning of sleep health care treatments into existing and future Indigenous health service delivery need to be prioritised.

3. Preventative education and increasing clinical awareness

3.1 Community public health campaigns and health messages should be targeted at the individual, family, community, and societal levels and include education of health professionals and policy makers. The priority would be in training a workforce that includes Indigenous professionals at primary, secondary and tertiary levels of health care to deliver sustainable, effective appropriate and optimal sleep health messages. Although increasing awareness and education does not in itself necessarily lead to behaviour change, it is the imperative first step in understanding the determinants of sleep health.

3.2 Encouraging and supporting Indigenous health professionals to train in sleep medicine. Indigenous health care professionals should receive specialist training in sleep at the primary, secondary, and tertiary levels to increase the availability of expertise within front-line health service contexts.

4. Increased research and evaluation

4.1 Development and Inclusion of Indigenous researchers in evaluation and research.

In order to achieve tailored approaches, and to strengthen reporting of health research involving Indigenous peoples, all future research and investigation should be in collaboration with Indigenous populations and communities. However, Indigenous authorship and/or membership on research teams is not always prioritised. Future studies will be better served to systematically include Indigenous researchers and clinicians, and the reporting of results utilising appropriate frameworks (e.g. Huria et al [71]). Subsequently, research programs and organisations must be assisted in prioritising the study of Indigenous sleep health, led by Indigenous researchers and communities. Whilst what constitutes "collaborative" is likely to be specific to different Indigenous Australian communities, health services and geographic locations, all future research must consider the need for an ongoing commitment and significant consideration of resources availability and sharing.

4.2 Reporting and data management regarding the ongoing state of sleep health must be prioritised, devised, developed, and integrated into the health care networks. Monitoring of the morbidities and co-morbidities of sleep and other chronic diseases prevalence in Indigenous populations will enable quality assurance and ongoing vigilance concerning the contribution of sleep health to overall Indigenous health.

This report increases our understanding of Indigenous sleep health as an important first stage in improving sleep and general health in Indigenous Australians.

Increasing awareness of sleep health and clinical interventions for the prevention and management of common and easily amenable sleep disorders, in Indigenous populations, with Indigenous Australians, for Indigenous Australians.

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Table S1: Results of Quality assessment of the studies included in the review using the risk of bias tool by Hoys et al.

List of Question for Quality assessment (Q1-Q10) (Highest possible score = 10)

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11
Amarasena et al 2015	0	0	1	1	1	0	1	0	0	0	4
Attard et al 2017	0	0	1	1	1	0	1	0	0	0	4
Blunden et al 2010	1	1	1	1	0	0	0	0	0	0	4
Blunden et al 2018	0	0	1	1	1	0	1	0	0	0	4
Cooper et al 2010	0	1	1	1	1	0	1	0	0	0	5
Deacon- Crouch et al 2018	0	0	1	1	1	0	1	0	0	0	4
Deacon- Crouch et al 2019	0	0	0	0	1	0	1	0	0	0	2
Deacon- Crouch et al 2020	0	0	0	0	0	0	1	0	0	0	1
Fatima et al 2020	0	0	1	1	1	0	1	0	0	0	4
Macniven et al 2016	0	0	1	0	0	0	1	0	0	0	2
Priest et al 2020	0	0	0	0	0	0	1	0	0	0	1
Shepherd et al 2017	0	0	1	1	1	0	1	0	0	0	4
Valery et al 2004	0	0	0	0	0	0	1	0	0	0	1
Yiallourou et al 2017	0	0	1	1	0	0	0	0	0	0	2

External validity

1. Was the study's target population a close representation of the national population in relation to relevant variables?
2. Was the sampling frame a true or close representation of the target population?
3. Was some form of random selection used to select the sample OR was a census undertaken?
4. Was the likelihood of nonresponse bias minimal?

Internal validity

5. Were data collected directly from the subjects (as opposed to a proxy)?
6. Was an acceptable case definition used in the study?
7. Was the study instrument that measured the parameter of interest shown to have validity and reliability?
8. Was the same mode of data collection used for all subjects?
9. Was the length of the shortest prevalence period for the parameter of interest appropriate?
10. Were the numerator(s) and denominator(s) for the parameter of interest appropriate?
11. **Summary item on the overall risk of study bias**

Table-S2: Results of the selected questions from the Cultural Identity Interventions Systematic Review Proforma for Indigenous Australian involvement in the research

Author (year)	Q1	Q2	Q3	Q4	Q12	Q16	Q19	Q20
Amarasena et al 2015	Y	Y	Y	Y	Y	Y	Community engagement, protection of privacy, large sample size, geographical and socioeconomic diversity of participants	Parent-reported data
Attard et al 2017	Y	Y	Y	Y	Y	Y	Community engagement, protection of privacy, large sample size, geographical and socioeconomic diversity of participants	Parent-reported data
Blunden et al 2010	Y	N	Y	NC	NC	NC	First study to compare sleep problems in Indigenous children vs Nonindigenous children	Lack of representative sample
Blunden et al 2017	Y	Y	Y	Y	Y	Y	Community engagement, protection of privacy, large sample size, geographical and socioeconomic diversity of participants	Parent-reported data
Cooper et al 2010	Y	N	Y	Y	NC	NC	First study to objectively describe the sleep of indigenous Australian children	Small sample, lack of data on key covariates
Deacon-Crouch et al 2018	Y	Y	Y	Y	Y	Y	Community engagement, protection of privacy, large sample size, geographical and socioeconomic diversity of participants	Parent-reported data
Deacon-Crouch et al 2019	Y	NC	Y	NC	NC	NC	Large sample representative sample	Parent reported data
Deacon-Crouch et al 2020	Y	NC	Y	NC	NC	NC	Large sample representative sample	Self-reported data
Fatima et al 2020	Y	Y	Y	Y	Y	Y	Community engagement, protection of privacy, large sample size, geographical and socioeconomic diversity of participants	Parent-reported data
Macniven et al 2016	Y	NC	Y	NC	NC	NC	Large sample representative sample middle-older age adults	Self-reported data
Priest et al 2020	Y	NC	Y	NC	NC	NC	Large-scale, population representative survey	Self-reported data
Shepherd et al 2017	Y	Y	Y	Y	Y	Y	Community engagement, protection of privacy, large sample size, geographical and socioeconomic diversity of participants	Parent-reported data
Valery et al 2014	Y	NC	Y	Y	NC	NC	Random sample of communities within the Torres Strait region represented approximately 39% of the 0–17-year-old population for the entire Torres Strait Region, very high participation rates	Parent/self-reported data
Yiallourou et al 2020	Y	NC	Y	NC	NC	NC	Objective assessment of sleep health	Convenience sample

Questions from the Cultural Identity Interventions Systematic Review Proforma for Indigenous Australians research
Y=Yes, N=no, NC=Not Clear

1. Ethics approval
2. Aboriginal and/or Torres Strait Islander researchers
3. Aboriginal and/or Torres Strait Islander participants
4. Community involvement with the research: development, design or implementation
12. Was the research reported back to community?
16. Did the interpretation of the results include local Indigenous knowledge?
19. Particular strengths
20. Particular weaknesses

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