SLEEP CHARACTERISTICS AMONG IN-SCHOOL ADOLESCENTS IN SOUTH-WESTERN NIGERIA: PATTERN, DETERMINANTS AND ASSOCIATION WITH CARDIOMETABOLIC RISK FACTORS

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DECLARATION

I, Oluwatosin Eunice Olorunmoteni hereby declare that this PhD Thesis titled '**Sleep Characteristics among In-school Adolescents in South-Western Nigeria: Pattern, Determinants and Association with Cardio-metabolic Risk Factors'** is original and my unaided work. It is being submitted for the degree of Doctor of Philosophy at the University of the Witwatersrand, Johannesburg, South Africa. It has not been submitted in part or in full for any degree or examination to this or any other university.

Oluwatosin E. Olorunmoteni

27th March, 2025

DEDICATION

This work is dedicated to the Almighty God and the flourishing of Sleep Medicine practice in Africa.

PRESENTATIONS ARISING FROM THIS STUDY

1. Brain Function Research Group Day 2022. Oluwatosin Eunice Olorunmoteni**,** F Xavier Gómez-Olivé, Adesegun Fatusi, Karine Scheuermaier Disparities in sleep health among rural and urban-dwelling in-school adolescents in Southwestern Nigeria.
2. 10th Annual Joint Advanced Seminar 4 Conference of the Consortium for Advanced Research and Training held at Makerere University, Kampala, Uganda on 18th August 2023. The oral presentation was titled: Poor Sleep Health and Cardio-metabolic Disease Risk in Urban and Rural Nigerian Adolescents
3. World Sleep Congress 2024 held from 20th to 25th October 2023 at Windsor Convention Centre, Rio de Janeiro, Brazil.

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ABSTRACT

Problematic sleep is a major threat to the well-being of adolescents globally. However, little is known about the sleep health of adolescents in Africa. Thus, this study aimed to map studies on adolescent sleep health in Africa, determine the sleep characteristics of Nigerian adolescents in rural versus urban communities and the association between their sleep health and cardio-metabolic risk factors.

We conducted a scoping review by searching five databases from the inception (beginning) of each database to June 2023 using Joanna Briggs Institute (JBI) methodology. Furthermore, a quantitative, cross-sectional study was conducted among adolescents aged 13-19 in six rural and six urban schools in Osun State, Nigeria. We used structured questionnaires to measure sleep duration and quality, daytime sleepiness, and sleep apnea risk and used actigraphs on a subset. We measured their anthropometry, blood pressure and blood sugar. A continuous cardiometabolic (CMR) score was calculated using z-scores of mean arterial pressure (MAP), body mass index (BMI), waist circumference (WC), and random blood glucose. The data obtained was analysed using Stata 15 and SAS software.

The 31 studies (77% cross-sectional) included in the scoping review were mainly focused on sleep quantity and quality. Inadequate sleep duration during weekdays was common among adolescents, often compensated by longer weekend sleep durations. Additionally, the prevalence of poor sleep quality and sleep disorders, such as insomnia and sleep-disordered breathing, was high across various regions. Younger age was reported as protective of good sleep health, while gender disparities in adolescent sleep health were noted across regions. The use of electronic devices at bedtime was a major risk factor for sleep disturbances among urban-dwelling adolescents while poor sleeping conditions impaired sleep, especially among adolescents in rural communities and for those in lower social class. Among the 900 participants in the quantitative study, (51% rural; 59% female; average age (SD) = 15.1(1.4) years), the adjusted odds of having poor sleep quality

(p = .008) and daytime sleepiness (p = .007) were 2-fold higher among urban compared to rural adolescents. Poorer sleep quality was associated with a higher CMR score (β=0.02), BMI z-score (β=0.04) and WC z-score (β=0.03) (all $p<0.05$). Lower sleep duration was associated with a higher CMR score (β=0.04), BMI z-score (β=0.11), and WC z-score (β=0.07) (all $p<0.05$). Risk of sleep apnea was associated with higher CMR score (β=0.08), MAP z-score (β=0.17) and WC z-score (β=0.14) (all $p<0.05$). Using actigraphy for 170 adolescents, shorter total sleep time and earlier wake times were seen on weekdays than weekends.

In conclusion, adolescents in rural communities had better sleep than their urban counterparts. Urban adolescents have later bedtimes, earlier wake times and shorter time in bed and total sleep time than rural adolescents. Furthermore, poor sleep health was associated with higher CMR. Interventions aiming to improve the sleep characteristics of adolescents are crucial, especially for urban-dwelling adolescents and may be important for preventing cardiometabolic diseases.

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ABBREVIATIONS

ALAN	Artificial light at night
BV	Bedtime variability (BV)
BP	Blood pressure
BMI	Body mass index
CMR	Cardiometabolic risk
CVS	Cardiovascular
CSDH	Commission on Social Determinants of Health
DBP	Diastolic blood pressure
FGD	Focused Group Discussions
HR	Heart rate
HOMA-IR	Homeostatic model of insulin resistance
LMIC	Low and middle-income countries
MAP	Mean arterial pressure
NC	Neck circumference
NCDs	Non-communicable diseases NCDs
NREM	Non-rapid eye movement
NW	Normal weight
OW	Overweight
PA	Physical Activity
PSG	Polysomnography
PSQI	Pittsburgh Sleep Quality Index
RBG	Random blood glucose
REM	Rapid eye movement
SBP	Systolic blood pressure
SC	Sleep chronotype
SD	Sleep duration
SDH	Social determinants of health SDH
SH	Sleep health
SP	Sleep problems

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CHAPTER 1: INTRODUCTION

1.1 Background

Adolescence is a stage of transition from childhood to adulthood characterized by important physical and physiological changes.[1] According to the World Health Organization (WHO), adolescents, aged between 10 and 19 years, have significant health needs.[2] Many adolescents live with morbidities associated with ill health and may develop multi-morbidities if not addressed.[1] The adolescence phase of development is characterized by physical, biological, cognitive and behavioural changes.[3] The behavioural changes include changes in diet, reduction in physical activity and the development of poor sleep hygiene in some adolescents.[4] Consequently, the behavioural changes may be risk factors for worse life expectancy trajectories in adult life.[4] Hence, the WHO rightly asserts that "Investments in adolescent health brings a triple dividend of health benefits'.[2] These benefits can be achieved by promoting healthy behaviour such as healthy sleep habits and detecting health risks or disorders early among adolescents globally.[2] Healthy sleep contributes significantly to the adolescent's physical and mental health and normal development to adulthood.[4]

Poor sleep in adolescents has been linked to adverse physical, psychosocial, and mental health outcomes. These adverse outcomes include poor academic performance as a result of memory and cognitive impairment.[5–7] Sleep deprivation in adolescents has also been linked with increased rates of accidents from drowsy driving, alcohol use, substance abuse, and other risky behaviours.[5,7,8] Furthermore, poor sleep in adolescents is related to mental health problems such as anxiety and depression, though the relationship appears to be bidirectional.[7,9,10] There is a growing body of literature suggesting a link between poor sleep health and the development of NCDs such as hypertension, diabetes, and cancers.[11–14] Therefore, poor sleep is now being recognised as a risk factor for cardiovascular and metabolic diseases.

In Nigeria and other countries in Sub-Saharan Africa, adolescents and young people constitute about one-fourth of the population.[15,16] The adolescent health problems in Nigeria include sexual and reproductive health, violence, and substance abuse among others.[16,17] However, there has been a rapidly increasing burden of new adolescent health problems over the last decade with the emergence of internet addiction, negative effects of electronic media use and sleep disorders.[18,19] Among Nigerian adolescents, night-time awakenings, excessive daytime sleepiness and parasomnias have been reported as common.[20,21] It is therefore important to pay more attention to sleep problems in the Nigerian adolescent population.

In Nigeria, there are widespread disparities between rural and urban populations that can affect adolescent sleep health. There is a larger supply of electricity at night in urban areas than in rural areas with a resultant increase in artificial light at night (ALAN) among urban adolescents.[22,23] It has been shown that exposure to ALAN is associated with delayed bedtimes and shorter sleep duration.[24] Also, there are increasing changes in the lifestyle of urban dwellers resulting in higher physical activity, a higher tendency to consume refined foods with high carbohydrate/high-fat content and a higher tendency to sedentary lifestyles than in rural areas.[25] Hence, urban adolescents may have a higher likelihood of cardiometabolic risk (CMR) than rural adolescents. Therefore, there is a need to compare sleep health, its determinants and the consequences of poor sleep between in-school urban-based and rural-based adolescents.

Various methods have been employed to characterize the sleep pattern across the age groups which revealed an age-related decline in sleep need from childhood through adolescence to adulthood.[10-13,26] These studies utilized objective measures such as polysomnography and actigraphy which are not readily available in many low and middle-income countries. The few published studies done in Nigeria were questionnaire-based.[9, 22-25] Actigraphy can be used in the school, home, and hospital settings together with a sleep diary as a reliable method of assessing sleep patterns in low resource settings.[27, 28] Both subjective (questionnaire-based) and objective measurements such as actigraphy bring complementary information on different dimensions of sleep health and thus using both may be of use in better describing the sleep health of Nigerian adolescents. However, at the beginning of this study, and to the knowledge of the researchers, no study had been done to investigate the different dimensions of adolescent sleep health (subjectively and objectively measured) in Nigeria.

To address the above research gaps, a study of the sleep characteristics among Nigerian adolescents in rural and urban communities is necessary. Further exploration of the contributory factors to their sleep and the association with physical well-being is timely and relevant. Therefore, this study aims to determine the sleep health of adolescents living in urban and rural communities, the factors associated with their sleep characteristics and the association of the sleep health variables with cardio-metabolic risk (CMR) factors among Nigerian in-school adolescents. Thus, the research hypotheses include: i. In-school adolescents living in rural communities have better sleep health than the urban in-school adolescents in Nigeria and ii. there is an association between poor sleep health and the presence of CMR factors in adolescents.

1.2.2 Statement of the Purpose of the Literature Review.

This literature review summarises what is known about adolescent sleep, the physiology of adolescent sleep regulation, the determinants of adolescents' sleep health, and the relationship of their sleep with CMR factors. It also presents the research gaps to be filled through a critical appraisal of the literature such as the disparity in sleep patterns and problems between adolescents living in rural communities versus urban-dwelling adolescents. This literature review discusses adolescent sleep health, its determinants, and its association with cardiometabolic risk factors. It also introduces the need for a scoping review of studies on adolescent sleep health on the African continent.

1.3. 1. Definition of adolescence

Adolescence is a stage of transition from childhood to adulthood. It involves a movement toward physical and psychological maturity with associated physiologic changes.[26] Several efforts have been made to define the exact age group referred to as 'adolescents' but it can be difficult to define as there are diverse indicators.[27,3,28] Adolescence is generally considered to be the period between the onset of puberty and the achievement of social independence.[27] However, according to WHO adolescents are regarded as people aged from 10 to 19 years.[29] Furthermore, adolescence can be divided into stages based on the developmental changes being experienced as early adolescence (10-13 years), middle adolescence (14-17) and late adolescence (18-19 years).[28] Overall, adolescence and its associated changes can be explained by puberty and other cultural, socialization processes, emotional and biological factors.[3]

1.3.2. Sleep and Adolescence

Sleep is an important physiological change that characterizes adolescence. The beginning of adolescence is heralded by prominent developmental changes in the sleep-wake cycle, as reflected in the sleep patterns and architecture of adolescents.[30] These sleep changes have been suggested to reflect the maturation of the sleep regulatory mechanisms during adolescence.[31] The changes in the adolescent sleep-wake schedule are often associated with changing socio-environmental requirements that affect the physical, mental, and emotional development of adolescents.[32] Consequently, poor sleep can have multiple effects on adolescent health which include excessive daytime sleepiness, poor academic performance[33] and cardio-metabolic dysfunctions.[34] The sleep changes during adolescence, therefore, have implications for their biological, psychological, and social well-being.[35]

1.3.3 Sleep Health

The sleep health concept describes the characteristics of sleep as a component of overall health and wellbeing. In 2014, Buysse[36] defined sleep health as "a multidimensional pattern of sleep-wakefulness, adapted to individual, social, and environmental demands, that promotes physical and mental well-being. Good sleep health is characterized by subjective satisfaction, appropriate timing, adequate duration, high efficiency, and sustained alertness during waking hours."[36] Sleep health (SH) helps to understand the role of sleep as a "cause or determinant of adverse health outcomes and morbidity rather than just a consequence or symptom of ill health".[37–39] Sleep health also presents poor sleep as a predictor of overall ill-health rather than only a cause of sleep disorders.[36,40] Thus, sleep health encompasses the various sleep characteristics which include its duration, quality, alertness, timing, regularity, and efficiency.[36,37] Though the concept of sleep health has been more studied in adults, it is worth exploring it in children and adolescents.[37,40]

1.4.1. Physiology of human sleep

Sleep is "a reversible behavioural state of perceptual disengagement from and unresponsiveness to the environment."[4] It comprises physiologic and behavioural processes and can be described based on its pattern or architecture. Sleep pattern refers to sleep duration (total sleep time in twenty-four hours) and sleep cycle (sleep-wake cycle). Sleep architecture, on the other hand, comprises the two physiological stages of sleep: rapid eye movement (REM) and non–REM (NREM) cyclical sleep that alternate during an episode of sleep. The sleep-wake cycle is a cycle that revolves from wakefulness to rounds of NREM sleep phase and REM sleep phase, then wakefulness again as controlled by nuclei in the brainstem, hypothalamus and the forebrain.[41]

1.4.2. The Two-process model of regulating human sleep and wakefulness

The "Two-process model" was first described by Borbely in 1982 as the physiologic process that regulates sleep and wakefulness by a homeostatic system that promotes sleep and a circadian system that promotes wakefulness.[42] The two processes are Process S and Process C.[42] In regulating the sleep-wake cycle, the circadian system acts as a wake-promoting system while the homeostatic sleep system reflects sleep need or sleep debt and provides a drive for sleep.[42,43]

1.4.2.1. Process S: Mechanisms that determine the relative level of sleepiness or alertness over 24 hours

The Process S is the homeostatic sleep drive that regulates the relative level of sleepiness or alertness.[42] It refers to the gradual build-up of sleep pressure during wakefulness such that the need to sleep is increased progressively by the homeostatic drive as shown in Figure 1.1.[44] This drive is influenced by factors such as the time awake since the last sleep period, the duration of previous sleep and the quality of previous sleep.[45] Process S also regulates the depth and duration of sleep and the sleep pressure decreases during slow-wave sleep.[45] During wakefulness, there is a gradual build-up of the production of adenosine, a product of adenosine triphosphate which enhances sleep drive when bound to its receptors. Therefore, the markers of the activities of the homeostatic sleep drive are slow wave sleep, sleep latency (time taken to fall asleep), and the brain adenosine levels.[43,45]

1.4.2.2. Process C: Mechanisms that determine the relative level of sleepiness or alertness over 24 hours

The circadian pacemaker serves as the intrinsic biological clock that regulates normal physiologic functions in the body, including sleep.[44] It is a nearly 24-hour clock that defines the daily rhythms in physiological functions and behaviour.[46] It is characterised by a circadian pacemaker trough which gives the timing of maximum sleepiness and the circadian-dependent peak (also called ‘wake maintenance zone’) which gives the period of maximal alertness.[46] These rhythms also regulate physical activity, nutritional intake and other bodily functions such as temperature, heart rate or hormone secretion.[44]

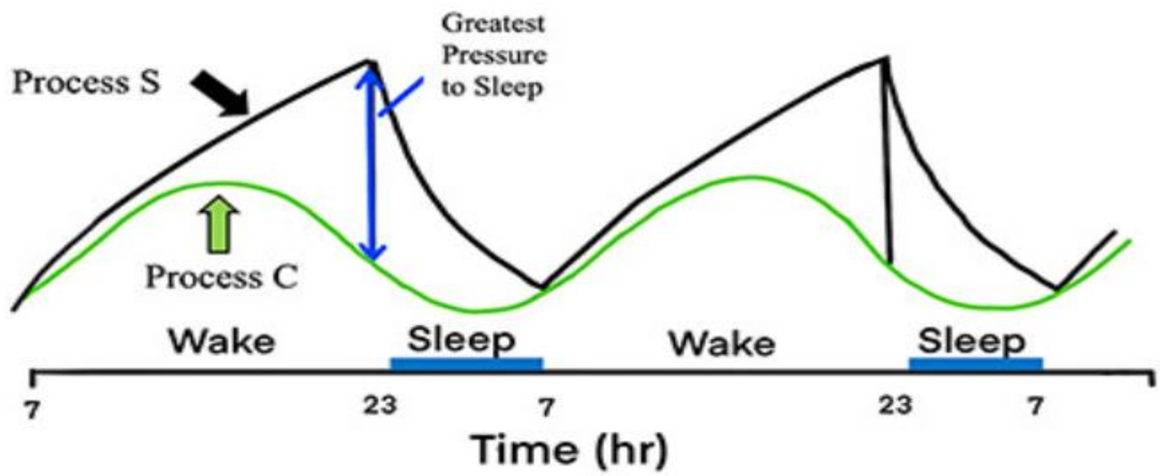

Figure 1.1. The two-process model of sleep regulation as adapted from Overton *et al*[44]

The timing of sleep and wakefulness as controlled by the circadian pacemaker can be influenced by intrinsic and extrinsic factors. The intrinsic circadian rhythm is affected to an extent by external time cues also known as "zeitgebers" such as timing of meals, physical activity, and the exposure to the light-dark cycle which is regarded as the strongest of these zeitgebers.[43,47] The light signal acts through the photopigment melanopsin to stimulate the suprachiasmatic nucleus (SCN) from the intrinsically photosensitive retinal ganglion cells (ipRGCs), which transmit their signal through the retinohypothalamic tract.[47] From the SCN, several neurological and hormonal outputs drive circadian rhythmicity throughout the body. A particular well-described hormonal output of the SCN is melatonin secretion by the pineal gland.[48] Through the production of melatonin, the pineal gland communicates the time of the day to the body such that melatonin levels are low during the day and high at night.[47] Melatonin receptors are found ubiquitously, from specific regions in the central nervous system to the kidneys, heart, and immune cells amongst others.[48,49] The circadian system also regulates the production of cortisol such that the production of cortisol peaks during wakefulness.[46] Therefore, the biological night is characterized by high melatonin levels and the occurrence of sleep while a reduction in melatonin secretion occurs during the biological day/ wake, regardless of light cues (Figure 1.2).

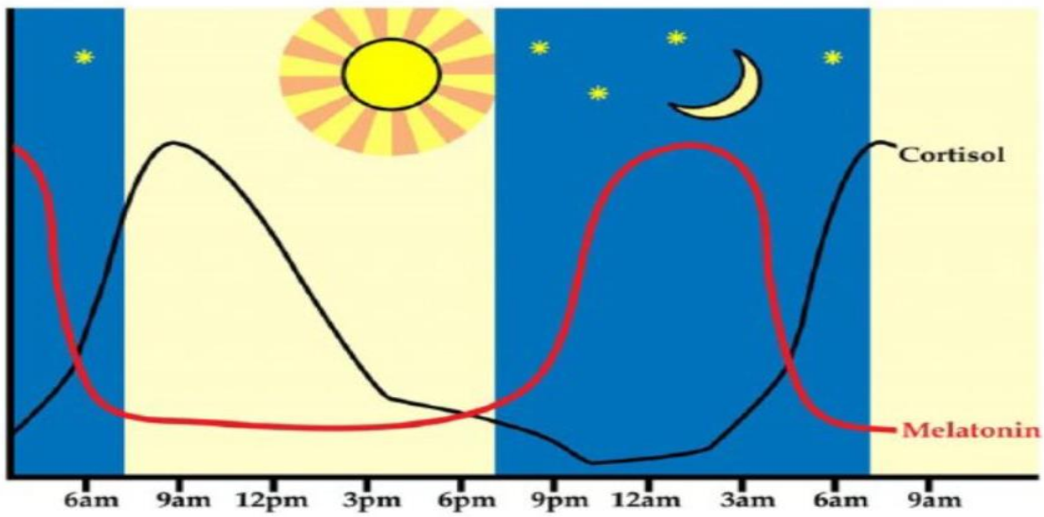

Figure 1.2 The circadian-driven production of cortisol and melatonin as shown in the image adapted from Manganaro *et al*.[50]

Therefore, the two systems interact continuously but act in opposition to each other. The dual processes regulate the sleep-wake cycle with Process S acting as the sleep homeostat while Process C act as the circadian oscillator that determines the timing of the sleep-wake cycle (Figure 1.1.).[44] The circadian system influences functioning capabilities, alertness or fatigue levels, sleep/wake timing, and sleep structure (REM sleep) while the homeostatic system influences sleep duration and the need for sleep.

The timing of the circadian pacemaker is exquisitely sensitive to light. Phase response curves have described the effect of light according to its timing within the 24-hour day. In humans, light exposure in the late biological night/early biological day (i.e. *just after* core body temperature trough) is associated with phase advances (earlier timing) of the circadian pacemaker's activity. Light exposure in the late biological day/early biological night (i.e. *before* core body temperature trough) leads to phase delays (later timing of the circadian pacemaker's activity) and thus of its outputs such as the sleep-wake cycle.[51,52] In addition, melanopsin in the ipRGCs has been shown to have a peak sensitivity to light of the blue spectrum (460 nm).[52] Blue-enriched lights used for electronic devices' screens have thus been involved in delaying circadian timing when used in the evening.[53]

1.4.2. The neuronal control of sleep

The regulation of sleep is under the control of diverse sleep-promoting and wake-promoting brain areas. The first brain area identified to control wakefulness when stimulated is located between the pons and the midbrain.[41] It was first described as the "reticular activating system" by Moruzzi and Magoun in the 1940s.[41] Thereafter, other areas of the brain were discovered to control wakefulness and sleep as research continued to advance. These brain areas work through the production of wake-promoting neurotransmitters and sleep-promoting neurotransmitters. The wake-promoting areas include monoaminergic and cholinergic nuclei.[41] The monoaminergic nuclei include the tuberomammillary nucleus which contains histaminergic neurotransmitters, the locus coeruleus which contains neurons releasing noradrenaline, and the dorsal raphe which releases serotonin.[41] Monoaminergic activity is enhanced by the orexinergic lateral hypothalamus which releases orexin/ hypocretin.[41] Monoaminergic nuclei are most active during wake, decrease their firing during NREM sleep and have their lowest firing during REM.[54] The laterodorsal and pedunculopontine tegmental nuclei are cholinergic nuclei involved in REM sleep.[41] Their activity is maximal during REM sleep, lower during wake and at its lowest during NREM sleep.[41]

Sleep promotion occurs through a network of neurotransmitters too. These include inhibitory GABAergic and galaninergic neurotransmitters produced by a cluster of neurons found in the ventrolateral preoptic area (VLPO) in the anterior hypothalamus.[41,55] Adenosine is another NREM sleep-promoting neurotransmitter which acts by inhibiting wake-active neurons and activating the sleep-promoting neurons in the VLPO.[56] VLPO activity is at its maximum during NREM, decreases during REM (while a zone referred to as the extended VLPO has its highest firing during REM) and is at its lowest during wake (Table1.1).[55] On the other hand, REM sleep is controlled by neurons located in the brainstem such as the glutaminergic-producing neurons of the sub-laterodorsal nucleus which induces REM sleep onset ("REM-on") as well as acetylcholine, noradrenaline and serotonin-producing areas inhibit the REM-on neurons to end REM sleep.[57] Therefore, sleep and wake alternate following a 'flip-flop' switch whereby activation of the monoaminergic wake pathways inhibits the VLPO. Conversely, once the VLPO is active, it inhibits monoaminergic nuclei, thus enabling continuous bouts of wake and continuous bouts of sleep.

Some substances interfere with sleep-wake regulation by enhancing or blocking the effects of the neurotransmitters involved. For example, non-selective anti-histaminic drugs induce drowsiness during wake as they block the TMN-histamine wake pathway.[58] Caffeine is an adenosine antagonist which prevents the binding of adenosine to its receptor, thus limiting the sleep drive and helping with wakefulness.[59] Similarly, there are effects on sleep, in particular REM sleep, of selective serotonin reuptake inhibitors prescribed in depression.[60] Thus sleep-wake may be affected by medication and substances, which are thus usually reported in sleep studies.

1.5. Determinants of adolescent sleep health

1.5.1. Biological factors

Sleep regulation in adolescents results from both biological and psychosocial processes.[61,62]

The biological process is the reason for the delayed sleep phase observed in adolescents.[63] A sleep phase delay (preference for later bedtimes and wake times) is a common observation in adolescents all over the world.[63] As discussed previously, the biological processes involved in sleep regulation comprise the circadian system and the homeostatic system.[42] Laboratory studies Jennihave mainly focused on explaining the delay in preferred bedtimes and wake times in adolescence through a delay in the timing of circadian rhythms.[64,65,66] It has also been hypothesized that there might be modifications in the homeostat, however evidence for this is still scant.[67,66,68]

The circadian phase delay in adolescents has been explained by two hypotheses.[63] The first hypothesis suggests that the biological clock is slowed down during puberty such that adolescents experience their 'biological night' later than usual.[5] The second hypothesis suggests that the sensitivity of the circadian system (ie from the retina to the suprachiasmatic nucleus of the hypothalamus) to light is modified during adolescence.[5] Consequently, melatonin production is delayed.[5] Thus there is evidence of a biological process explaining the sleep phase delay in adolescents.

Thus biologically, adolescents experience a phase delay in their sleep-wake cycle with a preference for later bedtimes and wake times. However, as much as delayed bedtimes are not constrained, societal pressures have been shown to prevent the preference towards a later wake time as school start times remain fixed across childhood and adolescence. The result of delayed bedtimes and fixed-time wake times have now been largely shown to result in a decreased sleep opportunity and thus insufficient sleep duration. Other determinants have been shown to interfere with optimal sleep health, which we will examine in the following section.

1.5.2. The social determinants of adolescent sleep health

"Social determinants of sleep health" are an emerging concept of how multiple levels of social factors influence sleep across age groups, including adolescents. It suggests that the SDH framework helps to identify social factors at the individual, family, community, and national levels that contribute to adolescent sleep health (Figure 1.3).[37,69] There is a growing body of evidence suggesting that sleep health is socially patterned.[37] According to Hale et al, the sleep problems of individuals are better understood and addressed when the social factors at the source of the problems are considered rather than focusing on the individual symptoms.[37,70] In a review also by Hale et al, key social determinants of sleep health across the different levels include individual media use, family factors, and neighbourhood factors.[39] The socio-ecological framework has been used in evaluating these determinants of sleep health.[37]

The sleep health of adolescents is determined by diverse societal factors. In adolescents, the family factors that can influence sleep health include family cohesion and parent-adolescent relationships among others. Furthermore, school-related factors such as school start times, workload and homework burden affect adolescent sleep health.[39,70] Neighbourhood factors such as peer influences, noise exposure, crime rates, accommodation type and access to physical activity are also important.[39,71,72] Other community-related factors contributing to sleep health include social discrimination and food insecurity.[73] Therefore, the social disadvantages that determine sleep health should be understood and addressed to improve adolescent sleep health. However, these determinants have not been well explored among Nigerian adolescents.

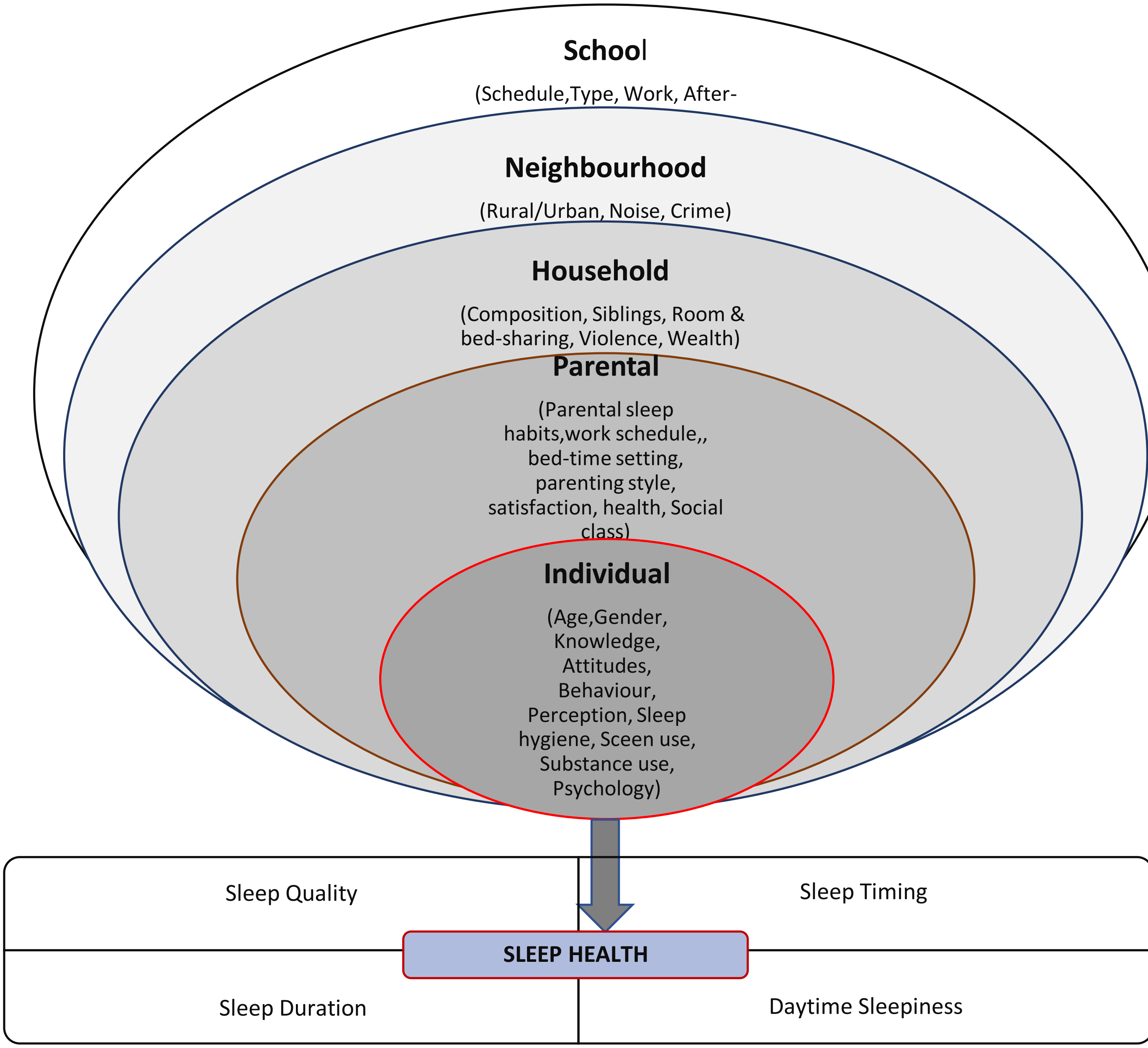

Figure 1.3. Socio-ecological model of sleep and health showing the multidimensions of sleep health, adapted from Grandner 2010 & Grandner 2014.[74]

1.5.3. Rural-urban disparities in adolescent sleep health

The sleep gap caused by various socially-determined disadvantages can be appreciated when sleep health is compared between rural and urban communities. There is no doubt that sleep problems exist among adolescents residing in both rural and urban communities.[75,76] In urban populations, the 24-hour lifestyle associated with urbanization, increased sedentary living behaviour and high exposure to screen use and artificial light at night may predispose adolescents to sleep problems.[75,77,78] Conversely, rural-dwelling adolescents may seem protected from the lifestyle-related risk factors of poor sleep from urban areas, but they may also have different sleep problems[79–81] such as residing in socially disadvantaged neighbourhoods with poor housing conditions that may be associated with sleep disruptions.[79,81,82] Hence, there is a need for more research on the differences in sleep characteristics between adolescents living in rural and urban communities and their different risk and protective factors of sleep health. In Nigeria, further studies are needed to explore these disparities since previous studies in the country were only done in urban communities.

1.5.4. Sleep health and light exposure

The introduction of artificial light changed human lifestyle, including sleep habits. Historical findings suggest that humans slept earlier and probably longer before the introduction of artificial light.[83,84] Exposure to natural light is important to maintain entrainment of human circadian rhythms to the Earth's light dark cycle .[85].[77] However, with the introduction of artificial light, the timing of melatonin production and the biological clock seemed to have been delayed.[77] Recent studies have suggested that artificial light at night (ALAN) is the major factor responsible for alteration in sleep patterns and possibly chronotype.[24,86–88] However, in sub-Saharan Africa, there is poor access to electricity, especially in rural populations.[22,89,90,91,92] In Nigeria, the World Bank report stated that 55.4 % of the population had access to electricity with 83.9% of these being in urban communities.[23] Consequently, ALAN may be responsible for the differences in sleep health between rural and urban populations[93] Thus, further studies are needed to explore these possibilities, especially in low and middle-income countries (LMIC) where electricity is lacking in many rural communities.

1.5.5. Sleep health and screen time

Screen use is a major contributor to the sleep difficulties experienced in urban populations. It is particularly important in adolescents where screen use has increased significantly over the years.[19,76] Thus, electronic devices such as smartphones, television, video games, etc have become part of the lives of young people. Problematic screen use is often measured by the number of hours spent on the screen in the last hour before bedtime.[94,95] Cabré-Riera *et al* used the Mobile Phone Problematic Use Scale to assess the dependency of adolescents on mobile phone use.[96] The number of hours spent on the screen in the last hour before bedtime has been associated with short sleep duration and poor sleep quality.[94,95] The mechanisms postulated as responsible for the effects of screen use include the disruption of circadian rhythms by ALAN due to the short-wavelength, blue-enriched light common on LED screens, the direct effect of bright light on alertness, and the effect of the content of whatever activity the screen is being used for on alertness.[76] While adolescents tend to enjoy screen use because of the great opportunities it provides for socialisation, they are often influenced by parents and their peers who also tend to have high screen time at night, when there are known phase delay effects.[53,76,97] Thus, night-time screen use is an important contributor to adverse sleep outcomes that can be targeted by interventions to improve adolescent sleep health.[98]

In summary, it has been shown that during adolescence, sleep is curtailed by the combination of biological phase delays in circadian timing and thus timing of the sleep-wake cycle and societal pressures. In addition, the widespread use of smartphones/ tablets may further worsen this sleep deficiency found in adolescents. There is wide evidence of this in high-income countries. However, it is not clear whether similar findings may be found in low and middle-income countries which may have less access to electricity, in particular in rural Nigeria.

Insufficient/ poor quality sleep in adults and adolescents has, in turn, been associated with poor health outcomes, which we will examine in the next section.

1.6. Adolescent sleep health and cardiometabolic risk

1.6.1. Cardiometabolic risk

Cardiometabolic risk refers to an increased tendency to develop "cardiovascular disease (CVD), diabetes, and metabolic syndrome".[99] The markers of CMR include CVS risk factors such as body mass index (BMI), blood pressure (BP), heart rate (HR), and measures of adiposity such as waist circumference, waist-hip ratio, body fat percentage, and superficial fat thickness".[100,101] In addition, metabolic measures such as fasting blood sugar, the homeostatic model of insulin resistance (HOMA-IR), Matsuda index, lipid profile, and inflammatory markers are also indicative of CMR.[100,101,102] Studies have shown that there may be a link between some of these CVS or metabolic health indicators and various sleep characteristics but we still need to fully understand their extent and mechanisms.[103,104]

1.6.2. Sleep health and cardio-metabolic risk factors

Emerging evidence has suggested associations between CMR and sleep disorders.[105,106] The investigation of the relationship between sleep health and CMR is an important research need. The existing studies have suggested possible associations but lack consensus on the mechanisms involved.[106,107] While many research findings have linked short sleep duration to adverse CMR, emerging evidence suggests that sleep chronotype or bedtime variability may also be an important link between sleep and CMR.[12,108] The most common indicators of CMR studied concerning sleep in adolescents include physical activity, adiposity, body mass index, and blood sugar, though, most of these studies focused on one or two sleep health variables.[102,105,109] Further studies are needed to understand the association between the multiple dimensions of sleep health in adolescents and CMR as well as the mechanisms involved.

The relationship between sleep health, social determinants of health (SDH) and CMR. The SDH, described as the 'cause of causes,' influences adolescent sleep health at various levels.[110,111] The levels at which these factors can occur include the individual, family or parental, household, school, community, and societal levels.[69] At the same time, the SDH are linked to CMR either by increasing the likelihood of the CMR factors directly or by altering sleep health and resulting in sleep problems which can, in turn, increase or worsen CMR.[103,37] Furthermore, the relationship between CMR and adolescent sleep problems is bi-directional.[112] While poor sleep can lead to the development of CMR especially in the long-term, the presence of sleep disorders such as sleep apnoea and circadian rhythm disorders has been found to increase CMR.[106,7]

Thus insufficient/poor sleep quality has been associated with higher cardiometabolic risk. Documenting sleep health in adolescents is thus important to better tailor interventions which may improve adolescent sleep. In the next section, we will examine the different instruments which are available to describe sleep health in adolescents.

1.7 Measurement of adolescent sleep health

The measurement of adolescent sleep health involves both subjective and objective measures. Sleep questionnaires are the most widely used method of measuring sleep. The questionnaires are often used in large population studies for screening and evaluating sleep intervention programmes.[113] They are largely validated with clear psychometric properties and some have adapted forms for specific conditions.[114,115,116] They are, however, subjective due to a high rate of recall bias.[117,116] To overcome this limitation, sleep diaries were introduced as a simple and cost-effective alternative that provides a day-by-day recording of sleep. However, such diaries may also be incomplete and inaccurate.[118] Therefore, objective measures are advocated for the diagnosis of sleep problems in both clinical and research settings.

The gold standard objective sleep measurement tool is Polysomnography (PSG).[118] Nevertheless, the use of PSG is expensive due to the required skilled manpower and equipment cost.[118] Another objective sleep measuring tool is the wrist actigraphy, which was introduced about 35 years ago and has gained popularity among researchers due to its ease of application, especially in the home setting.[118] Validation studies have proven the actigraphy to have good sensitivity and accuracy when compared to PSG but with low specificity.[117,119] Its effectiveness can be improved if combined with sleep diaries, which increases the specificity, making it useful for large population studies.[120,121] It is equally useful across various populations such as children with neurodevelopmental disorders like autistic spectrum disorders.[122] About 10 years ago, wearable sleep monitors (Fitbits) were introduced and attained widespread use among consumers but their use in research is yet to be fully ascertained.[118]

1.8 Study justification and research gap

Sleep problems in adolescents have been declared a public health issue[112] However, there is a dearth of studies on its prevalence and contributory factors in many African countries where four out of five of the world's 1.2 billion adolescents reside.[21] Though the huge burden of insufficient sleep has been reported from studies done in developed countries since the early 1980s,[8-10,16] the extent of studies on adolescent sleep on the African continent has not been explored. In Nigeria, the few available studies were all conducted in the last decade.[9,22-25] These studies showed the prevalence of sleep insufficiency and problems in Nigerian adolescents to be between 16.4 to 60.8%.[9,22-25] The wide range of the prevalence may be due to the use of different sleep instruments.

In Nigeria, there is less access to electricity in rural areas. In comparison, the urban areas have better access to electricity and an increased likelihood of artificial light at night (ALAN) exposure. Furthermore, there are differences in lifestyles and school schedules between the rural and urban adolescents which may contribute to differences in their sleep health. The available Nigerian studies on adolescent sleep were conducted in urban communities, utilized sleep questionnaires, and focused mainly on sleep duration and sleep quality as sleep health variables. Furthermore, the studies did not employ objective sleep measures nor studied multiple levels of factors associated with adolescents' sleep health (individual, family, societal and school). Also, the changing lifestyles, increased consumption of refined food, reduced physical activity and the increase in sedentary lifestyle, especially in urban adolescents make them more predisposed to cardiometabolic risk.[25] Research from high-income countries has shown an association between sleep quality and cardiometabolic risk in adolescents.[12,34] The rural versus urban difference in this association between sleep health and cardiometabolic risk needs to be further studied. Hence, the studies in this thesis will be addressing the highlighted research gaps.

1.9. Contribution to knowledge

This study provides a detailed description of the sleep characteristics among Nigerian adolescents and the similarities as well as the disparities in the sleep characteristics between rural and urban-dwelling adolescents. It also describes the risk and protective factors associated with the adolescent's sleep characteristics. Furthermore, the study describes the association between adolescent's sleep characteristics and cardio-metabolic risk factors among Nigerian in-school adolescents.

1.10. Research Questions

The overarching question is: What are the determinants of sleep health among rural and urban-dwelling in-school adolescents in southwestern Nigeria and the association of their sleep characteristics with CMR factors?

The following are the specific research questions aiming to bridge the existing research gap on the sleep health of Nigerian adolescents:

1. What are the differences in the sleep characteristics of Nigerian In-school adolescents in rural versus urban communities?

2. What is the association between sleep health and CMR factors such as body mass index, abdominal adiposity, blood sugar and blood pressure, in Nigeria among rural versus urban adolescents?

3. Do the sleep patterns reported by the adolescents using questionnaires match those obtained using actigraphy, an objective measurement of sleep?

1.11. Aims and objectives

1.11.1. Aim of the study

To determine the differences in the sleep characteristics among rural versus urban adolescents, the determinants of their sleep health, and the association between their sleep health and CMR factors among In-school adolescents in southwestern Nigeria.

1.11.2 Specific objectives

1. Objective 1: To map out the studies on adolescent sleep health in Africa using a scoping review methodology.
2. Objective 2: To determine the differences, if any, in the sleep characteristics of in-school adolescents in rural versus urban areas in Nigeria.
3. Objective 3: To determine the association between the sleep health of adolescents and CMR factors in adolescents.

4. Objective 4: To describe the sleep characteristics obtained with a sleep diary and actigraphy using a subset of the adolescents and the factors associated with their sleep characteristics.

1.12 Structure of the Doctoral thesis

To address the above research gaps, this study of the sleep characteristics among Nigerian adolescents in rural and urban communities will be presented in the following order. The next chapter (Chapter 2) presents the protocol of the scoping review on adolescent sleep health in Africa (published paper).[123] Thereafter, the findings of the scoping review are presented in Chapter 3. The chapter gives a detailed review of existing literature on the pattern of adolescent sleep health in Africa, the determinants and the association between adolescents' sleep and health outcomes (mental health and cardiometabolic risk). Chapter 4 presents a published paper on the multidimensions of sleep health among 900 Nigerian in-school adolescents, comparing the sleep characteristics between rural and urban-dwelling adolescents.[124] The next chapter (Chapter 5) focuses on the relationship between adolescents' sleep health variables and cardio-metabolic risk (CMR) factors in the same sample of 900 Nigerian in-school adolescents. Chapter 6 uses a subset of 170 of the 900 Nigerian adolescents in rural and urban schools to describe sleep health using an objective measurement (actigraphy) together with sleep diary. The thesis ends with an integrative discussion (Chapter 7) of the findings, the implication of its conclusions, the strengths and limitations of the study, and the recommendations for future studies and policy generation.

1.13 Study site and population

The initial scoping review (Chapters 2 and 3) involved publications on adolescents residing in any of the 54 countries in the African continent. The subsequent studies (Chapters 4-6) were conducted among 900 adolescents in six rural and six urban schools in the Osun East Senatorial District of Osun State, Nigeria (Figures 1.4 and 1.5). It involved the use of the quantitative study design to achieve the objectives. These adolescents were visited at their school to collect data for the various components of the study using questionnaires. In addition, at the time of enrolment into the study, a subset of the initial participants who filled out the questionnaires were invited to wear an actigraphy device for one week and fill out the sleep diary during the same period (Chapter 6). The participant characteristics for each study are presented in the respective chapters.

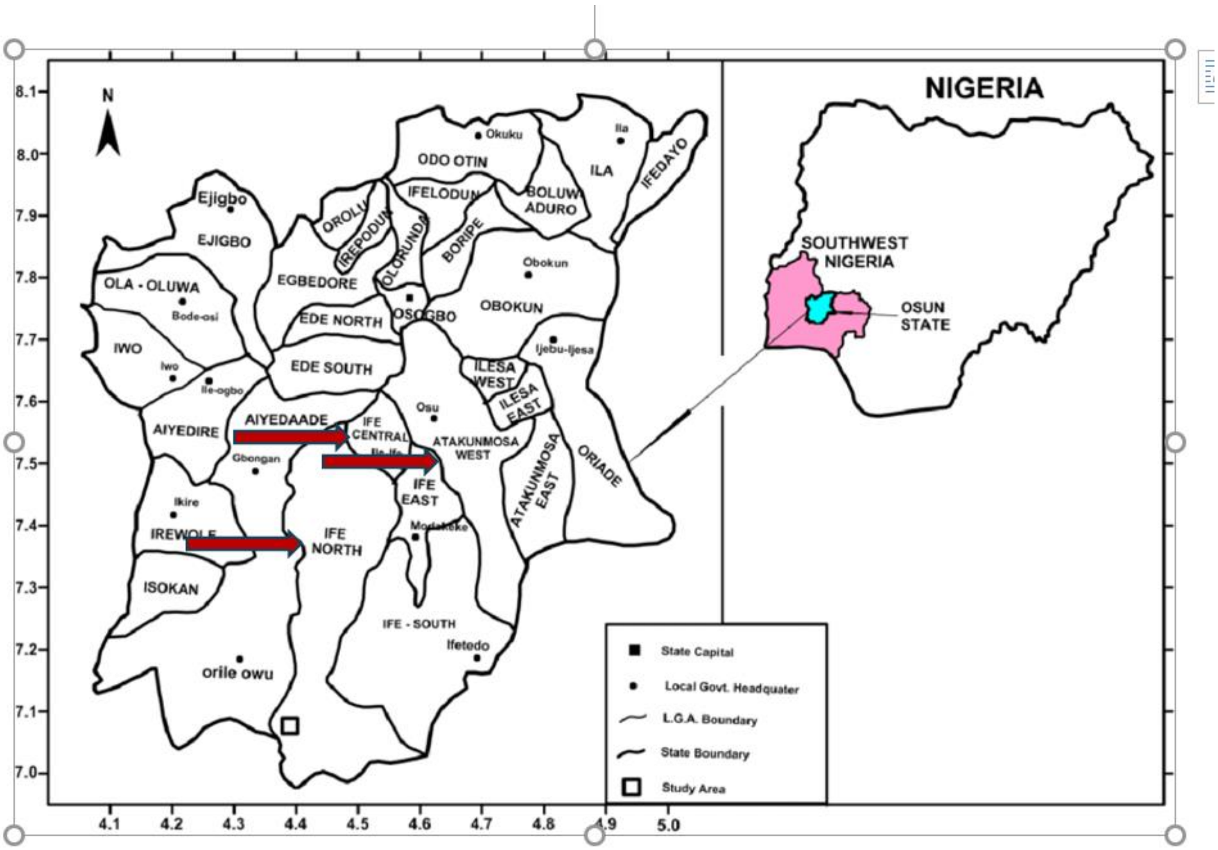

Figure 1.4: Map of Nigeria showing the Southwest geopolitical zone (pink), Osun State (Blue) and the three local governments where the study was conducted indicated by the red arrows on the enlarged Osun state map.

Figure 1.5: Map of Osun State showing the Osun East Senatorial District (Blue) and the three local governments where the study was conducted indicated by the red arrows

1.14 References

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The next chapter presents the protocol of a scoping review on adolescent sleep health in Africa conducted as a part of this thesis.

CHAPTER 2

ADOLESCENT SLEEP HEALTH IN AFRICA: SCOPING REVIEW PROTOCOL

2.1 Publication details

This chapter is presented as a publication of the scoping review protocol. This protocol was published with the British Medical Journal (BMJ) Open. The journal is open-access and the manuscript is presented as in the published form without amendments. The information about the journal where the work was published is presented on Table 2.1

Table 2.1 Journal Information where the Protocol was published

Title of publication	Adolescent Sleep Health in Africa: a Scoping Review Protocol
Authors	Oluwatosin Eunice Olorunmoteni,[1,2] F Xavier Gómez-Olivé,[3,4] Biliamin O. Popoola,[5] Adesegun O. Fatusi,[6,7] Karine Scheuermaier.
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2.2 Author Contributions

Table 2.2 shows the contributions to the publication made by each author

Table 2.2: Author Contributions to the paper titled Adolescent Sleep Health in Africa: a Scoping Review Protocol

	Olorunmoteni	Gómez-Olivé	Popoola	Fatusi	Scheuermaier
Conceptualisation	√	√	√	√	√
Project administration	√		√		√
Methodology	√	√	√	√	√
Initial data analysis	√		√		
Writing – original draft	√		√		
Writing – reviewing and editing	√	√	√	√	√
Visualization	√	√	√	√	√
Supervision		√		√	√

2.3 Associated Documentation:

The documentation associated with this publication are included as appendices and are labelled:

- Appendix 2: Published article

2.4 Published Article: Adolescent Sleep Health in Africa: a Scoping Review Protocol

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Abstract

Introduction: Problematic sleep is a major threat to health and quality of life among adolescents. Hence, to provide directions for research and interventions, there is a need to examine the literature on adolescent sleep health in Africa. However, studies on adolescent sleep health in Africa have not been properly mapped. Thus, this scoping review aims to investigate the extent and type of available evidence concerning sleep health am/ong adolescents in Africa and to highlight the relationship of adolescent sleep health with adverse mental health outcomes and cardio-metabolic risk (CMR) factors. The review will further highlight areas of agreement and controversies on adolescent sleep health, and identify evidence gaps that require research attention across the continent.

Methods and analysis: This scoping review will be conducted using Arksey and O'Malley's six-step procedure. Thus, we have prepared this protocol according to the framework for scoping reviews developed by the Joanna Briggs Institute. To identify eligible studies, we will search MEDLINE, Scopus, PsychINFO, AJOL, JSTOR, HINARI and Google Scholar. The review will include all published articles in English, French, Spanish, Portuguese and Italian languages on adolescent sleep health in Africa from the inception of the databases, while relevant information will be extracted from included studies using an adapted data extraction tool. The results will be presented using tables and charts as appropriate.

Ethics and dissemination The scoping review does not require ethical approval because the publications to be used for the review are publicly available and the study does not involve contact with humans or other animals as research participants. Furthermore, clinical records will not be used for the study. Upon completion, findings from the study will be disseminated through presentations at scientific meetings and publication in a relevant peer-reviewed journal.

Registration: Scoping Review Registration: Open Science Framework (https://osf.io/5sjwq/)

Keywords

Adolescent sleep quality; Sleep duration; Sleep chronotypes; Teenage sleep deprivation; mental health; cardiovascular risk factors.

Strengths and limitations of this study:

- By interrogating the association of adolescent sleep health with mental health and CMR in the wide cultural and geographical context of Africa, the review will provide the needed evidence to elicit action for improved adolescent health in Africa.
- The scoping review will capture studies published in the major languages spoken on the African continent to ensure inclusivity.
- As a limitation, the review will not analyse the size of the effects of the relationship between adolescent sleep health, mental health and CMR factors.

2.4 INTRODUCTION

Sleep health is an important component of overall health. It was first defined in 2014 by Buysse[1] as "a multidimensional pattern of sleep-wakefulness, adapted to individual, social, and environmental demands, that promotes physical and mental well-being". Good sleep health is characterized by subjective satisfaction, appropriate timing, adequate duration, high efficiency, and sustained alertness during waking hours."[1] Sleep health has since evolved as a concept that explains the role of sleep as a cause or determinant of adverse health outcomes and morbidity rather than just a consequence or symptom of ill health.[2–4] Furthermore, the understanding of the concept of sleep health is widening the focus of sleep medicine beyond seeing poor sleep as a cause of sleep disorders to identifying sleep health as a predictor of overall health.[1, 5] Thus, sleep health has emerged as a holistic view of sleep and its multiple characteristics: duration, quality, alertness, timing and continuity.[4] Sleep variability or regularity is being considered as an additional characteristic.[4] While earlier studies have focused on the concept of sleep health as it relates to the adult population, there is growing evidence of its applicability to child and adolescent health.[4, 5] Hence, it is important to investigate the available evidence on the sleep health of adolescents in Africa.

While poor sleep is widely recognized as an important cause of morbidity, research on the subject is lacking both in quantity and quality in Africa.[6, 7] Studies in high-income countries (HIC) have associated short sleep duration with increased physical and behavioural problems.[4, 8, 9] Nevertheless, evidence on the role, extent and scope of the various aspects of sleep health characteristics such as sleep duration, sleep quality, sleep chronotype and bedtime variability of adolescents in Africa have not been well reviewed or synthesised. Thus, there is a need for a review to examine the available evidence on adolescent sleep health, and the determinants and possible outcomes for adolescent sleep health in Africa.

Furthermore, existing studies have highlighted racial and social disparities in sleep health.[10–12] Some disparities have been described among people living in urbanized communities when compared with dwellers of rural communities. This suggests that differences may exist in the sleep health dynamics of adolescents in Africa when compared with adolescents in other low and middle-income countries (LMICs) as well as those in HIC. Similarly, there may be similarities or differences in the sleep health of adolescents dwelling in the various regions of the African continent. The sleep characteristics of adolescents in sub-Saharan Africa may be different from that of their counterparts in North Africa. Conversely, the sleep characteristics of adolescents within the entire African continent may be similar due to similarities and overlap of cultures, including the nomadic culture which cuts across the countries in North and West Africa. Furthermore, there may be disparities in the sleep health of rural-dwelling versus urban-dwelling adolescents in Africa. Thus, a detailed review of existing studies on African adolescents' sleep patterns and the sleep problems among adolescents residing in all the regions of the continent may help understand the effects of culture, religion, natural light exposures and electricity on adolescent sleep health.

In addition, there is a need to collate the available evidence on the contributory factors and outcomes associated with poor sleep health. The social determinants of sleep problems in adolescents have been well described in high-income countries (HIC) using various models, especially the socio-ecological model.[13–15] The leading factors identified by these studies were excessive screen use, early school start times, the burden of homework, caffeine use and parental influences.[16–18] However, the available studies on the social determinants of sleep health in Africa have not been well explored among the adolescent population.

Many studies of adolescent sleep are based on sleep duration (SD) as the main sleep variable measured. Other variables such as bedtime variability (BV), sleep quality and sleep chronotype have not been well explored.[19, 20] However, emerging evidence suggests that sleep chronotype (SC) and BV may be more important measures of sleep health.[21–23] Thus there is a need to synthesize the mechanisms by which other sleep health variables such as SC contribute to adolescent sleep problems. This will bring more understanding of the concept of sleep health as it relates to adolescent sleep, particularly in the context of Africa.

Aside from the socio-demographic variables, emerging pieces of evidence have shown links between cardio-metabolic diseases and poor sleep.[23, 24] This suggests a possible association between cardiometabolic risk (CMR) and sleep health. CMR refers to an increased predisposition to cardiovascular (CVS) disease, diabetes and metabolic syndrome.[25] The markers of CMR include CVS risk factors such as weight-height ratio, body mass index (BMI), blood pressure (BP), heart rate (HR) and measures of adiposity such as waist circumference, and waist-hip ratio, body fat percentage, superficial fat thickness.[26, 27] Others include fasting blood sugar, homeostatic model of insulin resistance (HOMA-IR), Matsuda index, lipid profile, and inflammatory markers among others.[26–28] These factors have been linked to various sleep parameters such as short or long SD, poor sleep quality, sleep chronotype, bedtime irregularity and intra-individual variability (IIV) in bedtime.[13, 21] Also, a high CMR in adolescence has been associated with a higher risk of cardiovascular disorders in adulthood, in particular young adulthood.[29]

However, inconsistencies in findings limit the generalisability of many suggested associations between sleep and CMR. The majority of these studies are cross-sectional in design and suggest a bi-directional relationship between poor sleep and CMR. [13, 30] Furthermore, a gender disparity was observed between short SD and increased adiposity in females suggesting the need for an improved understanding of the mechanisms of the association.[28, 31]The postulated mechanisms for the adverse effects of sleep disruption on CMR include inflammation, increased oxidative stress and endothelial dysfunction, elevated ghrelin and leptin levels, etc.[24, 32, 33] However, the type of sleep disruption associated with CMR are mainly those with altered circadian rhythms such as IIV or bedtime irregularity.[19, 21, 28]Thus, the collation of evidence from existing studies is needed to identify research gaps and suggest the direction for future research.

Studies in HIC suggest an association between poor sleep and adverse health outcomes.[31, 34, 35] In some African countries, there is an already worrisome increase in non-communicable diseases (NCDs).[36, 37] This is mainly due to changes in lifestyles and the consequent increase in the risk factors for NCDs.[38] Sleep problems in adolescents, especially circadian misalignment or bedtime variability have been linked with NCDs such as diabetes, cardiovascular diseases and cancers.[26, 39, 40] In addition, the presence of risk factors for the development of NCDs such as obesity has been linked to sleep problems.[26, 27, 31] Furthermore, obesity and poor sleep have been recognised as dual epidemics in adolescents worldwide.[26] However, the attention of researchers appears skewed towards obesity while sleep problems and health outcomes have not been well-explored.

The association between sleep health and the mental health of adolescents needs to be well studied. Sleep problems have been reported to result in adverse mental health outcomes such as anxiety, depression and behavioural disorders.[41–44] Many mental health disorders have sleep disturbances as a component of their symptomatology.[22] In addition, sleep problems can be an early pointer to the existence of a mental health disorder and sleep is a modifiable factor that can be targeted in mental health promotion programs.[44] Furthermore, many of the medications used in treating mental health conditions have significant effects on sleep architecture and quality.[45] Thus, the relationship between sleep and mental health is multidimensional. According to the World Health Organisation (WHO) "mental health is more than the absence of mental health disorders."[46] Mental health problems occur for one in seven adolescents.[47] Also, many of the determinants of mental health in adolescents contribute to sleep health.[44] These determinants would be worth exploring among African adolescents. Thus, this scoping review will include studies on the relationship between sleep health variables and the mental health of African adolescents.

After conducting preliminary searches on MEDLINE, the Cochrane Library of Systematic Reviews and *JBI Evidence Synthesis*, no existing or underway systematic or scoping review on the topic were identified. Thus, the objective of this scoping review will be to assess the extent of the literature on adolescent sleep health in Africa. We present here the methods proposed for this scoping review.

2.5 Review questions

1. What are the key concepts, beliefs and cultural practices on sleep health in adolescents in Africa?
2. How have publications in adolescent sleep health evolved in Africa?
3. What is the geographical distribution, trends, sources and types of evidence available on adolescent sleep health in Africa?

4. What disparities exist in sleep health among rural versus urban-dwelling African adolescents?
5. What are the barriers and facilitators to good sleep health among rural and urban-dwelling adolescents in Africa?
6. What relationship exists between sleep health and mental health among adolescents in Africa?
7. What relationship exists between sleep health and cardiometabolic risk among adolescents in Africa?
8. What association exists between sleep health and school schedule among adolescents in Africa?
9. What interventions have been implemented for improving the sleep health of adolescents in Africa and how effective have they been?

2.6 METHODS AND ANALYSIS

2.6.1 Study design:

This scoping review will be used to map out literature on the topic "Adolescent sleep health in Africa". We will be using the six-step procedure described by Arksey and O'Malley.[48] Thus, we have written this protocol according to the framework for scoping reviews developed by the Joanna Briggs Institute (JBI) and the proposed scoping review will be conducted following the JBI methodology for scoping reviews.[49] The result will be presented following the Preferred Reporting Items for Systematic Reviews and Meta-analyses extension for scoping review (PRISMA-ScR).[50]

2.6.2 Search strategy

The search strategy will aim to locate published studies. An initial limited search of MEDLINE (via Pubmed) and CINAHL will be undertaken to identify articles on the topic. The text words identified in the titles and abstracts of relevant articles, and the index terms used to describe the articles will thereafter be used to develop a full search strategy for MEDLINE (Pubmed), Scopus, CINAHL, AJOL, HINARI Summons, and PsychINFO. The search strategy, including all identified keywords and index terms, will be adapted for each included database and/or information source. Aside from database searching, a reference snowballing approach will be deployed to identify more studies from the reference lists of screened and eligible articles. The initial search strategy developed for the study is presented in Table 2.3.

2.6.3 Planned Start and End Dates

The study is planned to start in July 2023 and end by August 2023.

Table 2.3: Initial search strategy for MEDLINE (via PubMed)

	Search strategy
#1	Sleep[Mesh] OR "Sleep quality"[Mesh] OR "Circadian rhythm"[Mesh] OR "Sleep hygiene"[Mesh] OR "Sleep duration"[tw] OR "sleep chronotype*"[tw] OR "Bedtime variabilit*"[tw] OR "Sleep pattern*"[tw] OR "Total sleep time"[tw] OR "Sleep efficienc*"[tw] OR "Sleep sufficienc*"[tw] OR "Sleep habit*"[tw] OR sleep[tw] OR "Sleep Deprivation"[Mesh] OR "Sleep Deprivation/complications"[Mesh] OR "Sleep Initiation and Maintenance Disorders"[Mesh] OR "Sleep Wake Disorders"[Mesh] OR "Disorders of Excessive Somnolence"[Mesh] OR Parasomnias[Mesh] OR "Sleep disorder*"[tw] OR "Sleep insufficienc*"[tw] OR "Sleep difficult*"[tw] OR Insomnia[tw] OR Hypersomnia[tw] OR "Excessive daytime sleepiness"[tw] OR "Sleep-related movement disorder*"[tw] OR "Sleep-related breathing disorder*"[tw] OR "Sleep apnoea"[tw] OR "Sleep apnea"[tw] OR "Obstructive sleep apnoea"[tw] OR "Obstructive sleep apnea"[tw] OR "Daytime sleepiness"[tw] OR “sleep deprivation”[tw]
#2	Adolescent[Mesh] OR Youth[tw] OR "Young people"[tw] OR Teenager*[tw] OR adolescent[tw]
#3	"Africa, Western"[Mesh] OR "Africa, Southern"[Mesh] OR "Africa south of the Sahara"[MeSH] OR "Africa, Eastern"[Mesh] OR "Africa, central"[MeSH] OR "Africa, Northern"[Mesh] OR Cameroon[tiab] OR "Central African Republic"[tiab] OR Chad[tiab] OR Congo[tiab] OR "Democratic Republic of the Congo"[tiab] OR "Equatorial Guinea"[tiab] OR Gabon[tiab] OR "Sao Tome and Principe"[tiab] OR Burundi[tw] OR Djibouti[tiab] OR Eritrea[tiab] OR Ethiopia[tiab] OR Kenya[tiab] OR Rwanda[tw] OR Somalia[tiab] OR "South Sudan"[tiab] OR Sudan[tiab] OR Tanzania[tiab] OR Uganda[tiab] OR Angola[tiab] OR Botswana[tiab] OR Eswatini[tiab] OR Lesotho[tiab] OR Malawi[tiab] OR Mozambique[tiab] OR Namibia[tiab] OR "South Africa"[tiab] OR Zambia[tiab] OR Zimbabwe[tiab] OR Benin[tiab] OR "Burkina Faso"[tiab] OR "Cabo Verde"[tiab] OR "Cote d'Ivoire"[tiab] OR Gambia[tiab] OR Ghana[tiab] OR Guinea[tiab] OR Guinea-Bissau[tiab] OR Liberia[tiab] OR Mali[tiab] OR Mauritania[tiab] OR Niger[tiab] OR Nigeria[tiab] OR Senegal[tiab] OR "Sierra Leone"[tiab] OR Togo[tiab] OR Algeria[tiab] OR Egypt[tiab] OR Libya[tiab] OR Morocco[tiab] OR Tunisia[tiab] OR "cape verde"[tiab]
#4	#1 AND #2 AND #3

2.6.4 Inclusion criteria

The scoping review will include all published articles on the various sleep characteristics of adolescents, aged 10-19 years living in Africa from the inception of the databases. We will include peer-reviewed publications in English, French, Spanish, Portuguese, Italian and Arabic languages since the official language in most African countries is anglophone, francophone, lusophone, and Arabic. This will enable appropriate inclusion and evaluation of the evolution of publications over the years on adolescent sleep health in Africa.

2.6.5 Exclusion criteria

Studies published in languages other than English, French, Spanish, Portuguese, Italian and Arabic languages and those based on geographical location outside Africa will not be included in the review. Blogs, web pages, books, conference presentations and other grey literature will also be excluded from the review. Types of Sources: For comprehensive coverage of available evidence, the scoping review will include analytical observational studies (epidemiological studies) including prospective and retrospective cohort studies, case-control studies and analytical cross-sectional studies. In addition, the review will consider descriptive observational study designs including case series, individual case reports and descriptive cross-sectional studies for inclusion. In addition, studies from experimental and quasi-experimental study designs including randomized controlled trials, non-randomized controlled trials, before and after studies and interrupted time-series studies will be included. Qualitative studies that focus on qualitative data including, but not limited to, designs such as phenomenology, grounded theory, ethnography, qualitative description, action research and feminist research will be considered for inclusion. In addition, relevant systematic reviews that meet our inclusion criteria will also be for inclusion in the review. Only studies available in the full text will be included in the review.

2.6.6 Study/Source of Evidence Selection

Following the search, all identified citations will be collated and uploaded into the Mendeley citation management software for deduplication. Following this, titles and abstracts will then be screened by two independent reviewers for assessment against the inclusion and exclusion criteria for the review. The full text of selected citations will be assessed in detail against the inclusion criteria by two or more independent reviewers. Reasons for the exclusion of studies whose full text does not meet the inclusion criteria will be recorded and reported in the scoping review. Any disagreements that arise between the reviewers at each stage of the selection process will be resolved through discussion, or with an additional reviewer. The results of the search and the study inclusion process will be reported in full in the final scoping review and presented in a Preferred Reporting Items for Systematic Reviews and Meta-analyses extension for scoping review (PRISMA-ScR)[50] flow diagram (Figure 2.1).

Patient and Public Involvement: None

2.6.7 Data Extraction

Data will be extracted from studies included in the scoping review by two independent reviewers using a data extraction tool developed by the team (Table 2), adapted from a previous scoping review on adolescent reproductive health in Africa.[51] The data extracted will include specific details about the participants, concept, context, study methods and key findings relevant to the review questions. A draft extraction form will be provided in the report of the scoping review. The draft data extraction tool will be modified and revised as necessary during the process of extracting data from each included evidence source. Modifications will be detailed in the scoping review. Any disagreements that arise between the reviewers will be resolved through discussion, or with an additional reviewer. Where required, authors of papers will be contacted to request missing or additional data.

2.6.8 Data Analysis and Presentation

We intend to map available evidence on adolescent sleep health in Africa. For this, we will characterise sources of evidence through the descriptive presentation of the yearly publication rates of adolescent sleep studies included in the scoping review and the countries of publication of the studies included in the review. Furthermore, extracted data from included publications will be presented according to the study design and sleep themes investigated by performing a basic qualitative content analysis of the publications. By utilizing the thematic content analysis, pertinent qualitative data (texts) extracted from all studies included in the review will be synthesized and descriptively presented under themes that address the review questions.

Specifically, the review will utilise the three phases of qualitative content analysis described by Pollock *et al*.[52] In the preparation phase, the deductive approach will be used to map the data to established frameworks (sleep quality, sleep duration, presence of sleep disorders, sleep as a comorbid condition with mental health) within the literature. The second phase, the organising phase, will involve open coding to allocate concepts or characteristics in the mapped data into overall categories. Thereafter, we will organise the categories of data into themes, based on the review questions, to draw appropriate conclusions from the findings. For these steps, we will use the NVIVO 12 software. Using the NVivo software, the primary author will chart the results obtained from the publications and identify the main themes while other authors will give feedback and review the synthesized results. These results will include themes and conclusions relating to adolescent sleep in Africa, rural versus urban disparities, the association between sleep and cardiometabolic risk and the association between sleep and mental health. The final results will be validated by the last author who is a specialist in Sleep research and the third author who is a Librarian. We will conduct the validation of sources using a test set of pre-identified relevant publications that should be captured using the database search. Following the first database search, we will check the identified publications based on our predetermined strategy to ascertain the comprehensiveness of the search. We will utilize the information obtained to make the appropriate changes to the search strategy if needed. In the reporting phase, the bibliographic characteristics of studies included in the review will be presented through the use of tables and charts. These tables and charts will describe the publication year, country of publication, authorship information, study design and settings, funders, sample size and other available relevant information about the articles. Visual presentation tools such as word clouds, tree graphs and waffle charts will also be used in presenting the results as appropriate. The key findings and gaps will thereafter be presented in a narrative summary within the text of the review.

2.6.9 Ethics and dissemination

The scoping review does not require ethical approval because the publications to be used for the review are publicly available and the study does not involve contact with humans or other animals as research participants. Furthermore, clinical records will not be used for the study. Upon completion, findings from the study will be disseminated through presentations at scientific meetings and publication in a relevant peer-reviewed journal.

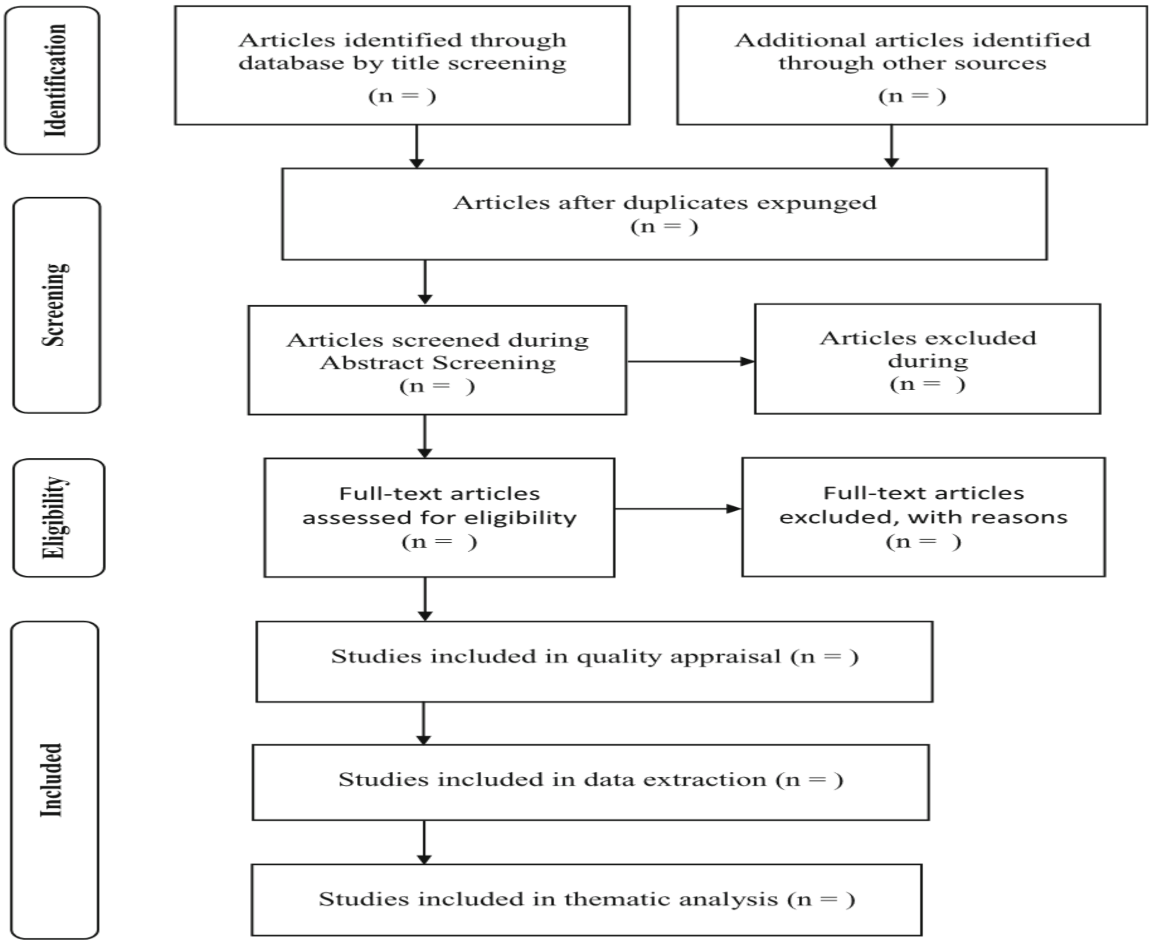

Figure 2.1: Example of a PRISMA-ScR flow diagram[41] The PRISMA-ScR flow diagram shown will be used to illustrate the processes involved in conducting this scoping review. These processes are 1. Identification: To state the number of articles identified and the respective sources. The number of the duplicates found and removed will also be provided 2. Screening: The total number of articles screened will be provided here. 3. Eligibility: The details of the number of full text articles assessed for eligibility, the number of eligible studies and the number of excluded studies. 4. Included: This section provided the number of studies included following quality appraisal, data extraction and thematic analysis respectively.

Table 2.4: Data extraction tool (adapted from a scoping review by Ajayi et al)[51]

Main Category	Subcategory	Description
Author Lead author		Indicate where the lead author is based (we will determine if a lead author is African or non-African by the institutional affiliation of the author)
Funder(s)		Indicate the funder (eg, Africa, European, USA, other North America)
Title		
Journal		
Year of publication		
Aim/objectives		Describe the stated aim and objectives of the study
Year of Research		
The country where the study was conducted		Indicate the country(ies) where the study was conducted
Study setting		Specify the location of study sites (eg, district(s))
Sub-region where the study was conducted		Indicate the sub-region study was conducted
Type of Study		Indicate the study type (e.g., primary research, secondary analysis, review, commentary, document analysis or discourse analysis)
Type of source		Indicate the type of publication (e.g., journal article, book chapter, report, thesis)
Is the study an intervention study or focusing on describing the problem		Indicate whether the study described a problem or examine the effect of an intervention
Thematic focus	If describing a problem	Identify the area of focus (e.g., sleep pattern, sleep duration, sleep quality, sleep hygiene/habits, sleep apnea, other sleep problems, sleep chronotype, risk and protective factors, association with CMR factors, association with other health outcomes).
	If an intervention study	Describe the nature of the intervention.

Methodology		
	Study design	Specify the study design adopted (eg, cross-sectional design, case study, pre-study, post-study design, longitudinal study, mixed methods, randomised control trial, qualitative study, review study)
	Population	Describe the characteristics of the target population
	Sampling strategy	Describe how sampling was done if applicable
	Data collection	Specify the methods of data collection
	Outcome measures	Indicate the outcome measures for quantitative studies
	Data analysis	Indicate method of data analysis
Results		
	Reported outcomes	Indicate the prevalence reported Highlight the determinants reported
	Key findings	Summarise the key findings
Conclusion		Highlight the main conclusion of the study
Limitations		Describe the study limitations

Authors contributions: OEO, FXG, BOP, AF and KS conceived the idea and design for the study. OEO drafted the paper. OEO, KS and BOP developed the protocol and prepared the tables and figures. OEO, FXG, AF BOP and KS all participated in the revision of the manuscript before submission. All authors have seen and given final approval to the final text.

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Leadership, Training and Science in Africa (DELTAS Africa) programme. The statements made and views expressed are solely the responsibility of the Fellow. For the purpose of open access, the author has applied a CC BY public copyright licence to any Author Accepted Manuscript version arising from this submission.

Competing interests statement: There is no conflict of interest to report in this project.

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CHAPTER 3

PATTERNS, DETERMINANTS AND ASSOCIATED OUTCOMES WITH ADOLESCENT SLEEP HEALTH IN AFRICA: A SCOPING REVIEW

3.1 PUBLICATION DETAILS

This chapter shows the actual scoping conducted following the published protocol presented above. The scoping review highlights the patterns, determinants and associated outcomes with Adolescent Sleep Health in Africa.

The information about the manuscript is presented in Table 3.1

Table 3.1 Manuscript Information

Title of publication	Patterns, Determinants and Associated Outcomes with Adolescent Sleep Health in Africa: a Scoping Review
Authors	Oluwatosin Eunice Olorunmoteni, Biliamin O. Popoola, Jeremiah Itodo Daniel, F Xavier Gómez-Olivé, Omobolanle Victoria Olubowale, Adesegun Olayiwola Fatusi, Karine Scheuermaier.
Journal name	PLOS ONE
Status	Under Review
Impact factor	2.9s
Manuscript ID	PONE-D-24-59725

3.2 Author Contributions

Table 3.2: Author Contributions to the paper titled Adolescent Sleep Health in Africa: a Scoping Review Protocol

	Olorunmoteni	Popoola	Daniel	Gómez-Olivé	Olubowale	Fatusi	Scheuermaier
Conceptualisation	√	√	√	√	√	√	√
Project administration	√	√	√	√	√	√	√
Methodology	√	√	√	√	√	√	√
Initial data analysis	√	√	√				
Writing – original draft	√		√				
Writing – reviewing and editing	√	√	√	√	√	√	√
Visualization	√	√	√	√	√	√	√
Supervision				√		√	√

3.3 Associated Documentation:

The documentation associated with this publication are included as appendices and are labelled:

- Appendix 3: Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist.

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3.4 Article Title: Patterns, Determinants and Associated Outcomes with Adolescent Sleep Health in Africa: a Scoping Review

Abstract:

Background: Sleep health in adolescence is a global public health concern. However, limited studies on adolescent sleep health in Africa exist, and the extent of the available literature on the African continent has not been previously mapped.

Objective: This review aimed to map the studies on adolescent sleep health in Africa with a focus on the geographical distribution, publication trends, pattern of sleep health measures, prevalence of sleep disorders, the barriers and facilitators to good sleep health, rural-urban disparities, as well as the associations of sleep health with mental health, school schedule and cardio-metabolic risk among the adolescents.

Eligibility criteria: All published articles on adolescent sleep health in Africa in English, French, Spanish, Portuguese, and Italian languages.

Sources of Evidence: We conducted a scoping review by searching five database: MEDLINE (via PubMed), CINAHL (via EBSCOHost), PsychINFO (via EBSCOHost), Scopus and the African Journal Online (AJOL), from the inception of the databases to June 2023.

Charting Methods: As previously highlighted in our published protocol (doi: 10.1136/bmjopen-2022-067373), we used the JBI methodology for the scoping review.

Results: After screening 759 titles and abstracts and 47 full-text articles, we included 31 articles. There has been an increasing number of studies on adolescent sleep in Africa, especially in the past 25 years. Cross-sectional studies were the most frequent design (77.4%). Most studies focused on sleep quantity and quality, with very scanty evidence on other aspects of sleep health. Inadequate sleep duration during weekdays was common among adolescents, often compensated by longer weekend sleep durations.

Additionally, the prevalence of poor sleep quality and sleep disorders, such as insomnia and sleep-disordered breathing, was high across various regions. Younger age was reported as protective of good sleep health, while gender disparities in adolescent sleep health were noted across regions. The use of electronic devices at bedtime was a major risk factor for sleep disturbances among

urban-dwelling adolescents while poor sleeping conditions impaired sleep, especially among adolescents in rural communities and for those in lower social class. Furthermore, adverse childhood experiences and the burden of schoolwork contributed as risk factors for adolescent sleep disturbances. Poor sleep was associated with poor academic performance, depression, and anxiety, as well as adverse cardio-metabolic risk factors, though these findings were from cross-sectional studies with limited strength of causality.

Conclusion: This review shows a lack of studies on the multidimensional aspects of sleep health besides sleep duration and quality in African adolescents. It also shows the need for objective sleep measures to better characterise the sleep health of adolescents in Africa. Further studies with longitudinal and mixed methods designs will be needed to provide stronger evidence that can drive the planning and execution of interventions to improve sleep health among African adolescents and to provide useful data for the development of such interventions.

3.5 INTRODUCTION

Sleep health is an important concept and a component of health across all ages globally. Understanding sleep health as a multidimensional pattern of sleep-wakefulness tailored to individual, social, and environmental demands is critical in promoting physical and mental well-being. According to Buysse[1], sleep health is not only about the absence of sleep disorders but involves subjective satisfaction, appropriate timing, adequate duration, high efficiency, and sustained alertness during waking hours. Over time, sleep health has evolved from being perceived as a consequence of ill health to a critical determinant of health outcomes, influencing various physical and mental conditions.[1–4] Hence, it is necessary to study sleep health across all ages to ensure the well-being of the entire population.

Research on sleep health has traditionally centred on adult populations.[5,6] The available studies on adolescent sleep health are mainly from high-income countries. Studies from high-income countries (HICs) have robustly linked inadequate sleep with a spectrum of adverse outcomes among adolescents, including physical ailments and behavioural issues.[2,7,8] However, emerging evidence suggests the importance of the multi-dimensions of sleep health among adolescents, revealing that poor sleep health can significantly impact the well-being of this age group, particularly in terms of physical and behavioural health outcomes.[3,9] However, there are limited studies on sleep health among adolescents in low and middle-income countries.

Furthermore, the extent, focus, and geographical distribution of studies on adolescent sleep health, especially within African populations on the African continent, have not been mapped.[5,10] By African, we refer to people residing on the African continent, as this scoping review aims to include all relevant studies from this region. The African continent is a vast and culturally rich landmass with a rich diversity of cultures, institutions, ethnicity and climate.[11,12] The African climatic zones include the hot and dry arid and semi-arid zones (Sahel region, Kalahari and Namib deserts), the Tropical Savanna grasslands zones (West Sub-Saharan Africa and Central Southern Africa), the warm and humid Equatorial (The Congo region and the East African highlands) and the Temperate (Southern Africa) zones.[12] An association between the different climatic conditions and differences in sleep architecture and habits have been reported among inhabitants of the African continent.[13] Despite the geographical, climatic, ethnic, religious, and cultural diversity in Africa, there is a unity in the experience of the continent's inhabitants that makes this review pivotal for understanding adolescent sleep health across Africa.

To date, the extent and implications of sleep health characteristics such as sleep duration (SD), sleep quality, sleep chronotype (SC), and bedtime variability (BV) among African adolescents have not been comprehensively reviewed. This lack of focused research presents a significant gap, given the potential unique socio-cultural and environmental influences on sleep health within the African context.[14–17] In exploring adolescent sleep health in Africa, it is critical to consider the multiple factors that may be involved. Climatic factors contribute to sleep habits and architecture in Africa with a higher tendency for afternoon naps and more of the N3 slow-wave sleep architecture among people living in the hot-dry Sahelian conditions than people in temperate and hot-humid climates.[13] Furthermore, genetic factors may contribute to the sleep health of Africans.[18] Though there is a paucity of studies on the association between sleep health and genetic factors among people residing in Africa, findings among individuals of African ancestry in the US showed genetic variations such as Per2, Per3, Clock, and AANAT influencing sleep timing and architecture. These variations predispose these individuals to shorter (<5 hours) or longer sleep durations (> 9 hours) and a higher risk for chronic conditions like cardiovascular diseases.[18] Additionally, obstructive sleep apnea (OSA) has been reported to be more prevalent in individuals of African ancestry and is influenced by genetic factors like the PPARGC1B, HTR2A, and PLEK genes.[18] Furthermore, the diversity of cultural, ethnic and religious groups on the African continent may affect sleep habits and practices across the continent. Northern African culture/ethnicity and religion are predominantly Arabic and Muslim; Western and Central African ethnicity and religion are African, Muslim and Christian; Eastern African culture includes Ethiopian / Somali / Erythrean and Central African influences, and Muslim and Christian beliefs. Sub-Saharan Africa is a mix of African cultures and European practices, with a predominance of both Christian and Muslim religions.

Moreover, prevalent diseases such as HIV and human African trypanosomiasis, also known as "sleeping sickness," directly disrupt normal sleep patterns, contributing further to the sleep health burden in the region.[19] Insomnia, which is more commonly reported among African Americans, compared to other ethnic groups in the US, has been linked to various social factors including social class, employment status, education levels, and marital problems, suggesting a complex interplay of environmental and social determinants affecting sleep health.[18,19] The use of khat, specific to Eastern Africa, has been associated with sleep effects.[20,21] Khat (Catha edulis) is a substance of abuse that has been reported to be widely used in East Africa and the Middle East.[22,23] It contains the alkaloids cathinone and cathine, which have similar structural and psychostimulant features with amphetamines.[22] It is often used in combination with other substances, which further worsens its adverse effects on central nervous system function.[24]

Higher access to electricity in Africa has been principally in urban areas. With light in the early evenings associated with a delayed circadian phase and bedtimes, adolescents living in urban areas with higher access to electricity may have delayed bedtimes and lower sleep duration.[14,25] Thus, there is an interplay between genetic, physiological, and environmental factors that may affect sleep in Africa, highlighting the complexity of sleep health issues among African adolescents.

Given these complexities, there is an urgent need for a comprehensive review of the available evidence on adolescent sleep health in Africa. Also, a scoping review is considered rather than a systematic review because of the need to map the extent and the nature of the available literature on adolescent sleep health in Africa and identify the knowledge gaps. Thus, this review aimed to elucidate the determinants and possible outcomes of sleep health among the African adolescent population, focusing on understanding how socio-economic, cultural, environmental, genetic, and mental health/ clinical health-related factors contribute to sleep variability and its associated health implications. It is therefore important to map out studies on adolescent sleep health within the African continent to correctly understand the current situation, identify research gaps and direct future research. By synthesising the current literature and identifying research gaps, this scoping review seeks to pave the way for future studies that could inform targeted interventions and public health strategies to improve sleep health and, consequently, the overall well-being of African adolescents. The review, therefore, explored answers to the following questions, as previously highlighted in the study protocol published in 2023.[26]

What are the key concepts, beliefs and cultural practices on sleep health in adolescents in Africa?

How have publications in adolescent sleep health evolved in Africa?

What is the geographical distribution, trends, sources and types of evidence available on adolescent sleep health in Africa?

What disparities exist in sleep health among rural versus urban-dwelling African adolescents?

What are the barriers and facilitators to good sleep health among rural and urban-dwelling adolescents in Africa?

What relationship exists between sleep health and mental health among adolescents in Africa?

What evidence is there of a relationship between sleep health and cardiometabolic risk among adolescents in Africa?

What association exists between sleep health and school schedule among adolescents in Africa?

What interventions have been implemented for improving the sleep health of adolescents in Africa and how effective have they been?

3.6 METHODS

3.6.1 Protocol and Registration

The protocol for this scoping review was published in BMJ Open in July 2023.[26] The review was conducted using the JBI standards for scoping reviews.[27] As detailed in the proposed review protocol, we deployed the Preferred Reporting Items for Systematic Reviews and Meta-analyses extension for scoping reviews (PRISMA-ScR) to report our findings from the review.[28]

3.6.2 Eligibility criteria

For the review, we included research articles from the global African continent on adolescent sleep characteristics. No time limit was applied in our search for eligible studies for inclusion in the review, to ensure that we capture all relevant perspectives. Studies that report on the sleep health of African adolescents from age 10 to 19 were included in the review. Studies that primarily focused on children and adolescents were also included if the mean age of the participants was in the adolescent age range or if more than half of the participants were adolescents.

As shown in the review protocol, the review plan was to include peer-reviewed studies published in all major languages in Africa, but we found studies published mainly in the English language, with only one in the French language. The French article was translated from French to English by KS. Intentionally, the review excluded information sources from grey literature, such as conference proceedings, web page information, and blogs, to ensure the quality of the source literature. The details of this review's inclusion and exclusion criteria have been previously published in the protocol.[26]

3.6.3 Information Sources and Search Strategy

We conducted the literature search in July 2023 in line with our review objectives. The databases searched for eligible studies include MEDLINE (via PubMed), CINAHL (via EBSCOHost), PsychINFO (via EBSCOHost), Scopus, and the African Journal Online (AJOL). The search strategies deployed for MEDLINE and Scopus are provided in Table 3.3. The strategy was translated for other databases during the search process. References from extracted studies were examined to identify other relevant studies for inclusion in the review. Search results from the databases were deduplicated using the Deduplicator function of Bond University's Systematic Review Accelerator tool (available at https://sr-accelerator.com/). Figure 3.1. shows a PRISMA Flow chart of the evidence search process with 31 studies included in the review.

3.6.4 Evidence Screening and Selection

The evidence screening for the review was conducted using Rayyan (available at https://www.rayyan.ai). Four research team members (OOE, BOP, JOI, and VO) were involved in the abstract and title screening, with Rayyan's blind function utilized to ensure an independent assessment of the studies. Differences in the screening results were resolved through discussion and consensus after turning off the BLIND function. Furthermore, two reviewers (OOE and JO) independently conducted the full-text screening, while BOP acted as an arbitrator to resolve conflicts. Any disagreements over included studies were resolved through the discussion and consensus between the reviewers.

3.6.5 Data Extraction

As presented in the review protocol,[26] the data extraction tools developed by the researchers were used to extract data from the included studies by two independent reviewers (OOE and JOI). Any disagreement in extracted data was resolved through discussion and consensus between the reviewers.

3.6.6 Collating, summarising and reporting the results

We collated data from the 31 studies that met our study criteria. The analysis and synthesis of the data obtained were guided by our review objectives. The descriptive data obtained included the year of publication, country of publication, study design, and language of publication. We extracted data on the relevant sleep health measures (sleep quality, sleep duration, daytime sleepiness, sleep apnoea), sleep pattern, sleep hygiene and presence of sleep disorders. We also identified the main sleep themes reported in the publications through basic qualitative content analysis. The final results were validated by a librarian (BOP), and a sleep research specialist (KS) as earlier explained in the review protocol.[26] The findings obtained are presented using charts and tables.

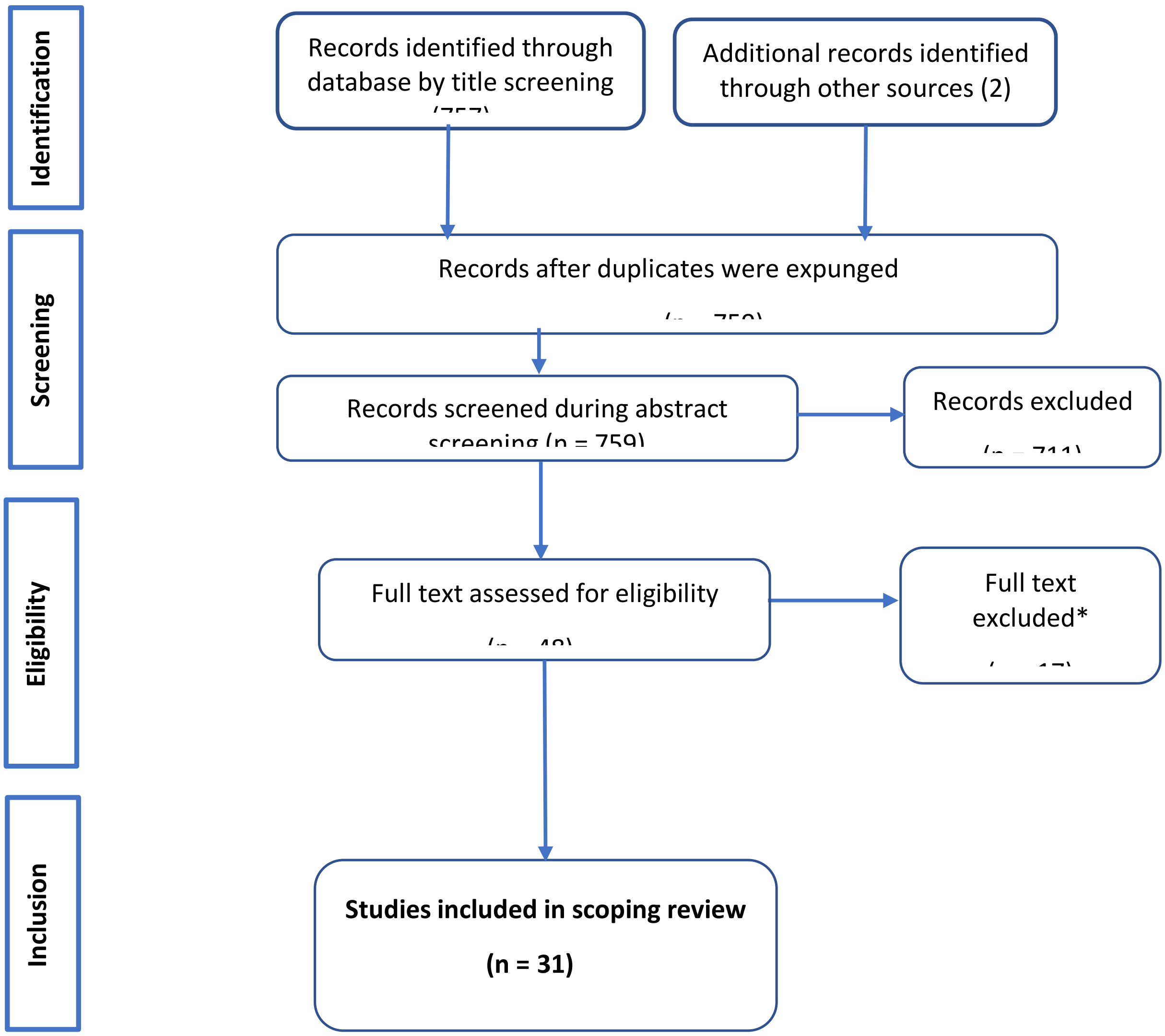

Figure 3.1.: PRISMA Flow diagram indicating evidence search process and included studies. *Reasons for exclusion of full texts: No disaggregated data on Adolescent sleep within age 10 to 19 years =13; primary focus, not adolescent sleep = 3; full text not retrieved =1.

Table 3.3.: Search strategy for databases searched

MEDLINE (via PubMed, 07-July-2023)		
	Search strategy	Number of results
#1	Sleep[Mesh] OR "Sleep quality"[Mesh] OR "Circadian rhythm"[Mesh] OR "Sleep hygiene"[Mesh] OR "Sleep duration"[tw] OR "sleep chronotype*"[tw] OR "Bedtime variabilit*"[tw] OR "Sleep pattern*"[tw] OR "Total sleep time"[tw] OR "Sleep efficienc*"[tw] OR "Sleep sufficienc*"[tw] OR "Sleep habit*"[tw] OR sleep[tw] OR "Sleep Deprivation"[Mesh] OR "Sleep Deprivation/complications"[Mesh] OR "Sleep Initiation and Maintenance Disorders"[Mesh] OR "Sleep Wake Disorders"[Mesh] OR "Disorders of Excessive Somnolence"[Mesh] OR Parasomnias[Mesh] OR "Sleep disorder*"[tw] OR "Sleep insufficienc*"[tw] OR "Sleep difficult*"[tw] OR Insomnia[tw] OR Hypersomnia[tw] OR "Excessive daytime sleepiness"[tw] OR "Sleep-related movement disorder*"[tw] OR "Sleep-related breathing disorder*"[tw] OR "Sleep apnoea"[tw] OR "Sleep apnea"[tw] OR "Obstructive sleep apnoea"[tw] OR "Obstructive sleep apnea"[tw] OR "Daytime sleepiness"[tw] OR “sleep deprivation”[tw]	299,692
#2	Adolescent[Mesh] OR Youth[tw] OR "Young people"[tw] OR Teenager*[tw] OR adolescent[tw]	2,243,445

#3	"Africa, Western"[Mesh] OR "Africa, Southern"[Mesh] OR "Africa south of the Sahara"[MeSH] OR "Africa, Eastern"[Mesh] OR "Africa, central"[MeSH] OR "Africa, southern"[MeSH] OR "africa, eastern"[MeSH] OR "africa, western"[MeSH] OR "Africa, Northern"[Mesh] OR Cameroon[tw] OR "Central African Republic"[tw] OR Chad[tw] OR Congo[tw] OR "Democratic Republic of the Congo"[tw] OR "Equatorial Guinea"[tw] OR Gabon[tw] OR "Sao Tome and Principe"[tw] OR Burundi[tw] OR Djibouti[tw] OR Eritrea[tw] OR Ethiopia[tw] OR Kenya[tw] OR Rwanda[tw] OR Somalia[tw] OR "South Sudan"[tw] OR Sudan[tw] OR Tanzania[tw] OR Uganda[tw] OR Angola[tw] OR Botswana[tw] OR Eswatini[tw] OR Lesotho[tw] OR Malawi[tw] OR Mozambique[tw] OR Namibia[tw] OR "South Africa"[tw] OR Zambia[tw] OR Zimbabwe[tw] OR Benin[tw] OR "Burkina Faso"[tw] OR "Cabo Verde"[tw] OR "Cote d'Ivoire"[tw] OR Gambia[tw] OR Ghana[tw] OR Guinea[tw] OR Guinea-Bissau[tw] OR Liberia[tw] OR Mali[tw] OR Mauritania[tw] OR Niger[tw] OR Nigeria[tw] OR Senegal[tw] OR "Sierra Leone"[tw] OR Togo[tw] OR Algeria[tw] OR Egypt[tw] OR Libya[tw] OR Morocco[tw] OR Tunisia[tw] OR "cape verde"[tw] OR Cameroon[ad] OR "Central African Republic"[ad] OR Chad[ad] OR Congo[ad] OR "Democratic Republic of the Congo"[ad] OR "Equatorial Guinea"[ad] OR Gabon[ad] OR "Sao Tome and Principe"[ad] OR Burundi[ad] OR Djibouti[ad] OR Eritrea[ad] OR Ethiopia[ad] OR Kenya[ad] OR Rwanda[ad] OR Somalia[ad] OR "South Sudan"[ad] OR Sudan[ad] OR Tanzania[ad] OR Uganda[ad] OR Angola[ad] OR Botswana[ad] OR Eswatini[ad] OR Lesotho[ad] OR Malawi[ad] OR Mozambique[ad] OR Namibia[ad] OR "South Africa"[ad] OR Zambia[ad] OR Zimbabwe[ad] OR Benin[ad] OR "Burkina Faso"[ad] OR "Cabo Verde"[ad] OR "Cote d'Ivoire"[ad] OR Gambia[ad] OR Ghana[ad] OR Guinea[ad] OR Guinea-Bissau[ad] OR Liberia[ad] OR Mali[ad] OR Mauritania[ad] OR Niger[ad] OR Nigeria[ad] OR Senegal[ad] OR "Sierra Leone"[ad] OR Togo[ad] OR Algeria[ad] OR Egypt[ad] OR Libya[ad] OR Morocco[ad] OR Tunisia[ad] OR "cape verde"[ad]	769,228
#4	#1 AND #2 AND #3	639

Scopus (via EBSCOHost, 10-July-2023)		
	Search strategy	Number of results
#1	(TITLE-ABS-KEY (“sleep health” OR “sleep duration” OR “sleep chronotype” OR “Bedtime variability” OR “Sleep pattern” OR “sleep”))	332,848
#2	(TITLE-ABS-KEY (“sleep problems” OR “sleep disorders” OR “sleep deprivation” OR “Sleep Deprivation” OR “Sleep Wake Disorders”))	102,269
#3	(TITLE-ABS-KEY (Adolescent OR youth))	2,586,760
#4	(TITLE-ABS-KEY (“South Africa” OR “Nigeria” OR “Angola” OR “Benin” OR “Burkina Faso” OR “Burundi” OR “Cameroon” OR “Cameroun” OR “Canary Islands” OR “Cape Verde” OR “Central African Republic” OR “Chad” OR “Comoros” OR “Congo” OR “Democratic Republic of Congo” OR “DR Congo” OR “Cote D’ivoire” OR “Ivory Coast” OR “Kenya” OR “Lesotho” OR “Liberia” OR “Madagascar” OR “Malawi” OR “Mali” OR “Mauritius” OR “Mozambique” OR “Mocambique” OR “Namibia” OR “Niger” OR “Principe” OR “Reunion” OR “Rwanda” OR “Sao Tome” OR “Senegal” OR “Seychelles” OR “Sierra Leone” OR “Somalia” OR “Sudan” OR “Swaziland” OR “Tanzania” OR “Togo” OR “Uganda” OR “Zaire” OR “Zambia” OR “Zimbabwe” OR “South Sudan” OR “Ghana” OR “Ethiopia” OR “Botswana” OR “Gabon” OR “Eritrea” OR “Guinea-Bissau” OR “Equatorial Guinea”))	942,880
#5	#1 AND #2 AND #3 AND #4	196

3.7 RESULTS

3.7.1 Geographical distribution, trends, sources and types of evidence available on adolescent sleep health in Africa

The descriptive characteristics of the 31 studies included in the review are presented in Table 2. The Northern and Western Africa region had the highest number of studies with 12 and 11 studies from each region respectively. There were six studies from the Southern Africa region, two from the Eastern Africa region and none from the Central Africa region. Most of the studies were from Nigeria (7;22.6%) in the Western Africa region, South Africa (6;19.4%) in the Southern Africa region, and Egypt (5;16.1%) in the Northern Africa region. About three-quarters (24;77.4%) of the studies were cross-sectional in design while prospective longitudinal studies, interventional studies, randomised clinical trials, and case reports contributed about 23.3% of the study designs of included studies in the review. The only non-English publication was in French.[29] The trend of evidence on adolescent sleep health in Africa showed a gradual rise in the number of publications evolving from a single publication in the year 2000 to two publications in both the 2001-2005 and the 2006-2010 period with a peak of ten publications from 2021 to 2023. (Figure 3.2.). Furthermore, the summary of the included studies showed that most studies had a female preponderance (17/31) with two studies having only female participants (Table 3.4.). There was a case report on Kleine-Levin syndrome in a South African adolescent. The cross-sectional studies had numbers of participants ranging from 20 to 1695, while the longitudinal studies had participants between 40 and 3273. The only randomised clinical trial in the review had ten participants. The majority of the studies utilised questionnaires (27/31) to obtain information on the adolescents' sleep health, four studies utilised polysomnography, while two studies used accelerometers. The Pittsburgh sleep quality index was the most commonly used validated sleep questionnaire (7/27; 25.9%). However, many studies used a few questions about duration or quality of sleep to determine adolescents' bedtime, waketime, and sleep hygiene. The types of sleep health measures reported in the publications and the various outcome measures studied are summarised in Table 3.5.

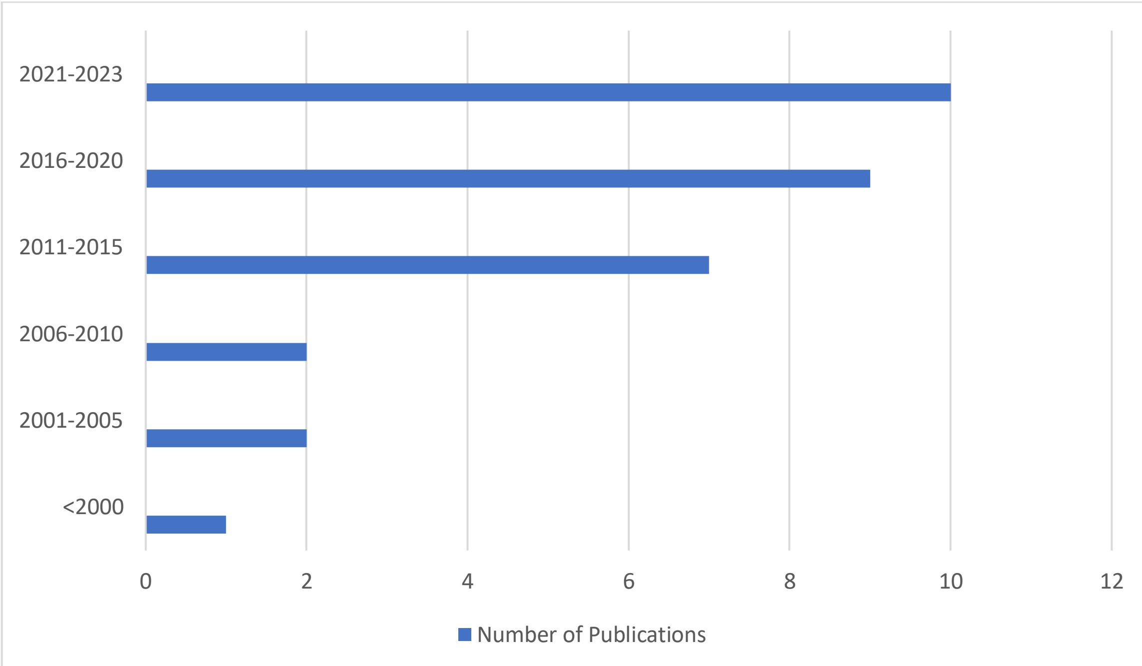

Figure 3.2. The time trend of the number of publications on Adolescent sleep in Africa.

Table 3.4.: Descriptive characteristics of included publications

Characteristics	Frequency (n)	Percentage (%)
Country of Publication		
Nigeria	7	22.6
South Africa	6	19.4
Egypt	5	16.1
Tunisia	4	12.9
Others*	9	29.0
Study Design		
Cross-sectional	23	77.4
Longitudinal	2	6.5
Interventional	2	6.5
Others#	3	9.6
Language of Publication		
English	30	96.8
French	1	3.2

*Senegal and Morocco had two publications each; Sudan, Cote d'Ivoire, Ethiopia and Uganda had one publication each while a single publication was conducted in Cape Verde and Mozambique.

The following methods were used in one study each: case-control, case report, and randomised clinical trial design.

Table 3.5.: Findings on prevalence and pattern of sleep characteristics among African adolescents, in chronological order

Reference	Year	Study design; Sample size Participants' characteristics	Sleep health variables:	Outcome domain studied	Sleep measure	Patterns of sleep characteristics
	Country	**(Age, Sex)**				
Galal *et al*[30]	2001; Egypt	Cross-sectional; n: 863 age: 12 - 18 y; sex: 54% M.	Sleep disturbance	Sleep perceptions, physical health symptoms	**Questionnaire** used was an adaptation of the 'Health of Youth Questionnaire'. Self-reported Sleep disturbance was assessed by adolescents on how frequently they experienced disturbed `sleep in the preceding week. Perceptions of health and sleep were rated as very healthy, healthy, average or bad.	Significantly, more boys than girls perceived their sleep health as very healthy
Reid *et al*[31]	2002; South Africa	Cross-sectional; n: 25 age: 16±1; sex: 61% F	Sleep onset latency, Sleep duration, Sleep quality	Sleep hygiene and habits	**Questionnaire** included questions used at the University of Witwatersrand Sleep Laboratory: - Sleep habits: times they go to bed and wake up, how long they take to fall asleep (subjective sleep onset latency; SOLs), how many times they had woken up and for how long they remain awake (wake after sleep onset; WASO) on the previous night, use of medications to sleep and alarm clock to wake up. - Daytime functioning the previous day. They were asked if they took a nap, the nap duration if they exercised, and for how long, if they took caffeinated beverages and how many cups. - Subjective morning alertness on the day of filling out the questionnaire.	Frequency of awakening: at least once/night: 52%; WASO Duration of awakening ≤ 30 minutes: 6% Mean SOL: 17 minutes (with 45% SOL < 10 minutes) 72% consumed caffeinated beverages the day before the survey 8% took sleep medications 62% needed an alarm or wake-up call (external aids) in the morning.

					They answered whether or not they thought they could fall asleep within five minutes if they had the chance.	
Bénéfice *et al*[32]	2004; Senegal	Longitudinal (three consecutive years), Cohort; n: 40 age: 13.3 ± 0.5; sex: 100% F;	Sleep duration Sleep quality Sleep variability	Nutritional status; Growth Puberty Season	Sleep duration: **Accelerometry** counts of smooth movements between 20:00h and 8:00h were used to determine sleep length. Sleep onset: is determined as a consecutive sequence of zero counts and wake-time as successive counts above 100, Sleep quality: based on the depth of sleep derived from mean counts of movements/minute during the sleep period. Sleep variability: based on standard deviation in mean counts during sleep period.	Mean sleep duration: 8.5 ± 0.9 Sleep duration improved by 30 minutes between the baseline and final measurements. Sleep quality improved as the number of movements during sleep reduced progressively over the three years
Garnier & Bénéfice[33]	2006; Senegal	Cross-sectional; n: 80 age: 14.2 ±0.6 for boys and 14.4 ± 0.5 for girls sex: 50.0% F	Sleep duration, Sleep efficiency, Sleep onset latency.	Sleep and Physical activity	**Acceleromete**r: Used an Excel Visual Basics macro programming (Microsoft Corporation, Redmond, WA) to objectively calculate characteristics of sleep and diurnal physical inactivity derived from the movement registration recorded by the accelerometer.	Sex differences in sleep and physical activity patterns: - Girls: mean sleep duration of 8 hours and 45 minutes; longer than boys ($p < 0.05$). - Sleep efficiency: 91.6%; Inactive for 4 hours and 23 minutes/day? - Boys: mean sleep duration of 8 hours and 9 minutes; Lower sleep efficiency than girls: (88.3%); were more active than girls with only 2 hours and 49 minutes of inactivity.

Cockcroft *et al*[34]	2009; South Africa	Case-control n: 23 children with ADHD -12 medicated -11 un-medicated age:6.4-12.7; sex: 69.6% F;	Daytime sleepiness, Sleep disorders.	Effect of methylphenidate on Perceived Levels of daytime sleepiness and prevalence of sleep disorders in medicated versus unmedicated Children with ADHD	**Questionnaires** (and a Parental Questionnaire on Sleep Habits). Wits Faces Sleepiness Scale: filled by children to measure their daytime sleepiness at 8:30 am, (before any break time), and at 13h00(after the lunch break) on the same day Parental Questionnaire on Sleep Habits: 12 open-ended questions, developed by the researchers. Measured total sleep time, sleep latency, nighttime arousals, daytime naps, symptoms and signs of the common sleep disorders according to DSM-IV and a parent-reported visual analogue scale children's general levels of sleepiness rated as "not at all sleepy" to "very sleepy" between 3:00 and 15:00 hours and between 17:00 and 19:00 the hours	No significant difference in the overall prevalence of disordered sleep symptoms between medicated and unmedicated children with ADHD ($p=0.06$) but a high prevalence of leg movements (50% vs36%) and nightmares (46% vs36%) in both groups Snoring (16%), apnea/ gasping (8%), restlessness (8%), various sleep positions (8%) and bedwetting (16%) were only reported among the medicated children. Between 08:30 and 13:00Perceived daytime sleepiness increased significantly in the medicated children ($t = -2.59$; $df = 8$; $p < 0.05$), compared to the un-medicated group. Parents of the medicated children perceived significantly increasing sleepiness in their children as the day progressed, compared to the parents of the unmedicated children ($t=2.45$; $df =8$; $p < 0.05$)
Aalouane *et al*[29]	2011; Morocco	Cross-sectional; n: 1451; sex: 56.7% M	Sleep pattern	School performance	**Questionnaires** (Self-report questionnaire containing questions on bedtime, waketime, sleepiness during classroom and school performance over the past three months).	Twenty-two per cent of the girls and 18.1% of the boys had symptoms of disordered sleep. Daytime somnolence in the classroom was found in 17.6% of the girls and 12.8% of the boys.

Fakier & Wild[35]	2011; South Africa	Cross-sectional; n: 703; age: LD:13- 20 Control: 14-18; sex: LD: 66% M; Non-LD: 47% M;	Sleep pattern	Learning difficulties and substance use	**Questionnaires** (Assessed Sleep problems using the sum of four items from the Child Behaviour Checklist on trouble falling asleep, trouble staying asleep, feeling tired in the morning and having a problem with sleepiness during the day)	No data on specific sleep characteristics but reported associations between sleep. problems, learning difficulties and substance use. Controlling for effect size, adolescents with sleep problems were more likely to use cannabis and inhalants.
Alabi *et al*[36]	2012; Nigeria	Cross-sectional; n: 909; age: 3-16; sex: 50.0%F;	Snoring, Sleep Disordered Breathing;	Snoring symptoms and complications	**Questionnaires** (Parent-report questionnaire on sleep habits and snoring)	34.2% of snorers with various sleep-related issues. 34.1% snorers with restlessness during sleep. 39.5% snorers with cessation of breathing. Obesity: present in 33.5% of snorers, and 17.5% showed signs of adenotonsillar hypertrophy.
Borchers & Randler[37]	2012 Côte d'Ivoire	Cross-sectional; n: 588; age: 10-15 (12.72 ± 1.63) sex: 57.5% F	Sleep duration, Sleep-wake cycle, Sleep regularity	Age, gender, religion, occupation	**Questionnaires**. The questions asked are as follows: "Think of one typical day during the week (when you are working or at school): - When do you get up in the morning? - When do you go to bed in the evening? Think about a day at the weekend (when you do not work): - When do you get up in the morning? - When do you go to bed in the evening? - Do you sleep/ nap during the day? If yes, how often do you sleep during the day? How many hours every time (nap)?" Using bed and rise times, they calculated a proxy of sleep duration	The mean midpoint of sleep on weekends (1:37± 00:42) was significantly later than on weekdays (1:26± 00:30) with p<0.001. Adolescents had later bedtimes, later waketimes, shorter sleep duration and later midpoint of sleep on weekends than weekdays (all p<0.001).

					(time spent in bed on weekdays and weekends) and a proxy of a chronotype measurement (midpoint of sleep on weekdays and weekends). To calculate the mid-sleep time they used the midpoint of time in bed (midpoint between bedtime and rise time).	
Maduabuchi *et al*[15]	2014 Nigeria	Cross-sectional; n: 443 age: 13 to 19 sex: 59.4% F	Symptoms of disordered sleep, Sleep duration on weekdays and weekends, Sleep quality, Daytime sleepiness, Sleep onset latency	Sleep hygiene	**Questionnaires** (PSQI, ESS)	The mean sleep duration during weekdays (7.84±1.9 hours) was significantly shorter than on weekends (8.65±2.07 hours) ($p<0.001$). 22.8% (101/443) had abnormal sleep onset latency. A high chance of sleeping was reported while sitting and reading in 14.4% (64/443) . while sitting and talking to someone(7.4%) and while driving (2.7%).
Lachman[38]	2014 South Africa	Case report n (age): 1 (14y)	Hypersomnia	Not applicable	Case report	First documented case of Kleine-Levin syndrome (KLS) in South Africa; associated with hypersomnia Diagnostic challenges were highlighted, including misdiagnosis as bipolar disorder or seizure disorder, due to the rarity and overlapping symptoms of KLS with other

						neuropsychiatric conditions.
Sanya *et al*[39]	2015 Nigeria	Cross-sectional n: 1033; age: 12-19 (15.3±1.6); sex: 51.7% F	Sleep pattern, Sleep duration, Daytime sleepiness	Sleep hygiene	**Questionnaires** (Sleep habits) The authors designed a sleep questionnaire from previous studies. It contained questions on "total duration of sleep in a day; time for bed; sleep latency; nocturnal awakenings (weekly and daily frequency, duration, reasons); waketime, time to leave the bed and daytime (school time) napping habits. The duration of the nighttime sleep was calculated as the difference between bedtime and waketime"	Adolescents had significantly shorter sleep duration on weekdays (9.33 ± 2.29 h) compared to 10.09 ± 1.32 h on weekends ($p< 0.05$) 13.3% of the adolescents had insufficient sleep duration (<8 h) 41% had adequate (>9 h) SD while 44%borderline SD (8–9 h) Daytime sleepiness was reported in 8.2%
Balogun *et al*[17]	2017 Nigeria	Cross-sectional; n: 450; age: 10-18(13.4±1.2); sex: 52% F	Sleep quality, Sleep quality, Sleep onset latency	Sleep hygiene, Symptoms of disordered sleep	**Questionnaire** (PSQI)	Poor sleep quality: 50.2% Prevalent frequent awakenings (23.3%), and reliance on sleep medication (28.7%)
Christoph *et al*[40]	2017 Uganda	Cross-sectional; n: 148; age: 11-16 (12.1±1.1) sex: 61.8% M	Sleep disorders, Sleep quality	BMI, Physical activity	**Questionnaires** (Four questions) - "During the past week, what time have you usually turned out the light and gone to sleep on school days/weekend days? - During the past week, what time do you usually wake up in the morning on school days/weekend days? - During the past week, how would you rate your sleep quantity?	Mean self-reported sleep duration Rural: 8.5 ± 1.1 h Urban: 8.4 ± 1.3 h No significant difference in sleep duration between rural and urban adolescents Self-rated sleep quantity as very good:

					- During the past week, how well did you sleep? (subjective sleep quality”	Rural: 86.7% Urban: 87.7% Self-rated sleep quality as very good: Rural: 96.0% Urban: 89.0%
Peter *et al*[41]	2017 Nigeria	Cross-sectional; n: 353; age: 15.89±1.93; sex: 61.8% M	Sleep problem, Sleep disorder, Sleep duration, Daytime Sleepiness, Sleep Regularity	Sleep hygiene	<u>**Questionnaire**</u> (BEARS Sleep Screening Tool): - **B**edtime problems - **E**xcessive daytime sleepiness - **A**wakenings during the night - **R**egularity and duration of sleep - **S**leep-disordered breathing	Frequent awakenings 34.6%; Problem falling back asleep after an awakening: 20.1% Excessive daytime sleepiness: 20.9%; Sleep-disordered breathing: 4.8% Difficulties with bedtime routines: 15.3% Mean sleep duration Early adolescents: 7.19 ± 1.26h Middle adolescents:7.13 ± 1.13 Late adolescents:7.16 ± 1.28 h

Regaieg *et al*[42]	2017 Tunisia	Cross-sectional; n: 1695 age: 15-18 years sex: 56.3% F	Sleep duration	Obesity (BMI and WC)	**Questionnaire** (Self-report of a typical sleep duration on school and weekend nights. The average time spent sleeping per day was calculated for each participant as [(minutes on weekdays x 5) + (minutes on weekends x 2)]/7. Short sleep duration was defined as <8 hours.	71.1% of adolescents had short sleep duration The prevalence of obesity and the waist circumference value was significantly higher for short sleepers as compared with normal sleepers (p=0.04 and p=0.05) respectively).
Cheikh *et al*[43]	2018 Tunisia	Randomised (double-blind design) clinical trial n: 10 Teenage athletes; age: 15.4 ± 0.3 sex: 100.0% M	Sleep architecture	Physical and cognitive wellness following melatonin administration (MEL)	**Polysomnography**	Following MEL, total sleep time increased by 24.55 min, Sleep efficiency by 4.47% (p < 0.001), and SOL by 8.45 min while Nighttime awakenings reduced (18.95 min versus 29.95 min; p < 0.001), N3-sleep increased (19.86% versus 18.3%; p < 0.05) and REM-sleep increased (18.72% versus 16.57%; p < 0.00) compared to the placebo condition
Olorunmoteni *et al*[14]	2018 Nigeria	Cross-sectional; n: 346; age: 10-19 (13.5±2.29) sex: 51.4% F	Sleep pattern	Socio-environmental factors, electronic device use	**Questionnaire** (Adolescent Sleep Habits Questionnaire)	Insufficient sleep: weekdays = 44.4%, weekends = 5% Mean total sleep duration on weekdays (7 h 15 min±86 min) was significantly lower than at weekends (9h 08 min ±113min) (p<0.001) Lower social class and public school attendance are associated with longer weekday sleep duration; Female gender, younger

						age, and living in a polygamous family are linked to longer sleep on weekends.
Carneiro *et al*[44]	2019 Cape Verde (CV) & Mozambique (M)	Cross-sectional; n: 1104; age: 2 -15y &4-13y 2 – 7Y: CV: 61%; M: 47% 8 – 10y: CV: 50%; M: 40% 11 – 15 CV: 15%; M: 13% sex: 51% F	Sleep disorder	Sleep hygiene	**<u>Questionnaires</u>** (CSHQ)	**CV sample:** 29.9% with sleep disorders; - restless sleep (67%); falling asleep in another bed (63%): Usually or sometimes used television as a sleep aid (30%); needs an object to fall asleep (12%). **M sample:** 28.4% with sleep disorders. Need awakening by others (85%); Usually or sometimes used television as a sleep aid (33%); needs an object to fall asleep (16%) More educated parents had children with better sleep patterns. In both populations, the median CSHQ score was not statistically different between the age categories. Among those aged >10 y, For CV: mean sleep duration on weekdays:11.70 ± 1.87 h while M: mean sleep duration on weekdays: 9.13 ± 1.04 h Bedtimes are similar in both samples of adolescents the CV sample had a later wake time of 7.19 ± 1.87

						am) than the M sample of 5.43 ± 0.27
Hanson et al[45]	2019 South Africa	Longitudinal n: 1,414; age: 12-17 sex: 52.7% F Group-based multi-trajectory modelling was done to group the participants into classes based on longitudinal trajectories (time spent in physical activity/ sports, sedentary behaviour, and sleep on weekdays and weekends	Sleep pattern	Sedentary lifestyle, physical activity	**Questionnaires** (Few questions): clock times at which adolescents went to bed and woke up on school nights and weekends/holidays, then calculated hours of sleep.	Maternal education is significantly associated with sleep trajectories (Adolescents with mothers with secondary school education are more likely to be in the 7h or 8h per night sleep trajectory compared to the 9h per night trajectory.) Sedentary behaviour and sleep trajectories did not cluster together with (were independent of) the physical activity domains
El-Baroudy *et al*[46]	2020 Egypt	Cross-sectional; n: 80 (40 children on regular hemodialysis, 40 controls); age: 6-15; sex: Patients: 65% F; Controls: 55% F	Sleep quality Daytime sleepiness Sleep pattern	Kidney dysfunction	**Questionnaires** (modified ESS) and **Polysomnography**	Children with end-stage renal disease had: -Lower sleep efficiency in (92.84 ± 6.62) compared to controls (96.12 ± 3.60) ($p=0.007$) -Shorter sleep duration in minutes (358.2 ± 40.8) than controls (438.5 ± 42.7) ($p<0.001$) - Higher AHI (4.8 ± 3.0) than controls (2.7 ± 2.1) ($p=0.004$)

						- Higher periodic limb movement index -Higher Excessive daytime sleepiness (15%) than controls(2.5%)
Abdelmaksoud *et al*[47]	2021 Egypt	Case-control n: 120 (60 Type 1 Diabetes mellitus, 60 controls); age: 10–18 (13.57 ± 1.76); sex: TID: 30% F; Controls: 36% F	Sleep quality, Daytime sleepiness, Sleep architecture	Glycemic control, insulin resistance and microvascular complications in Type 1 Diabetes Mellitus (TID)	**Questionnaire** (ESS-CHAD) and **Polysomnography**	Adolescents with T1D had significantly lower ESS-CHAD (P < 0.001) than controls. Adolescents with T1D had significantly lower sleep efficiency and REM sleep with higher SOL and AHI (all $p < 0.001$) compared to controls. T1D + microvascular complications associated with lower sleep efficiency and less REM sleep. Insulin sensitivity positively correlated with sleep efficiency; and negatively correlated with periodic limb movement index (PLMI).
Micklesfield *et al*[48]	2021 South Africa	Longitudinal (Birth-to-Twenty Plus) cohort n: 3273; age: 12 – 18; sex: 52% F	Sleep duration,	Body composition outcomes, Physical activity, Sedentary lifestyle	**Questionnaire** (school night and weekend bedtime and waketime)	Sex differences in sleep patterns: - Females: 65% slept 8 hours or less on school nights
El Refay *et al*[49]	2021 Egypt	Cross-sectional n: 765; age: 4-16;	Sleep disturbance	Psychological stress, Anxiety symptoms	**Questionnaire** (SDSC)	Overall mean Sleep Disturbance Scale for

		sex: 53.3% M				Children score (SDSC): 44.6 ± 11.72. Symptoms suggestive of sleep disturbance 65.6%. Disorders of initiating and maintaining sleep: 168 (33.4%) Excessive somnolence: 79 (15.7%). Prevalence of Anxiety: 48%. A significant positive correlation was found between family income affection, SDSC, and anxiety (p= 0.001 and 0.004).
Wolde *et al*[20]	2022 Ethiopia	Cross-sectional n: 799; age: 10-19 sex: 52.1% M	Sleep quality	Inhalant, khat, and internet use disorders; Physical illness	**Questionnaire** (PSQI)	38% had poor sleep quality (PSQ). Adolescents with physical illness had about 4 times higher odds of association with PSQ (AOR = 3.76 and inhalant use disorder (AOR = 1.98), internet addiction (AOR = 3.33), and khat use disorder (AOR = 1.74), were positively associated with PSQ.
Moustakbal & Maataoui[50]	2022 Morocco	Cross-sectional n: 730; age: 15.64 ± 1.66 sex: 55.5% F	Sleep duration, Sleep quality, Sleep onset latency	Mobile phone use	**Questionnaire** (PSQI)	Mean total sleep time = 8.01 hours. Poor sleep quality: 72%

						More in older adolescents, those from rural areas, and those with physical or psychological health issues.
Elfaki *et al*[51]	2023 Sudan	Cross-sectional n: 921; age: 10–15 sex: 57.9% F	Sleep duration	Metabolic syndrome	**Questionnaire**: Sleep duration was derived by asking how long on average the adolescents slept during the night in the past six months. For adolescents aged <14 years, short sleep is defined as <9 h and normal sleep as 9–11 h. For adolescents aged 14–15 years, short sleep is <8 h and normal sleep is 8–10 h.	Prevalence of short sleep was 55.0%. Males: 53.1% Females: 56.5%
Guembri[52]	2023 Tunisia	Cross-sectional n: 72; age: U14:13.44±0.5 sex: 100.0% F	Sleep quality, Daytime sleepiness, Sleep disorders	Sleep hygiene, balance, strength, agility, and maximum aerobic speed	**Questionnaires** (PSQI, ISI, and ESS)	Poor sleep quality: - 61.1% for the U14 group - 63.8% for the U17 group Mild insomnia: 8.3% of U14 players and 8.4% of U17 players Excessive daytime sleepiness: - 19.4% of the U14 group - 22.3% of the U17 group
Mlouki *et al*[53]	2023 Tunisia	Cross-sectional n: 404; age: 16-18 (17.18±1.5) sex: 63.0% F	Daytime sleepiness, Sleep quality	Adverse childhood experience	**Questionnaire** (PSQI)	A high prevalence of sleep disturbance which is defined as PSQI>5: 94%. Prevalence of internet addiction: 80.2%.

Olorunmoteni *et al*[54]	2023 Nigeria	Cross-sectional n: 448; age: 10-19; sex: 57.8% F	Sleep quality	School schedule, Mental Health	**Questionnaire** (PSQI)	High prevalence of poor sleep quality: 85% (particularly in older adolescents). Insufficient sleep: 55.1% on weekdays, 34.8% on weekends.
Tantawy *et al*[55]	2023 Egypt	Cross-sectional n: 20; age: 6-18 (10.22 ±3.28) sex: 63.3% M	Sleep disordered breathing (OSA)	Pulmonary function in sickle cell anaemia (SCA)	**Questionnaire** (modified STOPBANG) and **Polysomnography**	60% of participants had Obstructive Sleep Apnea (OSA) Six children (20%) had a high risk for obstructive sleep apnea (OSA), while nine (30%) were at intermediate risk. Children with moderate to severe OSA had significantly higher tricuspid regurgitation, velocity ($p = 0.007$) and left middle cerebral artery flow velocity(higher stroke risk) ($p = 0.049$) when compared to those with AHI < 5.

n: sample size; OSA: Obstructive Sleep Apnea Syndrome; CSHQ: Children Sleep Habits Questionnaire; ESS: Epworth Sleepiness Scale; PSQI: Pittsburgh Sleep Quality Index; ISI: Insomnia Severity Index; SDSC: Sleep Disturbance Scale for Children; SCA: Sickle cell anaemia; ADHD: Attention Deficit Hyperactivity Disorder; BMI: Body mass index; LD: Learning Difficulty; y: years; h: hours; M:Males; F: Females.

Table 3.6.: Risk and protective factors for sleep health and the association of sleep with academic performance, mental health and cardiometabolic risk among adolescents in Africa

References	Year Country	Risk and Protective Factors - **Sociodemographic factors** - **Electronic device use** - **Adverse childhood experiences**	Association of Sleep with - Academic Performance - Mental Health and - Cardiometabolic Risk	Association of Sleep Disorders with - Interventions and - Medical conditions
Galal *et al*[30]	2001; Egypt	**Sex difference:** Significantly, more boys than girls perceived their sleep health as very healthy	---	---
Reid *et al*[31]	2002 South Africa	**Sleep hygiene**: 72% consumed caffeinated beverages the day before the survey. 8% took sleep medications 62% needed an alarm or wake-up call (external aids) in the morning	---	---
Bénéfice *et al*[32]	2000; Senegal	**Puberty:** No association between sleep variables and puberty status **Season:** Earlier bedtimes, waketimes and shorter sleep duration were found in June (dry and earlier sunset season) than in March suggesting an association between sleep and seasonal change of daylight. No association between sleep habits and pubertal status	Significant relationship between BMI and sleep habits. Girls with lower BMI had longer sleep.	---
Garnier & Bénéfice[33]	2006; Senegal	**Sex differences:** - Girls: mean sleep duration of 8 hours and 45 minutes; longer than boys ($p < 0.05$) - Boys: mean sleep duration of 8 hours and 9 minutes; Lower sleep efficiency than girls: (88.3%);	---	---
Cockcroft *et al*[34]	2009; South Africa	---	---	Significantly higher sleepiness in medicated children in the early afternoon (13:00 to 15:00) un-medicated children suggesting

				medication influenced sleepiness post-administration.
Aalouane *et al*[29]	2011; Morocco	**Sex:** Females had earlier waketimes, more WASO and more nightmares.	About half of the adolescents thought that the quality of their sleep influenced their academic performance	---
Fakier & Wild[35]	2011; South Africa	**Substance use**: Sleep problems independently associated with tobacco, cannabis and inhalant use when learning difficulties were taken into account.	Adolescents with learning difficulties had more sleep problems	---
Alabi *et al*[36]	2012; Nigeria	---	Daytime sleepiness during class and poor memory more prevalent in snorers Obesity: present in 33.5% of snorers	---
Borchers & Randler[37]	2012 Côte d'Ivoire	Sex is the most influential factor with 9.9% of variance explained on Partial eta-squares followed by residence (8.3%), age (6.2%), religion (4.5%) occupation (2.9%). **Sex**: Girls got up earlier and had an earlier midpoint of sleep (weekdays & weekends) **Residence:** Urban adolescents had later waketimes, earlier bedtimes, longer sleep duration and later midpoint of sleep on weekdays. **Age:** Earlier waketimes, later bedtimes and later midpoint of sleep on weekdays among older adolescents. On weekends, older adolescents had later bedtimes but rise times remained similar **Religion:** Muslims had earlier waketimes on weekdays and weekends. **Occupation:** In-school adolescents had later waketimes and longer sleep duration on weekends than out-of-school (working) adolescents.	---	---
Maduabuchi *et al*[15]	2014 Nigeria		---	---
Lachman[38]	2014	---	---	---

	South Africa			
Sanya *et al*[39]	2015 Nigeria	**Age**: Older teenagers had later bedtimes and waketimes **Sex** did not significantly influence sleep habits.	---	---
Balogun *et al*[17]	2017 Nigeria	**Sex and age:** No significant association with self-rated sleep quality. Higher proportion of respondents with good sleep quality (70.8%) in junior secondary school.	---	---
Christoph *et al*[40]	2017 Uganda	**Residence:** (rural/urban) not associated with a difference in self-reported sleep duration and subjective sleep quality	Lower BMI percentile was associated with being female, living in a rural community, being physically active and having better subjective sleep quality	---
Peter *et al*[41]	2017 Nigeria	**Screen use:** 62.9% watched TV or played video games, and 42.8% used social media, both associated with delayed sleep onset and reduced sleep quality. 73.4% were exposed to **generator noise** till bedtime 31.2% consumed stimulants 27.8% felt hungry at bedtime	---	---
Regaieg *et al*[42]	2017 Tunisia	**Age:** 72.5% of older adolescents had short sleep duration (<8 hours/day) **Sedentary lifestyle:** 75.4% of those with sedentary activities of >4 hours/day had short sleep duration	The prevalence of obesity and the waist circumference value was significantly higher for short sleepers as compared with normal sleepers (p=0.04 and p=0.05) respectively)	---
Cheikh *et al*[43]	2018 Tunisia	---	Better subjective sleep quality, reduced fatigue, and muscle soreness after MEL ingestion compared to placebo.	Nocturnal ingestion of melatonin (MEL-10 mg) significantly increases TST and sleep efficiency (SE) while reducing SOL and decreasing nocturnal WASO MEL administration resulted in higher durations of stage N3 sleep and REM sleep while reducing N1- and N2-sleep

				stage durations.
Olorunmoteni *et al*[14]	2018 Nigeria	**Screen use:** Correlation between nighttime use of computers, cell phones, TVs and shorter sleep durations. Lower social class and public school attendance are associated with longer weekday sleep duration; **Female sex**, **younger age,** and living in a polygamous family are linked to longer sleep on weekends. Room sharing in 74.6%, but not associated with sleep duration on weekdays or weekends	---	---
Carneiro *et al*[44]	2019 Cape Verde (CV) & Mozambique (M)	**Screen use:** Both samples showed a correlation between watching television to fall asleep and higher CSHQ scores, indicating that electronic use before bed is associated with sleep disturbances Higher rates of co-sleeping were found among the Cape Verde sample than the Mozambique sample (63% vs 29%)	---	---
Hanson et al[45]	2019 South Africa	**Maternal education:** was significantly associated with sleep trajectories (Adolescents whose mothers had secondary school education were more likely to be in the 7h or 8h per night sleep trajectory compared to the 9h per night trajectory	Sedentary behaviour and sleep trajectories did not cluster together with the physical activity domains	---
El-Baroudy *et al*[46]	2020 Egypt	---	---	Higher prevalence of sleep disorders in children with end-stage renal disease (ESRD) compared to healthy children
Abdelmaksoud *et al*[47]	2021 Egypt	---	There was a negative correlation between insulin sensitivity score and total sleep time (p = 0.002); and a positive correlation with sleep efficiency ($p < 0.001$). There was a negative correlation between glycated haemoglobin levels and sleep efficiency($p<0.001$) and REM sleep(p= 0.003) and a positive correlation with sleep onset latency (p = 0.005)	T1D + microvascular complications associated with lower sleep efficiency and less REM sleep Sleep is associated with Glycemic control, insulin resistance and microvascular complications in TID

Micklesfield *et al*[48]	2021 South Africa	**Sex differences in sleep patterns:** - **Males:** 35% slept 9 hours or more on school nights\ - **Females:** 65% slept 8 hours or less on school nights	In adjusted analysis, male adolescents who sleep ≥9 h/night on weekdays had significantly lower -BMI (95%CI: -1.4 to -0.5) -Waist circumference (95% CI − 3.7 to − 1.1) - %Body fat (95%CI − 2.8 to − 0.1) than those who sleep <8 hr /night. There is no association between weekday sleep in females and anthropometry and body composition.	---
El Refay *et al*[49]	2021 Egypt	**increased screen time:** One of the factors associated with the prevalence of sleep disorders	Significant positive correlation was found between family income affection, SDSC, and anxiety (p= 0.001 and 0.004)	Psychological stress, Anxiety symptoms
Wolde *et al*[20]	2022 Ethiopia	**Substance use:** Adolescents with inhalant use disorder (AOR = 1.98), internet addiction (AOR = 3.33), and khat use disorder (AOR = 1.74) were positively associated with PSQ.	Adolescents with physical illness had about 4 times higher odds of association with PSQ (AOR = 3.76	--
Moustakbal & Maataoui[50]	2022 Morocco	**Age:** The prevalence of poor sleep quality increases with increasing age (58% for early adolescents, 76% for middle adolescents and 84% for late adolescents. **Screen use:** Shorter TST in mobile phone users (7.37± 1.50 h) than non-users (8.22±1.38 h) (*p* <0.001). **Health**: Poor sleep quality is more in adolescents with physical or psychological health issues **Residence:** Adolescents in urban areas had: - Better sleep quality 66% vs 77% (*p*=0.002) - Later bedtime (11:15 pm vs 10: 30 pm: (p<0.001) - Later wake time (7:51 am vs 7:08 am (*p* <0.001)	There was no significant difference between sleep duration and categories of BMI (underweight, normal and overweight) though adolescents with overweight had a lower sleep duration (7.35±1.43 h).	---

		- No significant difference in TST (p = 0.623)		
Elfaki *et al*[51]	2023 Sudan	**Age:** Higher prevalence of short sleep duration (<8h) in early adolescents: 62.09% **Gender:** No significant difference in short sleep duration between boys and girls **Residence:** No significant difference in short sleep duration between rural and urban dwellers	Higher prevalence of short sleep among overweight and obese adolescents ($p < 0.05$). The prevalence of metabolic syndrome (MetS) among short sleepers was 2.8% with the highest risk of MetS observed at less than 6.5 hours of sleep per night	---
Guembri[52]	2023 Tunisia	**Age:** No significant differences were shown between U14 and U17 players in sleep quality, insomnia and daytime sleepiness scores	---	---
Mlouki *et al*[53]	2023 Tunisia	Significant link between adverse childhood experiences (ACEs) and sleep disorders, **Internet addiction:** Partial mediator in the relationship between ACEs and sleep disorders Cyber addiction had a major mediation effect among females (% mediation =30 %)	Elevated risk of sleep disturbances in adolescents facing more adversities	---
Olorunmoteni *et al*[54]	2023 Nigeria	**School schedule and school type**: Statistically significant association between difficulty in concentrating in class and sleep quality as well as sleep duration on both weekdays (p = .012) and weekends (p = .031) Earlier school closing times were associated with better sleep quality. Attending a private school, longer school hours or extra activities was associated with poor sleep quality	Depression showed statistically significant association with poor sleep quality (p< .001)	---
Tantawy *et al*[55]	2023 Egypt	---	---	Sickle cell anaemic children with moderate to severe OSA had significantly higher tricuspid regurgitation, velocity (p = 0.007) and left middle cerebral artery flow velocity

				(higher stroke risk) (p = 0.049) when compared to those with AHI < 5

n: sample size; D: Sleep disorders; DS: Daytime sleepiness; SA: Sleep architecture with polysomnography; SDB: Sleep disordered breathing; SD: sleep duration; ST: sleep timing; SV: sleep variability; SQ: sleep quality; SR: Sleep regularity; SP: Sleep pattern; OSA: Obstructive Sleep Apnea Syndrome; CSHQ: Children Sleep Habits Questionnaire; ESS: Epworth Sleepiness Scale; PSQ: Poor sleep quality; PSQI: Pittsburgh Sleep Quality Index; ISI: Insomnia Severity Index; SDSC: Sleep Disturbance Scale for Children; SCA: Sickle cell anaemia; ADHD: Attention Deficit Hyperactivity Disorder; BMI: Body mass index; LD: Learning Difficulty; y: years.

3.7.2 Types of sleep health studied and prevalence of sleep problems

3.7.2.1 Sleep Health

The most studied sleep health dimensions among adolescents were sleep duration (13; 41.9%) and sleep quality (10; 32.3%). Nine studies (29.0 %) examined daytime sleepiness among African adolescents, while four studies (12.9%) focused on sleep-disordered breathing and two studies on sleep regularity or circadian rhythms. Some of the studies reported findings on multiple sleep health measures as shown in Table 3. The mean sleep duration reported in most studies was less than the recommended 8-10 hours for adolescents.[56] Also, there was weekday-to-weekend variability in the adolescents' sleep duration as reported by some of these African studies (Table 3). Maduabuchi *et al*, in Southeastern Nigeria, reported a significant increase ($p<0.001$) in sleep duration on weekends to a mean of 8.65 (2.07) hours from a weekday mean of 7.84 (1.9) hours.[15] Olorunmoteni *et al* in Southwestern Nigeria reported a mean weekday sleep duration of 7.25 ± 0.86 hours, with short sleep duration on weekdays among 44.4% of the respondents while only 5.5% of the adolescents had insufficient sleep on weekends.[14] Among adolescents in Northern Nigeria, Peter *et al* reported a similar sleep duration ranging between 7.13 and 7.19 hours, though the weekday-weekend difference in sleep duration was not investigated.[41] Sanya *et al* in northcentral Nigeria reported a mean sleep duration of 9.33 ± 2.29 h during school days with no report of the adolescents' weekend sleep duration. In South Africa, Reid *et al* studied the sleep behaviour of adolescents on a school day through specific questions on their sleep characteristics in the preceding night.[31] Sleep duration was assessed by determining the time in bed (TIB).[31] The adolescents reported significantly shorter ($p<0.001$) TIB during weekday school nights (453±70 minutes) when compared to weekend nights (476±128 minutes).[31] The sleep insufficiency experienced by adolescents on school nights was further shown by their reported mean sleep onset latency of 17 minutes, with 45% sleeping within ten minutes, probably because of a high sleep pressure.[31] The mean total sleep time for a study involving adolescents in Morocco was 8.01±1.46 hours.[50] In another Moroccan study, Aalouane *et al* reported a mean sleep duration of 7.75 hours on weekdays, 9.60 hours on weekend nights and 9.50 hours during the summer holidays.[29] There was no other study on the sleep pattern of adolescents during holidays. In total, the available studies on sleep duration showed insufficient sleep during school nights with a tendency to catch up sleep during weekends or holidays.

Sleep quality was assessed with the PSQI in seven studies (22.6%)[15,17,20,50,52–54] while four studies utilised self-reported subjective sleep quality measures including one study which used a visual analogue scale.[31] The prevalence of poor sleep quality, as defined by PSQI>5, reported among two adolescent populations studied in Nigeria was 50.2%[17] and 85%.[54] Similar high prevalence of poor sleep quality was reported in Morocco, with 72% of adolescent participants having poor sleep quality.[50] In Ethiopia, the prevalence of poor sleep quality among the 799 adolescents studied was 38%[20] while Mlouki *et al* reported a prevalence of 94% in a study involving Tunisian adolescents.[53] However, there were some other studies where PSQI was utilised, but they did not provide an overall prevalence of poor sleep quality. Instead, they described sleep problems measured by different components of the PSQI.

Among 825 South African adolescents, Reid *et al* reported that later bedtimes were associated with male gender, napping and taking medication and later wake times, with higher total sleep time (TST), higher sleep onset latency (SOL), more awakenings, and later bedtimes.[31] The timing of the sleep-wake cycle/chronotype of the African adolescents was only reported by Borchers *et al* who utilised the midpoint of sleep to determine the sleep-wake cycle of 588 adolescents in Côte d'Ivoire. The midpoint of sleep on weekdays (1:26 ± 00:30) was significantly earlier than that of the weekends at 1:37 ± 00:42 (t=-9.09; $p <$ 0.001).[37] The adolescents also had an average sleep duration of over 8 hours which is within the recommended guidelines for adolescent sleep duration.[37] Among a sample of 72 female handball players in Tunisia, the prevalence of poor sleep quality was reported at 61.1% for the U14 group and 63.8% for the U17 group.[52] Furthermore, excessive daytime sleepiness was reported by 19.4% of the U14 group and 22.3% of the U17 group, and mild insomnia was observed in 8.3% of U14 players and 8.4% of U17 players.[52] Thus, the majority of reports on sleep quality showed a high percentage of poor sleep quality among African adolescents.

3.7.3 Sociodemographic Disparities in Sleep Health

3.7.3.1 Rural-urban residence:

There were some disparities in the reported sleep patterns and sleep health components of African adolescents, especially among various socio-demographic groups and urban-rural locations. Christoph *et al*, in a sample of 148 adolescents, reported that rural Senegalese adolescents had a longer sleep duration but lower sleep efficiency compared to their urban counterparts, highlighting possible environmental influences on sleep health.[40] Also, Galal *et al*, in a sample of 863 Egyptian adolescents reported that 33.3% of urban adolescents and 29.5% of rural adolescents reported having a sleep disturbance, though this was not statistically significant.[30] In another study among Moroccan adolescents by Moustakbal,[50] urban adolescents had significantly later bedtimes (11:15 pm vs 10:30 pm), sleep latency, and wake-up time (7:51 am vs 7:08 am) than their rural counterparts, but there was no significant difference in total sleep time**.** Furthermore, the study reported that adolescents from rural areas, older adolescents, and those with physical or psychological health issues were more likely to report poor sleep quality.[50] Conversely, Borcher *et al*[37] reported that in Côte d'Ivoire, urban adolescents had shorter sleep duration, evidenced by later bedtimes and earlier wake times than rural adolescents. Therefore, most of the studies reported longer sleep duration but poorer sleep quality among rural adolescents compared to urban adolescents though the pattern of bedtimes and wake times between rural and urban adolescents appear inconsistent across studies probably from differences in living conditions or contexts.

3.7.3.2 Sex

Differences in sleep health and sleep behaviour by sex were reported in some studies as shown in Table 4.[14,21,26,28,29] Egyptian adolescents showed variations in self-reported sleep perceptions, with boys perceiving their sleep health as healthier compared to girls.[30] Similarly, Aalouane *et al*, in a study of a group of adolescents in Morocco reported that females had earlier wake times, more wake after sleep onset (WASO) and more nightmares than the males, though this was not associated with lower sleep duration.[29] Also, Micklesfield *et al* reported a short school-night sleep duration of ≤8h/night among 65% of female adolescents in the South African adolescent population studied while 35% of the boys slept 9 hours or more on weekdays.[48] Conversely, in Nigeria, being female was reported as an independent predictor of sufficient sleep on weekends, though both boys and girls had short sleep on weekdays.[14] Borchers *et al*[37] reported that female adolescents had earlier bedtimes, wake times, and an earlier midpoint of sleep than male adolescents. Sanya *et al* reported no sex difference in the sleep parameters studied among Nigerian adolescents.[39] However, in a longitudinal study of South African adolescents of the Birth-to-Twenty Plus Cohort, school night sleep decreased across adolescence in males but remained stable in female adolescents while weekend sleep duration remained stable from age 12 to 17 years for both genders.[45] The adolescents had four school-night sleep trajectories in males and 3 trajectories in females, with two of these trajectories being in the insufficient sleep duration range (7 hours and 8 hours trajectories. On weekends, there were 3 sleep trajectories identified for male adolescents and 4 trajectories for female adolescents with only one trajectory below 8.5 hours of sleep duration for both genders.

3.7.3.3 Age:

Some consistencies emerge in the association between sleep health and adolescents' age (Table 4). Younger age was reported to be associated with longer sleep on weekends among a population of Nigerian adolescents.[14] Borchers *et al* found later bedtimes, earlier wake times, shorter sleep duration and later midpoint of sleep on weekdays with increasing age among adolescents in Côte d'Ivoire.[37] Also, they reported later bedtime on weekends among older adolescents while wake times on weekends remained similar across all age groups.[37] Similarly, Sanya *et al* reported later bedtimes and delayed wake time among older adolescents compared to the younger ones though there was no significant difference in sleep duration on weekends across the age groups.[39] Among 730 Moroccan adolescents, poorer sleep quality (using PSQI) was observed with increasing age.[50] Also, 72.5% of older adolescents in a Tunisian study had short sleep duration (<8 hours/day).[42] Overall, the younger adolescents reported having better sleep health, longer sleep duration, earlier bedtimes, earlier wake times, better sleep quality and earlier chronotypes than the older adolescents, especially on weekends.

Other sociodemographic variables associated with sleep health in different studies include social class, parental education, adolescent's student status (full-time work vs full-time student) and religion. Olorunmoteni *et al* reported the association of lower social class and public school attendance with longer weekday sleep duration among Nigerian adolescents, highlighting socioeconomic disparities in sleep patterns.[14] In addition, this study showed the contribution of household dynamics where living in a polygamous family or room sharing was associated with longer sleep on weekends. This may indicate varying household factors that can affect sleep routines and serve as potential for the development of sleep disorders. Interestingly, the Nigerian study's finding showed a reverse association compared to what is seen in the US where socially disadvantaged people were reported to have poorer sleep health. Carneiro *et al* found that more educated parents had children with better sleep habits in Cape Verde and Mozambique.[44] In a longitudinal study involving South African adolescents, maternal education was significantly associated with sleep characteristics.[45] Adolescents having a mother who completed secondary school education had more likelihood of being in the 7 or 8-hour-per-night trajectory compared to being in the 9-hour-per-night trajectory in the boys.[45] Furthermore, in-school adolescents in Côte d'Ivoire slept longer and woke up later on weekends than working adolescents ($p = 0.002$) but there were no significant weekday differences in the sleep pattern or in-school versus working adolescents.[37] The Côte d'Ivoire study also reported that Muslim adolescents had earlier bedtimes, earlier wake times, and earlier chronotypes than Christian/ other religion adolescents, though both Muslims and Christians had shorter sleep duration on weekdays and weekends compared to adolescents of other religions (all $p < 0.05$).[37] Thus, sociodemographic factors contribute to sleep health disparities in African adolescents though there were conflicting findings for many of the studied variables as shown in Table 4.

3.7.4 Pattern of disordered sleep

The reported pattern of disturbed sleep among African adolescents varied widely. Symptoms of sleep disorders reported included insomnia, excessive daytime sleepiness, sleep-disordered breathing, and different forms of parasomnias. Among 20 studies where the pattern of disordered sleep was provided or discussed, the values differed based on the component of sleep health studied or the type of sleep disorders' classification system used. The findings in Table 4 show the prevalence of adolescent sleep problems and disorders across different regions in Africa. The prevalence of difficulty in initiating sleep (4.8%) and difficulty falling asleep (5.9%) were reported by Maduabuchi et al,[15] who also reported that unusual sleep behaviours (parasomnias) were notably prevalent among Nigerian adolescents with sleepwalking in 6.3%, sleep talking in 15.1%, bruxism in 7.6%, and restless legs syndrome in 6.5%.[15] Among adolescents, sleep-related breathing disorders were reported in some countries. In Nigeria, the prevalence of snoring, assessed through self-report, was 34.2%.[36] Also 34.1% of those who were snoring reported associated restlessness during sleep, while 39.5% of the snorers exhibited cessation of breathing.[36] In another Nigerian study, 4.8% of the adolescents were aware of having sleep-disordered breathing.[41] Some studies did not provide the prevalence of specific types of sleep disorders but provided the overall prevalence of sleep disorders among the adolescent population studied. In Tunisia, a high prevalence of sleep disorders was reported in 94% of the 414 adolescents studied, though the specific types of sleep disorders were not described.[53] Also, a significant proportion (65.6%) of the 765 Egyptian adolescents studied by El Refay *et al* had symptoms of sleep disorders, with problems initiating and maintaining sleep identified as the most prevalent symptoms.[49] Thus, the most common types of sleep disorders reported among the African adolescents in this review are insomnia (disorders of initiating or maintaining sleep), parasomnias and sleep-related breathing disorders.

3.9 Sleep disorders in adolescents with specific co-morbidities

The prevalence of sleep disorders among adolescents with specific medical conditions varied. A high prevalence of sleep disorders was reported among adolescents with end-stage renal disease (ESRD) undergoing hemodialysis as studied by El-Baroudy *et al*.[46] Among children with sickle cell disease (SCD) in Egypt, 60% of participants had sleep apnea (defined as an apnea-hypopnea index of > 1 event/hour) when compared with the children without SCD.[55] Among the 30 children with SCD studied, Tantawy *et al* found an association between sleep apnea in the studied cohort and an increased risk of pulmonary hypertension and stroke as evidenced by abnormal cerebral blood flow velocities.[55] The children with various comorbidities studied had poor sleep health indices compared to the healthy controls studied.

Table 4 presents findings on the association of sleep disorders with specific comorbidities from various studies conducted in different countries and settings. In a study conducted by Alabi et al in Nigeria, obesity was identified as a comorbidity associated with sleep disorders in children. They found that obesity was present in a significant percentage of children with sleep disturbances. Obesity was present in 33.5% of snorers, and 17.5% showed signs of adenotonsillar hypertrophy, which can contribute to sleep disordered breathing. Abdelmaksoud *et al* in Egypt studied adolescents with Type 1 Diabetes (T1D) and highlighted a lower sleep efficiency in these individuals compared to healthy controls, emphasising the impact of T1D on sleep health.

3.7.5 Risk and Protective Factors for Adolescent Sleep Health in Africa

3.7.5.1 Description of Sleep Hygiene Practices

Several studies reported individual-level factors such as sleep hygiene practices among adolescents as shown in Table 4. These included bedtime screen use such as watching television to fall asleep, higher consumption of caffeinated beverages, and the use of sleeping pills at night, all potentially contributing to sleep disturbances.[31,44] In Nigeria, 80.9% of adolescents were reported to use electronic devices before sleep in a cohort of urban-dwelling adolescents.[14] Another study in northcentral Nigeria reported that 10% of teenagers make phone calls at night while 5.5% browse the internet and use computers at night, probably reflecting variations in access to electronic devices and/or internet services. In a comparative study between adolescents in Cape Verde and Mozambique, higher rates of co-sleeping were found among the Cape Verde sample than the Mozambique sample (63% vs 29%) with a higher prevalence of sleep problems also in the Cape Verde sample.[44] Furthermore, the consumption of stimulants (chocolate/coffee/any other stimulant) at night was reported in one-third of a cohort of Nigerian adolescents especially among late adolescents (49.1%).[41] Similarly, Reid *et al* reported caffeinated beverage consumption on the day before the study in 72% of the 825 South African adolescents studied while 8% of them regularly use sleeping medications to enhance their falling asleep at night.[31]Among Ethiopian adolescents, inhalant use disorder and khat use disorder was reported to be associated with poor sleep quality (AOR = 1.74).

3.7.5.2 Nighttime Electronic Device Use

The data from various studies on the association of sleep health with nighttime electronic use revealed varying degrees of association between late-night electronic device use and adolescents' sleep health (Table 4). Across the studies by Carneiro *et al*, Moustakbal *et al*, Olorunmoteni *et al.*, and Peter *et al*, nighttime use of electronic devices was common among adolescents with the prevalence of bedtime television use being 30% in Mozambique[44] and 33% in Cape Verde,[44] while electronic device use within one hour of bedtime was reported as 78% among Moroccan adolescents,[50] as well as 62.9%[41] and 80.9%[14] in two Nigerian studies. Some of the studied adolescents were reported to frequently use social media within one hour of bedtime.[41] Peter *et al* also reported that the adolescents' use of electronic devices within an hour of bedtime was more common among late adolescents, but this did not show any significant association with sleep problems.[41] Moustakbal *et al* reported a statistically significant association between the use of mobile phones late at night and poor sleep quality, measured with PSQI (p = 0.001).[50] Among Ethiopian adolescents, internet addiction contributes to increased odds of poor sleep quality.[20] These studies highlight that the use of electronic devices such as television, mobile phones and video games before sleep can predispose adolescents to delayed sleep onset and sleep disturbances.

3.7.5.3 Adverse Childhood Experiences

The study by Mlouki *et al* conducted in Tunisia among in-school adolescents revealed a significant association between adverse childhood experiences (ACEs) and sleep disorders.[53] The research highlighted that adolescents who had faced adversities were at higher risk of experiencing sleep disturbances (Table 4). The study also showed ACEs-predicted sleep disturbances with a mediation effect of internet addiction (% mediation =18.3 %, p = 0.005), particularly in female adolescents (% mediation =30 %).[53]

3.7.5.4 Household and Environmental Factors

Aside from co-sleeping as a factor that can contribute to adolescents' sleep problems, sleeping in a noisy environment was also reported as a likely barrier to healthy sleep. In the study by Peter *et al*, the main source of environmental noise was the noise from a power-generating set which was reported in 73.4% of the adolescents.[41] The contribution of other environmental factors such as household overcrowding, neighbourhood crimes and access to electricity did not appear well studied.

3.7.5.5 School Schedules:

Two studies from Nigeria reported on the association of sleep health with school schedules among adolescents (Table 4). Olorunmoteni *et al* found that later school closing times and private school attendance were associated with poorer sleep quality.[54] The majority of the adolescents also (81.7%) reported having difficulty concentrating in class due to poor sleep quality- associated daytime sleepiness.[54] Furthermore, 52% of adolescents in a Moroccan study reported that preoccupation with school-related demands contributed to their sleep disturbances.[29]

3.7.6 Association between Sleep and Diverse Outcomes

3.7.6.1 Sleep health and academic performance

The data from Table 4 presents a diverse array of studies examining the relationship between sleep disorders and academic performance across different regions and populations. Despite the variations in study design, settings, and demographics, certain similarities emerge from the findings. Alabi *et al*[36] (Nigeria) found that daytime symptoms like falling asleep during class and poor memory were more prevalent in snorers, with these symptoms contributing to disrupted sleep and a resultant poor academic performance. Moreover, the study by Fakier *et al* in South Africa highlighted that adolescents with learning difficulties had more sleep problems than those without learning difficulties.[35] Also, adolescents who had more sleep problems were more likely to use substances such as tobacco, alcohol, methamphetamine, cannabis, inhalants, cocaine, and ecstasy. with a negative effect on their academic performance.[35] This suggests a vicious cycle of relationship between sleep problems, academic performance and substance use. Aalouane *et al* also reported an association between short sleep duration and poor academic performance.[29] While some studies emphasize the detrimental effects of sleep disorders on academic performance, others highlight the importance of good sleep quality for better academic outcomes. This was supported by about half of a cohort of Moroccan adolescents who reported that the quality of their sleep influenced their academic performance.[29]

3.7.6.2 Sleep and mental health of adolescents

The study by Olorunmoteni *et al* conducted in Nigeria among in-school adolescents aged 10-19 years found a significant association between poor sleep quality and depression severity (assessed using the Patient Health Questionnaire-9).[54] Among adolescents with prior adverse childhood experiences (ACE), a threefold increased risk of sleep disturbances was observed for those experiencing three or four ACEs while those experiencing at least five ACEs had increased the adjusted odds of sleep disorders by 11.9 folds.[53] Furthermore, internet addiction was reported to mediate the association between ACE and sleep.[53]

3.7.6.3 Sleep health and cardio-metabolic risk

The data from Table 4 shows findings from various studies on the association of sleep health with cardio-metabolic risk (CMR) factors such as basal metabolic rate (BMR), physical activity, and body mass index (BMI) in different adolescent populations across Africa. The studies reveal both similarities and contradictions in their results. Alabi *et al.* from Nigeria found a significant association between snoring and obesity.[36] Furthermore, Micklesfield *et al* in South Africa, associated consistent physical activity and sufficient sleep with more favourable body composition outcomes, including lower BMI.[48] Similar findings of association of longer sleep and lower BMI was found among girls in Senegal studied over three years.[32] Conversely, Hanson *et al* in South Africa noted a decline in physical activity levels and a rise in sedentary behaviour, particularly in female adolescents, which may lead to less favourable cardiometabolic risk outcomes.[45] Furthermore, the study by ElFaki *et al* in Sudan highlighted a significant association between short sleep duration and metabolic syndrome components among early adolescents.[51] Tantawy et al. in Egypt, found an association between higher obstructive sleep apnea severity and worse cerebrovascular health markers, especially in sickle cell disease patients with moderate to severe OSA.[55] This finding contrasts with the study by Christoph *et al*. in Uganda, which associated higher BMI percentile with being female, living in a rural community, having a higher physical activity frequency and better subjective sleep quality, though the overall BMI in their study was quite low such that higher BMI may actually reflect better health, rather than detrimental health in certain contexts.[40] However the overall BMI average in this study was low and it may be that higher BMI reflected more favorable health in this context. In Tunisia, Regaieg *et al*[42] reported a higher prevalence of obesity (based on BMI and waist circumference) among adolescents with short sleep duration. The data from these studies demonstrate a complex interplay between sleep health, physical activity, and body composition. All studies except two[55,51] utilised anthropometry measures such as BMI and waist circumference. While some findings align in associating physical activity and sufficient sleep with better body composition outcomes, there are contradictions regarding the impact of factors like sedentary behaviour, noise exposure, and specific health conditions on sleep and cardiometabolic risk.

3.7.7 Association between sleep disorders and medical interventions

Two studies provided information on the effect of medication on the sleep health of adolescents as shown in Table 4. The studies by Cockcroft et al. in South Africa and Cheikh *et al.* in Tunisia both focused on interventions and their effects on sleep health in specific populations.[34,43] Cockcroft *et al.* conducted a comparative study on children with ADHD, comparing those taking methylphenidate with those not on medication.[34] They found that methylphenidate influenced the timing of sleepiness and perception of sleepiness but did not affect the overall prevalence of sleep disorders.[34] In their study, significantly higher levels of daytime sleepiness were reported by the parents of the un-medicated children from 13:00 and 15:00 hours when compared to the parents of medicated children, suggesting that treatment of ADHD may result in better sleep of the adolescents and their parents and thus lower daytime sleepiness in the parents/caregivers.

Cheikh et al. studied the effects of melatonin on sleep in adolescent judo competitors by the administering 10mg of a sustained-release formulation of melatonin after intensive late-evening exercise.[43] He found that the adolescents in the melatonin group had significantly improved total sleep time, sleep efficiency, and other sleep parameters, as well as cognitive performance and subjective sleep quality, compared to the adolescents in the placebo group.[43]

Both studies show how medication (methylphenidate and melatonin) can influence sleep-related outcomes in their respective populations. While medication like methylphenidate may influence sleepiness post-administration without affecting the prevalence of sleep disorders, melatonin shows promise in improving various aspects of sleep health in adolescents who have disrupted sleep due to intense physical activity.

3.8 DISCUSSION:

3.8.1 Principal Findings

There has been a gradual increase in the number of studies on adolescent sleep in Africa, especially in the past ten years, though the total of 31 papers on adolescent sleep in Africa obtained from the inception of the searched databases reflects overall poor attention to sleep in African adolescents. Though most of these studies were questionnaire-based cross-sectional studies, they provide the baseline information necessary to advance adolescent sleep research in the continent. Across studies, inadequate sleep duration during weekdays was common among adolescents, often compensated by longer sleep duration on weekends. Additionally, the prevalence of poor sleep quality (ranging from 50.2%[17] to 85%[54]) and the diverse range of sleep disorders reported across various African regions, emphasize the global burden of sleep-related issues. Sociodemographic variables also contributed to the adolescents' sleep health. Younger age was a protective factor for good sleep health while inconsistencies on the role of gender in adolescent sleep health were noted across regions. The use of electronic devices at bedtime was a major risk factor for sleep disturbances, especially among urban-dwelling adolescents. Also, substance use was associated with poor sleep health. Furthermore, adverse childhood experiences and the burden of schoolwork were reported in some studies as risk factors for adolescent sleep disturbances. Poor sleep was associated with poor academic performance, depression, and anxiety, as well as adverse cardiometabolic risk factors. However, the majority of the available studies on sleep and CMR studied only measures of adiposity such as BMI and waist circumference while only one study[51] utilised multiple measures of CMR such as blood pressure, serum glucose, and serum lipids.[51] Moreover, medications for the treatment of medical conditions such as methylphenidate, used for attention deficit hyperactivity disorder, may be associated with daytime sleepiness. In contrast, the use of melatonin was reported to improve sleep and performance in adolescents after exercise.

Among the multi-dimensions of sleep health, sleep duration, quality and timing were the most studied among African adolescents. Sleep duration of adolescents on weekdays was below the recommended range in some questionnaire-based studies,[14,15,41] while many demonstrated catch-up sleep on weekend nights.[14,15,37,41] Using objective sleep measures (polysomnography), El-Baroudy *et al* reported a sleep duration of less than 8 hours among children with end-stage renal disease and healthy controls, though their sample size of 40 cases vs 40 controls was small.[46] The ideal sleep duration in adolescents is above 8.5 hours per night[57] with sleep duration >10 hours being reported as long sleep duration. However, only a few studies had a weekday mean sleep duration above the cut-off,[39,40] while the weekend mean sleep duration, as well as the proportion of adolescents with insufficient sleep, improved over the weekend in most studies.[39,41] This pattern is similar to reports for adolescents in different parts of the world.[58,59,60] Gamble *et al* reported delayed sleep/wake schedules and late weekend wake time, especially among adolescents with a high dose of bedtime electronic device use.[60] The 'catch-up' sleep on weekends occurs as a result of the need to pay back the accumulated sleep debt over school days, and it's often referred to as "social jetlag".[61] Thus, as in other parts of the world, insufficient sleep is prevalent among African adolescents. A Nigerian study has reported inadequate sleep duration among Nigerian children akin to that observed in other parts of the world.[62] Our recent study has shown that this was particularly true for urban adolescents, who systematically reported lower sleep duration than rural adolescents in Southwest Nigeria.[63] African adolescents are equally affected by insufficient sleep and will require further studies and tailored interventions.

Furthermore, poor sleep quality was reported by more than half of adolescents in all the studies on sleep quality. Some studies reported a prevalence of more than three-quarters of adolescents with poor sleep quality[54]. The reported excessive daytime sleepiness in these studies is mostly a reflection of the poor quantity and quality of nighttime sleep in these adolescents. Aside from daytime sleepiness reflecting inadequate nighttime sleep, it also gives concern about the likelihood of disruptions in daytime functioning among adolescents.

Across diverse settings and populations, several studies reported a high prevalence of sleep disturbances among adolescents. For instance, studies in Cape Verde, Mozambique, Nigeria, South Africa, and Tunisia all highlighted significant percentages of adolescents experiencing sleep issues. The most prevalent sleep problems were insomnia, parasomnias and sleep-related breathing disorders. There were no results on the prevalence of hypersomnia, though the only case report was on Kleine-Levin syndrome which has recurrent episodes of hypersomnia as one of its features.[38] The lack of reports on disorders of hypersomnia like narcolepsy may be due to the non-availability of sleep laboratories and diagnostic facilities for polysomnography, multiple sleep latency tests and cerebrospinal fluid orexin assays for confirming narcolepsy.[19] Various disparities were noted in the pattern of risk and protective factors affecting sleep health. Using the socioecological model, these factors are better considered as individual, family, neighbourhood and school-level factors.[64] As described by Hale et al, sleep health is socially patterned and contributes significantly to overall health through multilevel factors.[2] At the individual level, inadequate sleep hygiene practices were the most reported in this review. Notably, bedtime use of electronic devices impaired sleep health significantly across different African adolescent populations.[14,41,44,49,50,53] The findings from these studies align with previous research on the negative impact of evening exposure to electronic devices on sleep quality and circadian rhythms among adolescents in other climes.[60,65,66] In a study among 1,184 Australian adolescents, a dose-response relationship was reported between bedtime use of electronic devices and delayed bedtime as well as lag in bedtime.[60] Delayed bedtimes due to electronic use, in turn, lead to lower sleep duration as adolescents still need to wake up early to go to school. Furthermore, a systematic review involving 49 studies from Western countries identified artificial light exposure at night, excessive screen time and social media use to be associated with problems falling asleep (longer sleep onset latency) and poor sleep quality among early and middle adolescents.[67] Exposure to light from screens, especially in the evening, leads to circadian phase delays[68,69] and to disruptions in the circadian clock and subsequent sleep disturbances.[67] Although there were variations in the types of electronic devices used by adolescents in this review, the association with adverse sleep health outcomes were common to all. However, further studies on the duration of electronic device use, the content of screen and internet use and the behavioural factors that potentiate this harmful sleep hygiene practice are needed to develop appropriate interventions.

Another, individual-level factor affecting adolescent sleep health is substance use. Generally, the association between substance use and sleep disturbances has been reported as bidirectional with many substances causing sleep problems and having a sleep disorder or disturbance also contributing to the tendency of abusing substances.[23] The adverse effects of khat use on sleep and overall well-being have been reported among pregnant women[22], adults[70], and college students[21] in Ethiopia. This is further supported by the findings of a qualitative study on the pattern, determinants and effects of substance use among Ethiopian students where a student was quoted as saying “I won’t be able to sleep if I didn’t smoke shisha. I chew khat daily and if I don’t smoke shisha, I won’t be able to sleep”.[71] Hence, there is a need for attention to be given to reducing substance use when developing sleep-promoting interventions for adolescents, especially in East Africa. Studies are also needed on the contribution of substance use to adolescent sleep health in other African regions.

Furthermore, this review identified other individual-level factors such as age and gender that may be associated with adolescent sleep. Younger adolescents had better sleep than older adolescents. On the other hand, there were disparities in the association between gender and sleep health. While some studies reported a lack of difference in sleep health between genders,[39,1749] a few found a longer sleep duration[14,33] and earlier wake times[29,37] in females while another study reported a shorter sleep duration in boys.[48] Hence, there are inconsistencies in the association between gender and adolescent sleep health in the African studies. These inconsistencies may probably be because of physiological factors, diverse cultural practices, and gender roles that may affect sleep patterns.[14] However, the gender differences reported in the studies were inconsistent. The differences in sample sizes and methods with respect to sampling and data analysis may have contributed to the disparities in findings. Thus, further studies, especially qualitative studies, are needed to explore and understand the role of gender and cultural factors on the adolescents’ sleep health.

Another risk factor for poor sleep in adolescents identified in this review is adverse childhood experiences (ACEs) which were traumatic events such as emotional abuse, physical abuse and witnessing violence at home or in the community during childhood.[53] The authors report that internet addiction could act as a partial mediator in the relationship between ACEs and sleep disorders, particularly among female.[53] In line with these findings, the research found that adolescents with past ACEs may develop psychosocial issues that may make them more interested in virtual relationships, and compensatory internet-based habits such as gaming. Thus, internet addiction can lead to poor sleep and may result in sleep disorders. Bhandari *et al.* reported that poor sleep quality was associated with internet addiction, and depression, suggesting a potential interplay between these factors.[72] A systematic review also emphasized the need to establish the connection between internet addiction and sleep problems, further supporting the idea that internet-related behaviour can influence sleep health. Overall, these studies underscore a consistent pattern of association between adverse childhood experiences, internet addiction, and sleep disorders. The research collectively suggests that internet addiction may serve as a mediator in the relationship between ACEs and sleep disturbances, particularly affecting the sleep quality of individuals, especially adolescents, who face adversities and engage in excessive internet use.

There were disparities in the role of family and household in influencing adolescents' sleep. The finding of a significant impact of maternal education on adolescents' sleep trajectories reported by Hanson *et al* shows the importance of parental factors such as their education on adolescent sleep. Previous studies in other regions of the world have investigated parental education as well as parental work schedule, parental sleeping habits, sleep-related beliefs and adolescent-parent relationships. Olorunmoteni *et al*. in Nigeria associated lower social class and public school attendance with longer weekday sleep duration, suggesting that as socioeconomic status improves, sleep patterns in adolescents may become worse. This unexpected association between higher SES and poorer sleep quality may be due to lower parental oversight over bedtimes and/or higher availability of light-emitting devices at night in high SES households. The findings suggest a complex interplay between socioeconomic status, cultural norms, and individual behaviours in influencing sleep health. Moreover, the studies emphasize the importance of considering a holistic approach that integrates socioeconomic factors into interventions aimed at improving sleep health.

The school-related factors shown to have an association with poor sleep health included a perceived high burden of schoolwork and late closing time.[26,54]bThe social jetlag described earlier could contribute to the development or exacerbation of sleep disorders like insomnia or circadian rhythm disorders.[73] The findings from the studies in this review align with existing research which demonstrated that delaying school start times provided better opportunities for sleep and improved sleep and daytime functioning in adolescents.[74] While research consistently emphasizes the importance of adequate sleep for adolescent well-being, variations in sleep patterns, school schedules, and associated factors exist across different

African populations. Hence, interventions targeting school schedules, including school start and end times, in African communities may help improve the sleep health of adolescents.

The association of school schedules with adolescent sleep was further shown by studies showing that poor sleep was associated with poor academic performance. Also, adolescents who had more sleep problems may have an increased tendency to use substances with a negative effect on academic performance, suggesting a vicious cycle of relationship between sleep problems, academic performance and substance use.[22,35] This indicates an interrelationship between harmful individual habits, poor sleep and poor academic habits. While some studies emphasize the association between poor sleep and academic performance or learning,[35,36,54] others highlight the importance of good sleep quality for better academic outcomes.[29] It is important to further explore factors that jointly affect sleep and academic performance in adolescents as possible targets towards improving the overall well-being of adolescents.

The study by Olorunmoteni *et al* conducted in Nigeria among in-school adolescents aged 10-19 years found a significant association between poor sleep quality and depression severity. This aligns with findings, which highlighted the link between exposure to stressors and negative mental health outcomes such as depression and anxiety disorders.[75] The association between depression and poor sleep has been described as bidirectional such that poor sleep is associated with higher risk of developing depression while depression is associated with higher risk of developing poor sleep. The cross-sectional nature of the Nigerian study makes it impossible to establish the direction of the relationship between sleep and mental health in adolescents. Hence, longitudinal studies are required to further explore the association between sleep patterns and mental health in adolescents, and the impact of insufficient sleep on various mental health issues of African adolescents. Such further studies will help to improve the understanding of the various factors affecting adolescents' sleep and mental health for developing comprehensive strategies to address mental health issues associated with sleep disorders during this sensitive part of neurodevelopment that constitutes adolescence.

3.8.2 Strengths and weaknesses:

Our study is the first to map available evidence on adolescent sleep in Africa. It contributes significantly to the literature on the global adolescent population by providing a comprehensive overview of the few studies on adolescent sleep in Africa. The scoping review highlights the trend and geographical distribution of these studies, the various aspects of sleep health and sleep disorders that have been studied, the risk and protective factors previously identified as contributing to adolescent sleep health and the association between the adolescent and various health and scholastic outcomes. We utilised a comprehensive search strategy to search five databases with the largest selection of indexed journals from Africa and included all relevant articles from the inception of each database, since there was no previous review of publications on adolescent sleep health in Africa. Our review identified the gaps for improving adolescent sleep in Africa: the need for studies across all African countries, especially from the East Africa region which had the least number of studies; the need for studies on hypersomnia, circadian disorders, and other forms of sleep disorder that requires polysomnography; the impact of infectious diseases like malaria, trypanosomiasis, human immunodeficiency virus on adolescent sleep health in Africa; the association between sleep health and chronic health conditions like sickle cell anaemia, chronic kidney diseases and mental health conditions. The fostering of such studies will be helped by the formation of an African sleep network, and the collaboration of sleep researchers for multi-African countries studies for a better understanding of some unique aspects of sleep health in the African context such as the association of climate change and malaria prevention. We sought peer-reviewed publications in English, French, Spanish, Portuguese, Italian and Arabic languages since the official languages in most African countries are anglophone, francophone, lusophone and Arabic, to obtain as many studies as are available on adolescent sleep health in Africa.[26] We did not consider grey literature, blogs, web pages, books, conference presentations. Also, the quality of the publications and the strength of the evidence from the studies were not analysed in our review. This limitation of our study can be improved upon by a systematic review and meta-analysis to provide data on the strength of synthesized evidence.

3.8.3 Unanswered questions and future research

Our findings reveal that adolescent sleep health is understudied in Africa despite the previously reported high prevalence of sleep disturbance or disorders. The diversity in methods and instruments used to obtain data on the prevalence and pattern of these sleep health issues may explain the differences in the prevalence and types of sleep disturbances obtained from different studies. Most reviewed studies utilised questionnaires for studying sleep rather than objective measures such as polysomnography and actigraphy. Furthermore, the questionnaires used to measure sleep characteristics were a mix of validated questionnaires and simple stand-alone questions about sleep. As a result, comparisons of findings are difficult. Hence, we recommend the use of validated sleep questionnaires or instruments, after systematically checking those instruments (developed elsewhere in the world) for internal consistency (Cronbach's alpha) and construct validity (using factor analysis)when used in the African context.[76] Questionnaires refined to better capture the local specificities on adolescent sleep in Africa should be developed (such as incorporating sleep disturbances from mosquitoes, and/or from the use of specific stimulants like khat in Eastern Africa, or cultural habits which may underlie aspects such as gender differences in sleep), to capture more accurately the multi-dimensions of sleep health in the African context Furthermore, the array of risk and protective factors identified in the studies reviewed, especially the rural-urban disparities in the factors, shows the need to study the determinants to explore these factors further, especially with mixed-methods designs that involve the adolescents themselves. In order to institute centres of excellence in adolescent sleep health in Africa, there is a need for more capacities for objective sleep measurements using actigraphy and polysomnography and the establishment of paediatric sleep laboratories for both diagnostic and therapeutic purposes.

3.8.3 Conclusion

Overall, while there are variations in sleep patterns and disorders among different populations, common themes of inadequate sleep, a pattern of catch-up sleep on weekends, and the impact of socioeconomic factors underscore the need for comprehensive interventions to promote better sleep health among African adolescents. Also, there is a need for collaborative multi-country research with stronger research designs, longitudinal and/or mixed-methods studies and the use of objective sleep measures to provide stronger evidence for adolescent sleep issues in Africa.

3.9 Conflicts of interest:

The authors do not have any conflicts of interest to disclose.

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The next chapters report on the studies conducted among in-school adolescents in urban and rural communities in Southwestern Nigeria. These studies aimed to answer some of the gaps identified from our scoping review. We utilized standardized sleep questionnaires to study the multidimensions of sleep health among in-school adolescents and compared the sleep characteristics between rural and urban adolescents (Chapter 4). We also determined the association between the measured sleep characteristics and cardiometabolic risk factors (Chapter 5).

In order to ensure the validity of the questionnaire to be used among rural and urban Nigerian adolescents, we tested the internal consistency using Cronbach's alpha and construct validity of the Pittsburgh Sleep Quality Index (PSQI) as presented in Appendix 4. Among urban adolescents, we obtained a Cronbach's alpha of about 0.63 which we regarded as adequate internal consistency, while that of the rural adolescents was slightly lower (0.54). We also carried out a test of the construct validity of the PSQI by running a factor analysis as shown in Appendix 4. We found reasonable construct validity in both urban and rural adolescents.

We further utilized actigraphy combined with sleep diaries to substantiate the findings we obtained from sleep questionnaires. Chapter 6 presents our findings from this actigraphy study which was conducted in a subset of the adolescents involved in the questionnaire study.

In each of these chapters, we present the tables/figures of the results all at the end of the results section.

CHAPTER 4

MULTI-DIMENSIONS OF SLEEP HEALTH AMONG IN-SCHOOL ADOLESCENTS IN RURAL AND URBAN AREAS IN SOUTHWESTERN NIGERIA

4.1. PUBLICATION DETAILS

This chapter is presented as a publication on the Multi-dimensions of sleep health among in-school adolescents in rural and urban areas in Southwestern Nigeria. This protocol was published with the Sleep Health Journal (BMJ) Open. The journal is open-access and the manuscript is presented as in the published form without amendments. The information about the journal where the work was published is presented in Table 4.1

Table 4.1 Journal Information where the Protocol was published

Title of publication	Multi-dimensions of sleep Health among in-school adolescents in rural and urban areas in Southwestern Nigeria
Authors	Oluwatosin Eunice Olorunmoteni,[1,2] F Xavier Gómez-Olivé,[3,4] Biliamin O. Popoola,[5] Adesegun O. Fatusi,[6,7] Karine Scheuermaier.
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Issue	8
DOI number	doi: 10.1136/bmjopen-2022-067373

4.2 Author Contributions

Table 4.2 shows the contributions to the publication made by each author

Table 4.2: Author Contributions to the paper titled Adolescent Sleep Health in Africa: a Scoping Review Protocol

	Olorunmoteni	Gómez-Olivé	Popoola	Fatusi	Scheuermaier
Conceptualisation	√	√	√	√	√
Project administration	√		√		√
Methodology	√	√	√	√	√
Initial data analysis	√		√		
Writing – original draft	√		√		
Writing – reviewing and editing	√	√	√	√	√
Visualization	√	√	√	√	√
Supervision		√		√	√

4.3 Associated Documentation:

The documentation associated with this publication are included as appendices and are labelled:

- Appendix 4: Cronbach Alpha and Factor Analysis for Sleep Questionnaire

- Appendix 5: Ethical Clearance Certificate from the Health and Research Ethics Committee of the University of Witwatersrand

- Appendix 6: Ethical Clearance Certificate from the Health Research Ethics Committee of the Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria

- Appendix 7: Permission from the Osun State Ministry of Education

- Appendix 8: Published article on the Multidimensions of Sleep Health among In-school Adolescents in Rural and Urban Areas in Southwestern Nigeria

- Appendix 9: Participant Information and Informed Consent forms
- Appendix 10: Study Questionnaire relevant
- Appendix 11: Scoring Template for the Pittsburgh Sleep Quality Index

4.4 Published Article:

TITLE PAGE

Multi-dimensions of sleep Health among in-school adolescents in rural and urban areas in Southwestern Nigeria

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CONTRIBUTORS

OEO, KS, AOF, and FXGO designed the study. OEO received funding from CARTA to help run the study. OEO supervised data collection and performed statistical analyses. All authors contributed to the write-up of the manuscript and have approved the final version of this manuscript**.**

ABSTRACT

Introduction: Previous studies have focused on sleep inequities among disadvantaged populations in high-income countries. However, little is known about the differences in the dimensions of sleep health among adolescents in Africa. We aimed to compare the multi-dimensions of sleep health in adolescents living in rural versus urban communities in Nigeria.

Methods: This cross-sectional study enrolled adolescents aged 13-19 in six rural and six urban schools in Osun State, Nigeria. We measured the prevalence of poor sleep quality (Pittsburgh Sleep Quality Index score>5), daytime sleepiness (Epworth Sleepiness Scale for Children and Adolescents score>10), and risk for sleep apnea (Teen STOPBANG). We compared the sleep health variables between the rural and urban populations using logistic regression, and adjusting for confounders.

Results: Of the 900 participants (51% rural; 59% female; average age(SD)=15.1(1.4) years), 79% per cent had short sleep duration (<8.5 hours), 14.9% had poor sleep quality, 9.6% excessive daytime sleepiness and 9.8% risk of sleep apnea. Urban adolescents had a higher prevalence of poor sleep quality (p=0.004) short sleep duration (p<0.001), and a higher prevalence of daytime sleepiness (p=0.044), and risk of sleep apnea (p=0.006) compared to rural adolescents. The odds of having poor sleep quality (OR=1.95 (CI=1.19-3.18) p=0.008) and daytime sleepiness (OR=2.25 (CI=1.25-4.05) p=0.007) increased by about 2-fold among urban compared to rural adolescents in adjusted analyses.

Conclusion: Adolescents in rural communities had better sleep health than adolescents in urban communities. There is a need to develop interventions to improve the sleep quality and overall sleep health of adolescents in urban areas.

4.5 Introduction

Poor sleep constitutes a public health issue as it affects about half of the global population,[1] and is of particular concern among adolescents.[2–7] The period of adolescence is characterized by changes in physical, physiological and psychological functions,[8] a physiological delay in adolescents' circadian and sleep phases with shorter sleep duration during weekdays.[4,9] Poor sleep in adolescents has been associated with risky behaviour, poor academic performance, adverse mental health and adverse cardiometabolic health.[10–12] Therefore, adolescent sleep issues can be linked to other aspects of their health and well-being.

In 2014, Buysse[13] defined sleep health as "a multidimensional pattern of sleep-wakefulness, adapted to individual, social, and environmental demands, that promotes physical and mental well-being". This definition has improved the understanding of poor sleep health as a "cause of adverse health outcomes, rather than just a consequence or symptom of ill health".[14–16] Sleep health, as defined by Buysse, comprises the following sleep characteristics: duration, quality, timing, variability or regularity, efficiency and continuity.[13,14] However, sleep apnea is a notable contributor to poor sleep and adverse health outcomes,[17,18] including cardiovascular health, especially among obese adolescents.[19,20] Sleep health disparities reflect the socioeconomic inequities at the family, school, community levels. Addressing sleep health disparities, by intervening on those socioeconomic inequities could in turn improve overall health.[14,21]

In high-income countries, the problems associated with poor sleep among adolescents have been studied across racial, social and ethnic groups. Reports indicate that poor sleep exists among both rural and urban-dwelling adolescents,[22,23] but the determinants of poor sleep are not the same in these populations. In urban populations, adolescent sleep-related problems include sleep deprivation and excessive daytime sleepiness (DS).[22,24] with shorter SD and later bedtimes among urban-dwelling adolescents compared to rural-dwelling adolescents.[25–27] In urban settings, technology use at bedtime, artificial light exposure(ALAN), environmental noise, school-related demands, and family dynamics were the major determinants of sleep health[22,24,28] In rural communities, poor sleep has been linked to poverty, low access to public – including health – amenities, and adverse mental health.[25,27,29] However, lack of access to electricity – more prevalent in rural communities - has been associated with earlier bedtimes.[30,31] Thus, there seemed to be a disparity in the determinants of sleep health problems among rural and urban-dwelling adolescents.

In Africa, the few available studies on adolescent sleep have focused on urban communities. In South Africa, Reid et al reported insufficient sleep among adolescents on weekdays with 40 % of them reporting excessive daytime sleepiness.[32] In Nigeria, rural-urban migration has led to the rural population decreasing from 70% to 46% of Nigeria's total population between 2000 and 2022.[33] [34] Urban communities in Nigeria have better access to social amenities,[34] access to the internet,[35] technology and electricity as well as alternative energy sources which are lacking in the rural communities.[34,35,36] In 2020, the World Bank reported a 55.4 % electricity access rate in Nigeria with a wide disparity (83.9%) in urban compared to rural areas (24.6%).[37] Technology use, electricity and artificial light at night (ALAN) disrupt the natural light-dark cycle and are associated with short sleep duration and later bedtimes.[38] These factors may contribute to a difference in sleep health characteristics between rural and urban dwellers in Nigeria.

The existing Nigerian studies also have additional limitations, including a concentration on only sleep quality or sleep duration components of adolescent sleep health.[5–7] The other components of adolescent sleep health such as daytime sleepiness and the risk for sleep apnea have not been studied individually or in combination. Therefore, this research aimed to compare the different components of sleep health, encompassing both sleep quantity and quality, between rural and urban in-school adolescents in Osun State, Nigeria. We hypothesized that adolescents living in rural communities have earlier bedtimes, earlier wake times, longer sleep duration, better sleep quality, and lower sleepiness than those living in urban communities.

4.6 Participants and Methods

4.6.1 Study design

This comparative cross-sectional study was conducted in six rural and six urban schools in Osun State, southwestern Nigeria. It was conducted from May to June 2022, among a representative sample of 900 adolescents who were selected using a stratified, multistage sampling technique.

4.6.2 Study setting

The site for the study is the Osun East Senatorial District, one of the three senatorial zones (regions) in Osun State, Nigeria. Osun State is one of the most populated southern Nigerian states with an estimated population of 5,521,901 and an estimated adolescent population of 810,558**.** Three local government areas (LGAs), namely Atakumosa West (representing rural), Ife North (representing rural) and Ife Central (representing urban), were selected from the 10 LGAs within the zone. We selected three LGAs out of the ten LGAs in the district based on their geographical proximity and ethno-religious similarities. Thus, the communities are only different based on their rural versus urban features. We selected three rural communities from each of the Atakumosa West, and Ife North LGA and one urban community (Ile-Ife) was selected from the Ife-central LGA. The rural and urban classification is based on the categorization of the communities within the State by the State Government. One school was selected from each rural community since most of these communities had only one or two secondary schools. Six schools were selected for the study in Ile-Ife, the urban community, using the proportion-to-population approach.

4.6.3. Study participants

The study participants were apparently healthy adolescents aged 13-19 years attending secondary schools in the selected rural and urban communities. Adolescents using sedative medications, anti-epileptics or narcotic preparations for any acute or chronic medical condition were excluded from the study using a screening questionnaire at the first school visit. The adolescent was asked to indicate which medication(s) they were taking for chronic treatment and the reasons for using such medications. We also excluded adolescents who have a known chronic medical condition.

Adolescents in the final class (senior secondary school 3 (SSS 3)) were also excluded because they were taking their final examinations during the time of data collection and would not be available for the data collection process. Finally, students living in boarding facilities within the schools were excluded due to the controlled day and night schedules in the school boarding facilities. The details of the screening, inclusion and exclusion process for the study participants are summarized in Figure 4.1.

4.6.4. Sampling procedures

The multistage sampling method was used for the selection of study participants. In the first stage, the list of secondary schools in each of the communities was obtained from the Education Office of the Osun State Ministry of Education. A stratified sampling technique was used to select six schools in the urban community and six schools in rural communities (a total of 12 schools). For the second stage, we obtained the list of classes in each selected school and a class was selected from each stratum of the classes from Junior Secondary School (JSS) 1 (age range is 10-13 years old in urban areas, 10-16 years old in rural areas) to Senior Secondary School (SSS) 2 (age range urban areas 14-16 years old; age range rural areas 14-19 years old) using the stratified sampling technique. In the third stage, the simple random sampling technique was used to select a predetermined number of students per class. This was done using a proportionate-to-population approach to ensure that the number of students selected per class was proportional to the class population.

4.6.5 Ethical considerations

We obtained approval for the study from the Health and Research Ethics Committee of the University of Witwatersrand (Reference number M210745) and the Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria (Reference number HREC NO: IPHOAU/12/1850). We also obtained permission to conduct the study from the State Education Authority, the School Principals and the Proprietors. We conducted the study in accordance with the Declaration of Helsinki. Written informed consent was obtained from each parent of the adolescents aged less than eighteen years, and the adolescents also gave signed assent. Adolescents aged 18-19 years gave written informed consent. During the first contact with the students, the lead researcher (OEO) provided general information about the study on the assembly ground in each school. Thereafter, the adolescents were given an information sheet about the study for delivery to their parents. The completed parental consent forms were collected from the adolescents the following day. Once parental consent and the adolescent's assent were obtained, we arranged for fully trained research assistants to be present at the school in the afternoons for one to two weeks for the data collection.

4.6.6 Data collection tools and measures

We used a pilot-tested questionnaire to obtain a self-report of information about the socio-demographic features, covariables and sleep characteristics of the rural and urban-dwelling adolescents. The questions on the socio-demographic information and other covariates were compiled by the research team based on earlier reported factors contributing to sleep characteristics, while the sleep health variables were obtained using standardised sleep questionnaires. Each adolescent was interviewed in the school setting to obtain their self-report of their sociodemographic features, sleep characteristics and other school schedule co-variables. The socio-demographic information obtained included the adolescent's age, sex, ethnicity, family type, nature of school and class. For analyses, we split age into 3 categories: Early adolescence: 13-14, Middle adolescence: 15-17, and Late adolescence: 18-19. We asked questions about the type of family, parental setting of bedtimes, bed sharing, ethnicity, nature of school, school start times, home-to-school commuting time, and the class in school.

Social class: We determined the social class of the respondents using the method described by Ibadin which utilizes the occupation and educational level of each parent in determining social class.[39] The occupation and the highest educational attainment of each parent are given a score from 1-6 based on the rating scale. The aggregate score for the respondents' social class was computed by dividing by four the score obtained from the occupation and the highest educational attainment of each parent (two, where only one parent or caregiver was available) and the derived value was approximated to the nearest whole number. The resultant score range of 1-6 was further used to classify the social classes into Upper class (scores 1 and 2), Middle class (scores 3 and 4) and Lower class (scores 5 and 6).

Sleep quality: The Pittsburgh Sleep Quality Index (PSQI) was used to assess sleep over a 1-month time interval. It has been validated among a Nigerian population of late adolescents and older young people in a university setting.[40] It comprises 19 items, which are used to generate component scores across the seven domains: subjective SQ, sleep latency, SD, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. A total score of 21 is obtainable from the composite scores from each domain. A cumulative score with Global PSQI >5 (out of 21) is considered poor SQ.

Sleep pattern: The sleep pattern of the adolescents was obtained from the components of the PSQI which contained questions about the adolescents' usual bedtime, wake time, total time in bed, self-reported SD and sleep efficiency. For the logistic regression analysis, we dichotomized SD in adolescents who slept <8.5h/night (insufficient SD) and those who slept ≥8.5h per night (sufficient SD). Among our study participants, there were only eight (8) adolescents in the long SD category using a cut-off of 10 hours. Therefore, we decided to merge the adolescents who had a SD of ≥ 8.5 hours in the sufficient SD category.

Daytime sleepiness: Daytime Sleepiness was assessed using the Epworth Sleepiness Scale for Children and Adolescents (ESS-CHAD, a modified form of the Epworth Sleepiness Scale (ESS) for children and adolescents). It comprises 8 items and has been validated in children and adolescents aged 12 to 18 years of age.[41] It assesses the presence and degree of DS in more or less active situations, on a Likert scale of 0-3 per item (with 0 representing the least chance of dozing and 3 representing the worst). The participant is asked to recall their situations over the past month in answering the questions, and a composite score is obtained from the sum of the score for each domain. A score of >10 for the ESS-CHAD is considered excessive DS.

Risk of Sleep Apnea: The modified STOP-Bang (teen STOP-Bang) questionnaire was used for assessing the risk of sleep apnoea in adolescents. It was modified from the STOP-Bang questionnaire for adults and validated for assessing sleep apnea in adolescents by inserting a question on academic difficulties in the place of age greater than 50 years.[42] A score of "1" was given for a "Yes" answer to each of the parameters which include Snoring, Tiredness, Observed apnea, blood Pressure ≥95th percentile for height and age, Body mass index (BMI) > 95th percentile, Academic problems and male gender. To obtain the BMI, we measured the adolescents' standing height (cm) to the nearest 0.01 cm with a standard calibrated stadiometer, and the body weight (kg) using a standard weighing scale to the nearest 0.1 kg with the adolescent dressed in minimal clothing. The BMI of each adolescent was calculated as weight (kg) divided by the square of the height (in meters). The BMI was then sub-classified into whether it was equal to or greater than the 95th percentile or not, using the growth chart of the World Health Organization (WHO).[43] We measured each adolescent's blood pressure on the right arm in the sitting position using an appropriate-sized cuff. Blood pressure was measured with three readings per participant to avoid any errors. Blood pressure was then classified as ≥95th percentile for height and age, or <95th percentile. The total score obtained with the Teen STOPBANG was classified as "no risk" if less than 3, while a total score of ≥3 was classified as a risk of sleep apnea (RSA).

4.6.7 Data analysis

The data obtained were analyzed using the Stata-15 software. Descriptive analysis was used for the socio-demographic characterization of the study participants and other relevant variables, such as age, sex, class, place of residence, and ethnicity. We categorized the adolescents based on their place of residence since the factors that may affect the adolescent goes beyond the school to the environment where they live and sleep. At the bivariate level, a Chi-square test was used to assess the association between the category of residence (urban and rural) and the categorical adolescent sleep health variables (SQ, excessive DS, SD<8.5h, and RSA). An independent Student t-test was used to assess the relationship between the category of residence and the continuous adolescent sleep health variables (bedtime, wake time, time in bed, SD and sleep efficiency). Multivariable analysis was undertaken using the binary logistic regression model to assess the relationship between urban-rural location and sleep health, with the following socio-demographic variables controlled for sex, age, social class, family type, nature of the school, class in school, ethnicity, parental setting of bedtimes, and bed-sharing. A p-value <0.05 was considered significant for all statistical analyses.

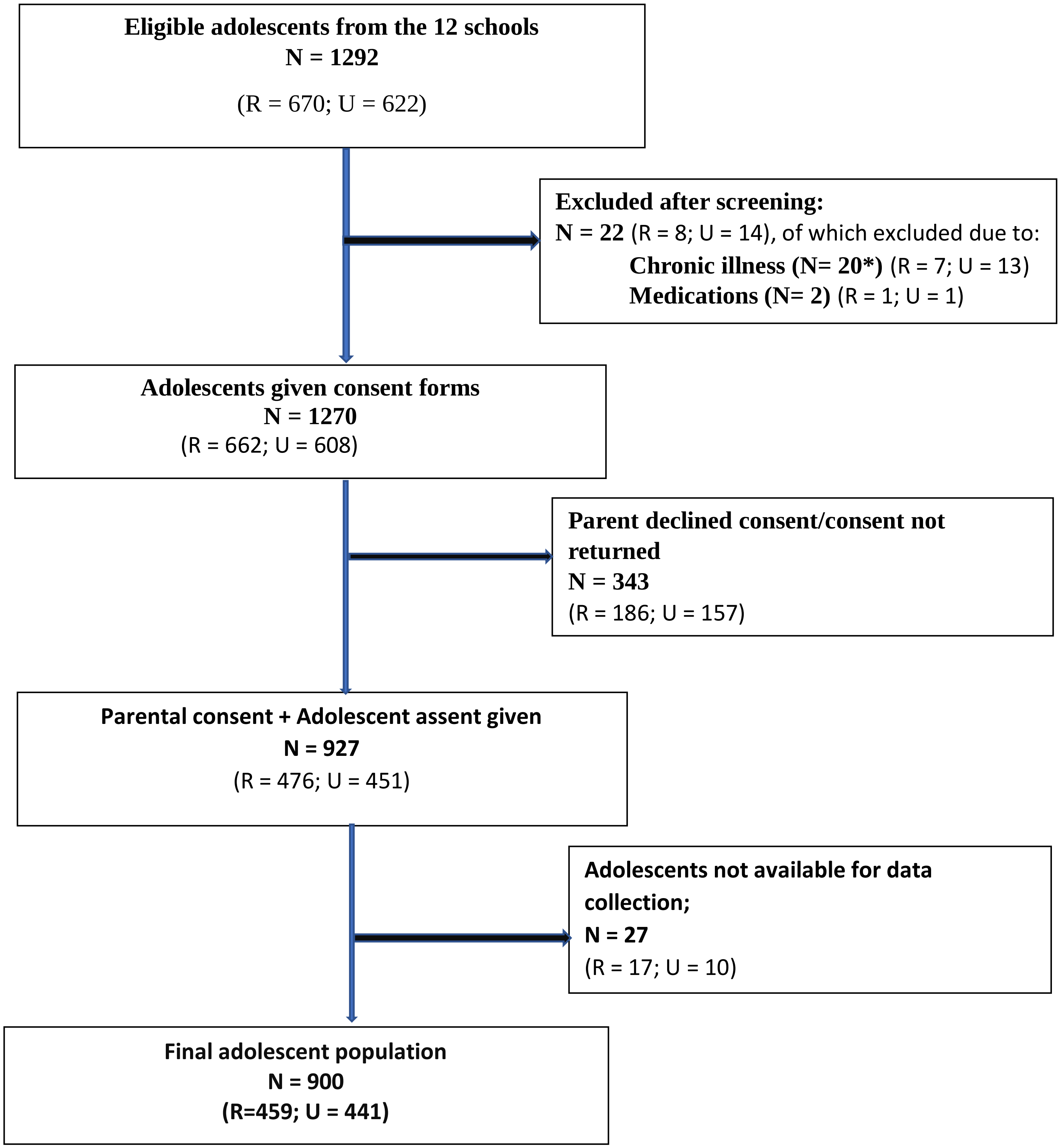

Figure 4.1.: Flow chart of participant recruitment process from the rural and urban schools. R= Rural; U= Urban.

4.7 RESULTS

4.7.1 Sociodemographic characteristics

Nine hundred adolescents participated in the study, and the mean age was 15.1±1.4. Fifty-one per cent were rural-dwelling adolescents, 59% were female, and 77.9% were in senior secondary school. The majority of our respondents were of Yoruba ethnicity – the dominant ethnic group in southwest Nigeria (Table 4.3.). The details of the sociodemographic characteristics of the respondents are shown in Table 4.3.

4.7.2 Sleep Quality

The overall prevalence of poor sleep quality was 14.9%. Compared to the 11.6 % of rural-dwelling adolescents with poor quality sleep, the urban-dwelling adolescents had a statistically significant higher prevalence of poor quality sleep of 18.4% (p=<0.004) (Table 4.4).

4.7.3 Excessive Daytime Sleepiness

Excessive daytime sleepiness was present in 86 (9.6%) of the in-school adolescents. Urban-dwelling adolescents had a significantly higher prevalence of daytime sleepiness compared to rural-dwelling adolescents (11.6% vs. 7.6%, p=0.044).

4.7.4 Sleep patterns

The mean ± SD sleep duration of the adolescents was 7:10 ± 1:40 h while their mean total time in bed was 7:40 ± 1:29 h (Table 2). The mean SD and the mean total time in bed were shorter among the urban-dwelling adolescents (p=<0.001). while the sleep efficiency was not different. The urban-dwelling adolescents also had later bedtimes compared to their rural-dwelling counterparts; while there was no statistically significant difference in their wake times (Table 4.4 and Figure 4.2).

4.7.5 Risk of Sleep Apnea

The risk of sleep apnea was recorded in 87 (9.8%) adolescents. Urban-dwelling adolescents had a significantly higher prevalence of sleep apnea compared to rural-dwelling adolescents (12.6% vs. 7.1%, p=0.006).

4.7.6 Multivariable analysis

Table 4.5 shows the crude and adjusted relationship between the type of residence (rural-urban) and sleep quality, daytime sleepiness, sleep duration and the risk of sleep apnea in adolescents. The adjusted odds of having poor sleep quality and excessive daytime sleepiness were higher by almost 2-fold among the urban-dwelling adolescents compared to those living in the rural communities. There was no statistically significant difference in the adjusted odds of reporting low sleep duration (<8.5h/ night) or risk of sleep apnea between the rural and urban communities (Table 4.5.).

The full multivariable model of the rural-urban difference is shown in Table 4.6 and shows other factors associated with sleep health. Female adolescents had higher odds of having poor sleep quality, but lower odds of having risk of sleep apnea than did male adolescents. Adolescents from lower and middle social classes had lower odds of having poor sleep quality and short sleep duration but higher odds of daytime sleepiness relative to those in the upper class. The odds of reporting poor sleep quality increased almost 3-fold in adolescents from single-parent families compared to adolescents from monogamous family settings. Adolescents from families where the parents were separated or from single-parent families had higher odds of having a risk of sleep apnea than adolescents from monogamous family settings. Furthermore, parental setting of bedtimes for adolescents was associated with lower odds of reporting poor sleep quality and daytime sleepiness. Finally, every later hour in the school end (closing) time, was associated with about a 1-fold increase in the odds of having poor sleep quality and daytime sleepiness while start times and commuting time were not associated with any sleep outcome.

Table 4.3.: Participant's characteristics in rural versus urban communities

Sociodemographic characteristics	Overall (N=900) N (%)	Rural (N=459) N (%)	Urban (N=441) N (%)	P
Sex				
Female	531 (59.0)	274 (59.7)	257 (58.3)	0.665*
Male	369 (41.0)	185 (40.3)	184 (41.7)	
Age in years Mean ± SD	15.1 ± 1.4	15.4 ± 1.4	14.8 ± 1.4	<0.001#
13– 14 (early adolescence)	323 (35.9)	123 (26.8)	200 (45.3)	<0.001
15 – 17 (middle adolescence)	535 (59.4)	308 (67.1)	227 (51.5)	
18 – 19 (late adolescence)	42 (4.7)	28 (6.1)	14 (3.2)	
Social class				<0.001
Upper	127 (14.1)	8 (1.7)	119 (26.9)	
Middle	323 (35.9)	137 (29.9)	186 (42.2)	
Lower	442 (49.1)	310 (67.5)	132 (29.9)	
Unclassified (no response)	8 (0.9)	4 (0.9)	4 (0.9)	
Ethnicity				0.002
Yoruba	814 (90.4)	429 (93.5)	385 (87.3)	
Others	86 (9.6)	30 (6.5)	56 (12.7)	
Family type				<0.001
Monogamous	672 (74.7)	308 (67.1)	364 (74.7)	
Polygamous	193 (21.4)	131 (28.5)	62 (14.1)	
Has single parents	22 (2.4)	13 (2.8)	9 (2.0)	
Have separated parents	13 (1.4)	7 (1.5)	6 (1.4)	
Parental setting of bedtime				0.892
Yes	296 (32.9)	150 (32.7)	146 (33.1)	
No	604 (67.1)	309 (67.3)	295 (66.9)	
Bed-sharing				<0.001
Yes	456 (50.7)	262 (57.1)	194 (44.0)	
No	444 (49.3)	197 (42.9)	247 (56.0)	
School start time (AM)†	7.7 ± 0.2	7.7± 0.2	7.7 ± 0.2	0.289
School end time (PM)†	3.5 ± 1.1	3.6 ± 1.3	3.4 ± 0.9	0.021#
Home-to-school commuting time (minutes)	24 ± 15	22 ± 14	26 ± 15	<0.001#
Nature of School				
Public	553 (61.4)	373 (81.3)	180 (40.8)	<0.001
Private	347 (38.6)	86 (18.7)	261 (59.2)	
Class in school				<0.001
JSS1-JSS3	199 (22.1)	127 (27.7)	72 (16.3)	
SSS1-SSS2	701 (77.9)	332 (72.3)	369 (83.7)	

*Chi-square test, #Independent t-test † units are decimal time (eg 7.5=7:30 am; 3.5=3:30 PM)

Table 4.4.: Comparison of sleep characteristics of Nigerian in-school adolescents in rural versus urban communities

Sleep variables	**Overall N (%)**	**Rural N (%)**	**Urban N (%)**	***P***
Sleep Quality (n=899)				
Good	765 (85.1)	406 (88.4)	359(81.6)	**0.004***
Poor	134 (14.9)	53 (11.6)	81(18.4)	
Excessive Daytime Sleepiness (n=900)				**0.044***
Absent	814 (90.4)	424 (92.4)	390 (88.4)	
Present	86 (9.6)	35 (7.6)	51 (11.6)	
Risk of Sleep apnoea				**0.006***
No risk	805 (90.2)	422 (92.9)	383 (87.4)	
Risk of apnoea	87 (9.8)	32 (7.1)	55 (12.6)	
	Mean ± SD	Mean ± SD	Mean ± SD	
Self-reported:				
Sleep duration (h:mm)	7:10 ± 1:40	7:23 ± 1:34	6:55 ± 1:44	**<0.001**#
Bedtime †	21.83 ± 1.19	21.57 ± 1.13	22.08 ± 1.18	**<0.001**#
Wake time †	05.45 ± 0.78	05.49 ± 0.76	05.42 ± 0.83	0.19#
Time in bed (h:mm)	7:40 ± 1:29	7:55± 1:23	7:24± 1:31	**<0.001**#
Sleep efficiency (%)	92.1 ± 13.2	92.3 ± 12.5	91.9 ± 14.0	0.570#

*Chi-square test, #Independent t-test. † units are decimal time (eg 7.5=7:30 am; 3.5=3:30 PM)

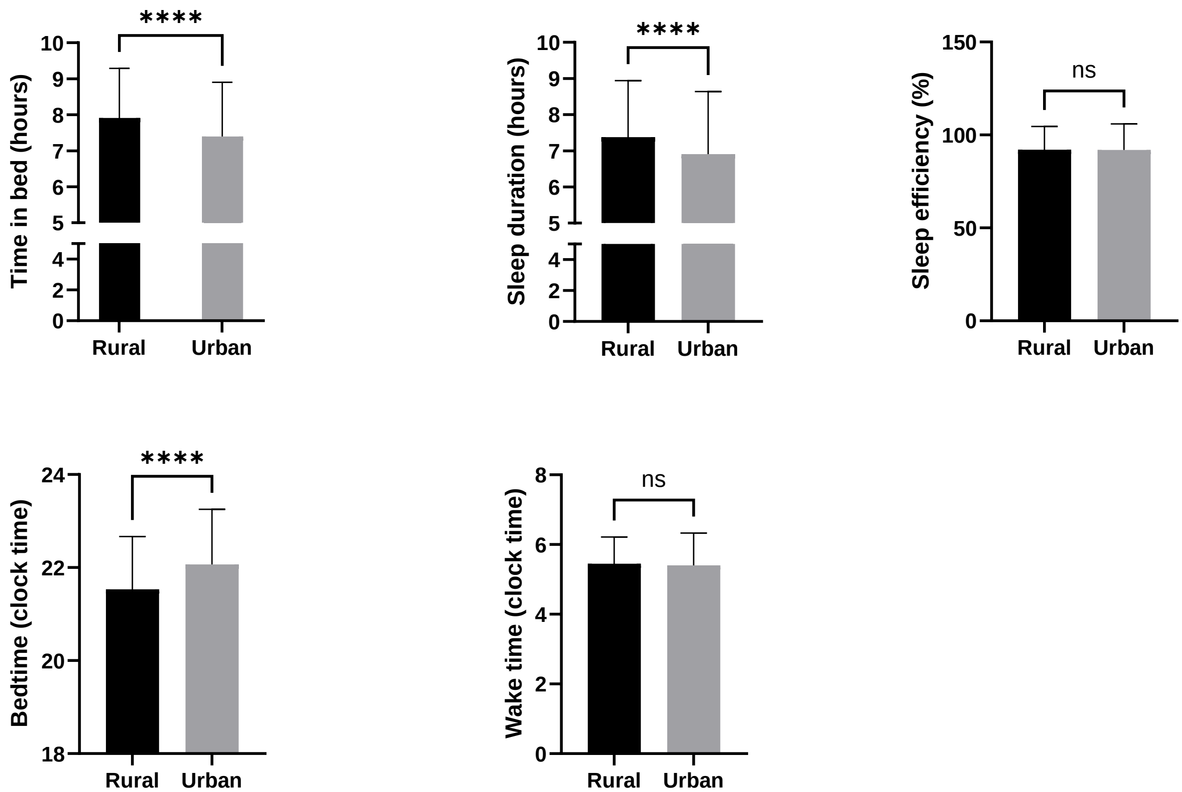

Figure 4.2.: Average (SD) time in bed, sleep duration, bedtime, wake time and sleep efficiency in rural vs. urban adolescents living in Osun State, Nigeria. **** $p<0.0001$, ns: non-significant using an independent t-test.

Table 4.5: Binary logistic regression analysis of the sleep health characteristics in Nigerian in-school adolescents in rural versus urban communities in crude (cOR) and adjusted analyses (aOR)*

Variable name	**Poor Sleep Quality**		**Excessive Daytime Sleepiness**		**Sleep Duration <8.5h**		**Risk of Sleep Apnoea**	
Residence	Crude	*Adjusted*	Crude	*Adjusted*	Crude	*Adjusted*	Crude	*Adjusted*
Urban								
OR 95%CI	**1.73 1.19-2.51**	**1.95 1.19-3.18**	**1.58 1.01- 2.49**	**2.25 1.25-4.05**	1.26 0.91-1.73	1.07 0.72-1.60	**1.89 1.20-2.99**	1.57 0.87-2.85
	0.004	**0.008**	**0.046**	**0.007**	0.162	0.741	**0.006**	0.136

We modeled the odds of having poor sleep quality (PSQI > 5) over good sleep quality (PSQI ≤ 5), the odds of having excessive daytime sleepiness (ESS-CHAD > 10) over having normal daytime sleepiness (ESS-CHAD ≤ 10), the odds of having low sleep duration (<8.5h) over the odds having normal sleep duration (≥8.5h) and the odds of having risk of sleep apnea over the odds of having low risk of sleep apnea.

*Binary logistic regression controlling for the confounders: sex, age, social class, family type, nature of the school, class in school, ethnicity, parental setting of bedtimes, bed-sharing, school start time, school closing time, and home-to-school commuting time.

Table 4.6: Multivariable analysis of the sleep health characteristics among Nigerian in-school adolescents in rural versus urban communities

Variable name	**Sleep Quality** aOR (95% CI)	***p***	**Excessive Daytime Sleepiness** aOR (95% CI)	***p***	**Sleep Duration<8.5h** aOR (95% CI)	***p***	**Risk of sleep apnoea** aOR (95% CI)	***p***
Residence[a]								
Urban	**1.95 (1.19-3.18)**	**0.008**	**2.25 (1.25-4.05)**	**0.007**	1.07 (0.72-1.60)	0.741	1.57 (0.87-2.85)	0.136
Sex[b]								
Female	**1.60 (1.06-1.41)**	**0.024**	1.11 (0.68-1.79)	0.681	0.98 (0.70-1.39)	0.928	**0.27 (0.16-0.44)**	**<0.001**
Age[c]								
Middle adolescence	0.99 (0.62-1.60)	0.981	1.10 (0.61-1.96)	0.758	1.40 (0.93-2.11)	0.103	0.95 (0.54-1.66)	0.846
Late adolescence	0.98 (0.36-2.67)	0.965	1.57 (0.54-4.59)	0.410	2.12 (0.80-5.63)	0.133	2.78 (0.99-7.84)	0.053
Social class[d]								
Middle	**0.46 (0.26-0.82)**	**0.007**	**2.51 (1.08-5.83)**	**0.028**	**0.29 (0.14 -0.61)**	**0.001**	1.17 (0.58-2.36)	0.658
Lower	**0.46 (0.25-0.87)**	**0.017**	**2.70 (1.09-6.69)**	**0.032**	**0.28 (0.13-0.61)**	**0.001**	0.85 (0.38-1.88)	0.683
Ethnicity[e] Not Yoruba	1.16 (0.62-2.20)	0.650	1.79 (0.91-3.53)	0.091	1.58 (0.85-2.94)	0.145	0.59 (0.24-1.46)	0.256
Family type[f]								
Polygamous	1.59 (0.99-2.54)	0.054	1.13 (0.68-1.99)	0.681	1.47 (0.96-2.27)	0.079	1.28 (0.69-2.37)	0.428
Single	**2.80 (1.06-7.42)**	**0.038**	1.61 (0.43- 5.92)	0.504	2.03 (0.56-7.40)	0.284	**4.95 (1.59-15.40)**	**0.006**
Separated	1.15 (0.23-5.88	0.863	----		2.83 (0.48-16.78)	0.250	**5.97 (1.43-24.87)**	**0.014**

Parent set[g] bedtime	**0.58 (0.37-0.91)**	**0.018**	**0.36 (0.20-0.67)**	**0.001**	0.79 (0.56-1.13)	0.205	1.13 (0.68-1.85)	0.643
Bed sharing[h]	0.82 (0.54-1.22)	0.327	0.81 (0.50-1.31)	0.383	0.78 (0.55-1.10)	0.156	1.00 (0.61-1.65)	0.989
Type of School[i]								
Private	**0.55 (0.31-0.97)**	**0.040**	1.10 (0.57-2.12)	0.782	0.94 (0.57-1.57)	0.825	1.85 (0.90-3.82)	0.095
Class in school[j]								
Senior	1.07 (0.62-1.87)	0.805	0.70 (0.37-1.30)	0.254	1.24 (0.81-1.90)	0.322	0.78 (0.41-1.50)	0.463
School start time (decimal time in hours)[k]	1.30 (0.55-3.08)	0.556	0.57 (0.23-1.43)	0.230	0.88 (0.43-1.83)	0.748	0.54 (0.19-1.53)	0.246
School end time (decimal time in hours)[l]	**1.29 (1.02-1.62)**	**0.031**	**1.37 (1.03-1.83)**	**0.032**	1.17 (0.97-1.41)	0.097	0.99 (0.74-1.31)	0.924
Commuting time (mins)[m]	1.01 (1.00-1.02)	0.170	1.00 (0.98-1.01)	0.669	1.01 (1.00-1.02)	0.174	1.01 (0.99-1.02)	0.255

Reference categories: a rural; b males; c early adolescence; d social class: Upper – missing social class for n=8; e Yoruba; f monogamous; g no parental setting of bedtime; h No bed sharing; i public; j Junior; k and l: the odds ratios show the odds of having the outcome for each later hour in the school start and school end times respectively; m : the odds ratio shows the odds of having the outcome each incremental minute in commuting time.

4.8 DISCUSSION

This study aimed to compare the sleep health of in-school adolescents in rural and urban communities within the Osun East Senatorial District, southwestern Nigeria using validated sleep questionnaires. About 15% of respondents reported poor sleep quality. The overall mean sleep duration was short (7 hours) for the general population of the participants. The odds of having poor sleep quality and excessive daytime sleepiness increased almost 2-fold among urban-dwelling adolescents compared to rural-dwelling students. Also, we found a shorter mean SD and later bedtimes among urban adolescents compared with rural adolescents.

The short sleep duration among urban-dwelling adolescents found in this study may be due to their later bedtime as they had similar wake times as the rural adolescents. Earlier studies have reported similar findings of a short sleep duration[6,7] and poor sleep quality[5] among urban-dwelling Nigerian adolescents. This may be due to some sleep stealers that reduce the sleep opportunities of urban-dwelling adolescents. Technology use at bedtime, artificial light exposure, environmental noise, school-related demands, and family dynamics were the major determinants of sleep health problems reported earlier in urban settings[22,24,28] The active late-night life in urban communities is often enhanced by the availability of electricity and the increased access to artificial light at night. Artificial light in turn may chronically cause circadian phase delays in urban-dwelling adolescents, contributing to their later bedtimes. Also, adolescents in urban communities are more likely to stay up late at night watching TV or chatting at night on social media due to access to electricity.[7] The higher odds of poor sleep quality and excessive daytime sleepiness among the adolescents whose schools close late support the contribution of school end time to adolescents' sleep health found in urban-dwelling adolescents in Ile-Ife.[44] However, the later school end time we found among the rural adolescents (who overall showed better sleep quality) shows that school end time alone does not explain the higher prevalence of poor sleep quality among urban versus rural adolescents.

We found no association between school start times and sleep health outcomes. School start times did not differ in the urban vs. rural settings, nor did they vary substantially from one school to another (standard deviation = 0:12 hour). Conversely, school end times were more varied (standard deviation = 1:06 hours). The lack of variability in school start times in our sample may have precluded us from finding an effect of school start times on overall sleep health outcomes. Nevertheless, our findings suggest that at identical early school start times, later school end times may also be associated with poorer sleep health.

Sleep health of rural-dwelling adolescents has been reported to be adversely affected by poverty, poor amenities, poor access to health and adverse mental health.[25,27,29] However, the effect of these factors on the sleep of rural adolescents may not be as severe as the factors that limit the sleep of urban-dwelling adolescents. The higher odds of excessive daytime sleepiness among urban adolescents is probably a direct result of their poor sleep quality and lower sleep duration. Previously we showed that the pressure of schoolwork and extracurricular activities was associated with a lower sleep opportunity of adolescents and lead to a worsened delay in bedtime.[7] The urban adolescents had shorter sleep duration compared to their rural counterparts. Therefore, the higher daytime sleepiness in urban adolescents is probably secondary to both poor sleep quality and short sleep duration. Parental setting of bedtimes was associated with lower odds of both poor sleep quality and excessive daytime sleepiness, possibly by mitigating the phase delay in bedtimes and allowing for a longer time in bed.

The higher prevalence of risk of sleep apnea in the urban-dwelling adolescents in our study supports the multiple dimensions of sleep health disparities in adolescents. In addition, adolescents living in single-parent family settings had higher odds of poor sleep quality and risk of sleep apnea. These findings may be driven by lifestyle differences.[45,46] Hence, there is a need to further study the contributory factors to the overall sleep health of adolescents in urban and rural communities. There may be lessons to learn from rural-dwelling adolescents that can improve the sleep of their urban-dwelling counterparts.

The few comparative studies of urban vs. rural-dwelling adolescents have been focused on SD, which is often determined by either asking the adolescents the usual number of hours they sleep every night or asking two questions about their usual bedtime and wake time.

Boraita *et al*[47] found a higher SD and better quality of life among adolescents in rural populations when compared to their urban-dwelling counterparts in Spain. In another study among adolescents aged 12-15 years, in urban and suburban populations, daytime somnolence and disorders of initiating and maintaining sleep were more prevalent in the urban population.[48] Pereira *et al*[49] in a study of the SD of rural adolescents in southern Brazil (Paraná) and its determinants concluded that "not all adolescents are sleep-deprived" because the rural adolescents had sufficient mean SD of 9.6 hours on weekdays and 10.1 hours on weekends; however, they did not compare them with urban adolescents. In two Brazilian studies, urban dwellers had significantly later bedtimes and waketimes than rural-dwelling adolescents.[30,50] Within the rural population, adolescents with access to electricity and television had shorter sleep duration than their peers without such facilities.[28] These findings suggest that rural adolescents may be experiencing some sleep enablers that are worth studying.

The higher odds of poor sleep quality among the female adolescents in our study are in accordance with other studies showing lower sleep quality in female versus. male adolescents.[41] Adolescents from the lower and middle classes had lower odds of poor sleep quality, short sleep duration but higher odds of excessive daytime sleepiness than those from the upper class. The higher number of rural-dwelling adolescents in the low and middle social class category may be contributory to the observation. However, the higher odds of daytime sleepiness in the same category require further studies. In one of our earlier studies among urban adolescents in Ile-Ife, we found low social class to be associated with short sleep duration.[7] The protective effect of low and middle social class in the present study may be more among the rural-dwelling adolescents who have other factors that enhance their sleep, possibly offsetting the adverse effects of low social class. These findings suggest the need to further study the factors predictive of the sleep health of adolescents.

4.8.1 Limitations

Our study has a few limitations: first, the sleep health characteristics of the adolescents were assessed with the use of self-report questionnaires, which can be subject to recall bias and social desirability bias. This limitation may have been mitigated by our use of multiple instruments, which have been previously validated. Secondly, we could not use an objective measure of the adolescent's sleep such as polysomnography due to its capital-intensive nature. However, the use of actigraphs and sleep diaries can be explored in our population where polysomnography is presently unavailable. Furthermore, the cross-sectional design of our study does not allow for cause-and-effect evaluations.

4.8.2 Strengths of the study

This present study has the following strengths: first, to the best of our knowledge, this is the first study comparing the multidimensions of sleep health variables among rural and urban-dwelling adolescents in Africa. Secondly, we had a large sample size of adolescents in rural versus urban communities. Thirdly, it employed the use of multiple instruments to measure the dimensions of sleep health, rather than the use of single measures such as sleep duration only.

4.8.3 Conclusions

This study showed that rural-dwelling adolescents living in Southwestern Nigeria have better sleep health than urban-dwelling adolescents. Further investigation of the risk and protective factors that affect the sleep health of adolescents in rural and urban communities can help guide the development of effective sleep health interventions. Therefore, we recommend further studies to better understand the sleep health of rural and urban–dwelling adolescents and the sleep health of out-of-school adolescents, including those living in slums. Qualitative surveys will be of help in exploring the perception of adolescents about their sleep and the consequences of their sleep health.

DR. CZEISLER'S CONTRIBUTIONS TO THIS WORK

Dr. Czeisler's research on the effects of circadian misalignment on sleep quality[51] and in turn on cognitive performance and health[52] has inspired us to investigate circadian and sleep health in African adolescents. Specifically, Dr. Czeisler showed that human circadian rhythms were entrained to the 24-hour Earth light-dark cycle by light.[53] With the rapid growth of urbanization[54] and concomitant higher access to artificial lighting and smartphones in Africa, the effects of light at night on adolescent circadian rhythms and sleep quality are of particular concern. As predicted from Dr Czeisler's circadian and sleep research, our study shows that adolescents living in an urban area in Nigeria have lower sleep duration,

worse sleep quality and later bedtimes than adolescents living in rural areas, where access to artificial lighting/smartphone technology is more limited. In addition, Dr Scheuermaier is also grateful to Dr. Czeisler for his support through the T32 HL07901 training grant, allowing her to complete her postdoctoral fellowship in sleep and circadian rhythms and start investigating sleep and health in Africa.

PUBLIC HEALTH RELEVANCE

We are documenting here for the first time the lower sleep duration and poorer sleep quality in urban compared to rural-dwelling adolescents in Nigeria. Those findings may help devise public policies to improve adolescent sleep, not only in Africa but also in the rest of the world, as we draw lessons from the sleep-enabling culture in the rural areas of Africa.

Conflicts of interest

There is no conflict of interest to report for in this project.

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In Chapter 4, we found rural-urban differences in self-reported sleep health characteristics; we also found a few determinants of sleep health in 900 adolescents in Nigeria. The next chapter (Chapter 5) now presents the association between the measured sleep health characteristics and cardiometabolic risk factors in those 900 adolescents.

CHAPTER 5

ASSOCIATION BETWEEN SLEEP HEALTH AND CARDIOMETABOLIC RISK

5.1 Publication details

This chapter is being presented as a manuscript on the association between poor sleep health and cardio-metabolic risk among rural and urban-dwelling in-school Nigerian adolescents

Table 5.1 Journal information and publication status

Title of publication	Poor sleep health is associated with worse cardio-metabolic risk among rural and urban-dwelling in-school Nigerian adolescents
Authors	Oluwatosin Eunice Olorunmoteni, Adesegun Olayiwola Fatusi, Karine Scheuermaier, F Xavier Gómez-Olivé.
Journal name	Scientific Reports
Status	Under Review
Impact factor	3.8

5.2 Author contributions

Table 5.2 shows the contributions to the manuscript made by each author

Table 5.2: Author contributions to the paper

	Olorunmoteni	Gómez-Olivé	Fatusi	Scheuermaier
Conceptualisation	√	√	√	√
Project administration	√	√	√	√
Methodology	√	√	√	√
Initial data analysis	√			
Writing – original draft	√			
Writing – reviewing and editing	√	√	√	√
Visualization	√	√	√	√
Supervision		√	√	√

5.3 Associated documentation:

The documentation associated with this publication are included as appendices and are labelled:

- Appendix 5: Ethical Clearance Certificate from the Health and Research Ethics Committee of the University of Witwatersrand

- Appendix 6: Ethical Clearance Certificate from the Health Research Ethics Committee of the Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria

- Appendix 7: Permission from the Osun State Ministry of Education

- Appendix 9: Participant Information and Informed Consent Forms

- Appendix 10: Study Questionnaire relevant

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Conflict of Interest Disclosures (includes financial disclosures): The other authors have no conflicts of interest to disclose.

5.4 Article Title: Poor sleep health is associated with worse cardio-metabolic risk among rural and urban-dwelling in-school Nigerian adolescents

Abstract

There is limited evidence on the association between sleep health and cardio-metabolic risk (CMR) in Sub-Saharan African adolescents. Using a cross-sectional design, we assessed the association between sleep health and CMR including 900 adolescents aged 13-19, attending six rural and six urban schools, in Osun State, Nigeria. Sleep health variables included sleep quality and duration (Pittsburgh Sleep Quality Index), risk of sleep apnea (Teen STOPBANG) and daytime sleepiness (Epworth Sleepiness Scale for Children and Adolescents). A continuous CMR-score was calculated using z-scores of mean arterial pressure (MAP), body mass index (BMI), waist circumference (WC), and random blood glucose. We analyzed the association between sleep health, place of residence and CMR using generalized linear models. Urban adolescents presented worse sleep health indicators and higher BMI, WC, and CMR-score (all $p<0.05$). Overall, poorer sleep quality was associated with higher CMR-score ($\beta=0.02$), BMI z-score ($\beta=0.04$) and WC z-score ($\beta=0.03$) (all $p<0.05$), and lower sleep duration with higher CMR-score ($\beta=0.04$), BMI z-score ($\beta=0.11$), and WC z-score ($\beta=0.07$) (all $p<0.05$). Risk of sleep apnea was associated with higher CMR-score ($\beta=0.08$), MAP z-score ($\beta=0.17$) and WC z-score ($\beta=0.14$) (all $p<0.05$). Improving the sleep health of adolescents may prevent cardiometabolic diseases later in life.

5.5 Keywords

Sleep characteristics, Sleep disorders, Metabolic disease, cardiovascular disease, cardio-metabolic disease

5.6 Introduction

Sleep is vital for human health and function.[1,2] Sleep is judged to be healthy if it is appropriate in duration, quality, and timing and is associated with sustained alertness in waking hours.[1,3] Hence, the association between sleep and health is better assessed using multiple dimensions of sleep. However, the available evidence for an association between poor sleep health and adverse health outcomes has largely focused on sleep duration and sleep quality.[4,5] Recent research studies have identified that it may be critical to assess other dimensions of sleep health when investigating the association with cardiometabolic health.[2] Among adolescents, insufficient sleep duration and /or poor quality sleep have been associated with increased cardiometabolic risk (CMR), including hypertension, obesity, diabetes, as well as mood disorders, impaired immune function, and poor health outcomes.[6,7] However, there is limited evidence of the association of the multiple dimensions of sleep health with CMR.[5,8] Also, sleep is a neglected aspect of adolescent health in general and in Africa in particular.[9,10] In addition, there is limited evidence on the association between adolescent sleep health and CMR in Africa. Individuals of African ancestry have been reported to have a higher prevalence of extreme sleep duration (short and long), higher prevalence of sleep-disordered breathing and insomnia as well as cardiovascular diseases.[11,12] Among individuals of African ancestry, sleep problems have been attributed to genetic causes, infections, immunological, cultural as well as environmental factors.[11,12] However, the few available studies on the association between sleep and cardiometabolic risk in Sub-Saharan African adolescents were focused on the association between sleep duration and body mass index (BMI) with some consideration of the effect of physical inactivity, although the findings were conflicting.[13,14] Therefore, the association between the different dimensions of adolescent sleep health and the development of CMR needs more in-depth study in the African setting.

In Nigeria, sleep problems among adolescents include disorders of quality and quantity of sleep.[15,16,17].[18] In addition, the presence of risk factors for non-communicable diseases has been linked to sleep problems.[6] Furthermore, obesity and sleep problems have been declared as a dual epidemic in adolescents worldwide.[6] However, in Nigeria, and other low and middle-income countries, studies have focused on obesity as a contributor to higher CMR[19] while sleep problems and their CMR outcomes remain poorly studied. The contribution of other variables such as sleep quality, sleep apnea and daytime sleepiness in CMR has not been well explored.[4] Thus, there is a need to understand the mechanisms by which sleep health contributes to cardiometabolic risk in adolescents. Nigerian urban areas have much larger electricity at night than rural areas.[20,21] which may result in higher light exposure at night in urban adolescents. Evening light exposure has a known association with delayed bedtimes and poorer sleep.[22] We have recently shown that, indeed, urban adolescents in

Nigeria have worse sleep health and more delayed bedtimes than rural adolescents.[23] Thus there is a need to compare sleep health and its consequences between urban-based and rural-based adolescents. Urban areas in Nigeria have also gone through lifestyle changes characterized by reduced physical activity and more sedentary lifestyles with higher access to high carbohydrate/high-fat diets than in rural areas, which may contribute independently to higher CMR.[19]

In a recently published white paper by the Sleep Research Society,[24] one of the gaps identified as requiring urgent attention is the need to study sleep health in children and adolescents by exploring sleep disparities.[24] Hence, this study's primary objective was to investigate the association between the sleep health of adolescents and markers of CMR in rural versus urban adolescents. We hypothesised that urban adolescents had higher CMR than rural adolescents and that poor sleep health indicators were associated with a higher CMR among Nigerian in-school adolescents.

5.7 Methods

5.7.1 Study design

This was a quantitative cross-sectional study involving adolescents aged 13-19 years attending six secondary schools in a rural setting and six secondary schools in an urban setting in the Osun East Senatorial District of Osun State, Nigeria. The details of the study setting, participants and sampling technique are available elsewhere as part of a descriptive study on sleep characteristics in rural and urban Nigerian adolescents.[23]

5.7.2 Ethical Considerations

Ethical approvals were obtained from the Human Research Ethics Committee of the University of the Witwatersrand (M210745) and the Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria (IPHOAU/12/1850). We also obtained permission to conduct the study from the State Education Authority, the School Principals and the Proprietors. In-school adolescents received the information about the study at first contact in their respective schools. Thereafter, they were given an information sheet about the study and a parental consent form to be filled in by their parents at home. On the next day, we retrieved parental consent forms and then obtained assent from the adolescents whose parents consented to their participation in the study.

5.7.3 Measures

We collected the socio-demographic characteristics, sleep characteristics, and cardiovascular risk factors of the adolescents. The demographic variables included: age as at the last birthday, sex of the respondent, location of adolescents' residence in rural or urban locality as designated by the National Population Commission. We also obtained history of parental history of cardio-metabolic disease by asking for history of hypertension or diabetes in the adolescents' father and mother. We categorized an adolescent as having a parental history of cardio-metabolic disease if either the father or the mother was known to have hypertension and/or diabetes. Further details on how information was obtained about the socio-demographic, sleep and cardiovascular variables are shown in the Supplementary Table.

5.7.4 Sleep questionnaires: We obtained a self-report of the sleep characteristics of the adolescents using validated questionnaires. We measured sleep quality and sleep duration using the Pittsburgh Sleep Quality Index (PSQI), (higher scores indicate lower sleep quality, PSQI global score>5 out of 21 indicates poor sleep quality),[25,26] daytime sleepiness using the Epworth Sleepiness Scale for children and adolescents (higher scores indicating higher daytime sleepiness),[27] and risk for sleep apnea with the Teen STOPBANG (risk of sleep apnea vs. low risk. Evaluate the presence of **S**noring, Ever feeling **T**ired, **O**bserved apnea, High Blood **P**ressure, **B**MI> 95th percentile, **A**cademic performance, **N**eck circumference >95th percentile, and Male **G**ender.[28] We also used the number of categories (0-8) present in the participant as the independent variable, denominated 'Teen STOPBANG continuous').[29] The Teen STOPBANG has been shown to detect obstructive sleep apnea in teens when compared to the polysomnographic cut-off of an apnoea-hypopnoea index of $\geq$ 1.5 events/hour, with a sensitivity of 0.64, specificity of 0.82 and a negative predictive value of 0.96.[29] The details of the characteristics of the sleep questionnaires used are provided in the Supplementary Table.

5.7.4 Anthropometric Measurements:

The anthropometric data obtained from each adolescent included their standing height, weight, waist circumference and neck circumference. We measured the adolescents' standing height (cm) to the nearest 0.01 cm with a standard calibrated stadiometer, and the body weight (kg) was noted on a standard weighing scale to the nearest 0.1 kg with the adolescent dressed in minimal clothing. The body mass index (BMI) was calculated as weight (kg) divided by the square of the height (m). The waist circumference was measured with a non-elastic measuring tape using the landmark of the midway between the pubic symphysis and the xiphisternum. Also, the adolescents' neck circumference was measured with a non-elastic measuring tape using the landmark of the mid-cervical spine and mid-anterior neck at the level of the most prominent part of the thyroid cartilage. We instructed the participants to stand with their heads held erect, eyes looking straight ahead and their necks in the horizontal plane. We measured each adolescent's blood pressure on the right arm in the sitting position using an appropriate-sized cuff. The blood pressure was measured with an average of three readings per participant to avoid an error. The age-, sex-, and height-specific percentile for BP were calculated according to WHO reference data. We also calculated the mean arterial pressure for each participant using the standard formula. Further details on how these measurements were taken using standard guidelines are shown in the Supplementary Table.

5.7.5 Random blood glucose (RBG)

We used the BGCheck BS-201 Blood Glucose Monitor (HealthCheck™) to measure the RBG of each participant. This blood glucometer utilizes the glucose dehydrogenase method. The accuracy of the glucometer is 100% (within±0.83mmol/L) for glucose concentrations <5.55mmol/L and 99.7% (within±15% for values ≥5.55mmol/L).

5.7.6 Cardiometabolic risk factors:

These included systolic and diastolic blood pressure and calculated mean arterial pressure (MAP), BMI, waist circumference (WC), and RBG, all measured using published guidelines. We then created age- and sex-adjusted z-scores for those variables. A continuous CMR score was calculated using z-scores of mean arterial pressure (MAP), body mass index (BMI), waist circumference (WC), and random blood glucose. We calculated the WHO z-scores using previously described methods, though we used non-laboratory measures, as agreed in the permission given by the school authorities. Previously used continuous CMR scores in pediatric[30,31] and adult populations,[32] were generated from the combination of available (i.e.

non-laboratory) markers of CMR collected. A non-laboratory cardiovascular method was previously validated in the NHANES cohort in adults.[33]

5.7.7 Physical activity:

We assessed the physical activity (PA) of the adolescents using the Modified Physical Activity Questionnaire for Adolescents (PAQA). We asked about the frequency of the adolescents' engaging in various physical activities in the past 7 days based on PAQA. We categorized the PA into three categories based on the cumulative frequency of PA in the past week. The three categories are Low if the score is <4 (coded 0), Moderate if the score is 4-11 (coded 1) and vigorous if > 11 (coded 2). We used PA as an ordinal categorical variable in the models, assuming linear changes in CMR with reporting a higher level of physical activity.

5.7.8 Data analysis:

We analysed the data with Stata-15 (StataCorp. 2017. Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC). Using the CMR score as the primary outcome variable, bivariate and multivariate analyses were used to determine the association between the CMR score and the following sleep variables: sleep duration, sleep quality, risk of sleep apnea (using the Teen STOPBANG continuous), and daytime sleepiness.

The Chi-square test was used for testing the association between categorical variables such as the rural-urban disparities in the sociodemographic characteristics of the participants and categorical variables. We used the independent t-test to compare CMR outcome continuous variables in urban vs. rural adolescents.

The univariable analysis of the relationship between CMR outcome variables and the sleep health of the adolescents was done using simple linear regression. As BMI and blood pressure were both components of the CMR score and the Teen STOPBANG continuous, we tested the association between those two variables using a Pearson's correlation which showed a weak significant correlation ($r=0.13$; $p<0.001$), probably because only blood pressure and body mass index were components of both variables. Similar weak correlations were found between the Teen STOPBANG continuous and the SBP, DBP and MAP z scores ($r=0.20$, $p<0.001$; $r=0.11$, $p<0.001$; $r=0.17$, $p<0.001$) respectively.

At the multivariable level, the generalized linear model was used to identify the relationship between key z-scores of the main CMR variables (CMR score, BMI, WC, NC, MAP and RBG as outcome variables, respectively) and 1) type of residence (urban vs. rural) and 2) sleep health variables while adjusting for parental history of cardiometabolic disease and physical activity levels. In the analysis, we used the PA variable as an ordinal categorical variable (taking values 0, 1 and 2).

Table 5.3: List of demographic variables, sleep variables and cardio-metabolic risk factors measured on the adolescents.

Variables	Measure	Questionnaire/Mode of assessment	Final measurement used and reference group (if applicable)
Demographic factors			
Age	Age at last birthday	Study questionnaire	Age (years)
Sex	Sex of the respondent	Study questionnaire	Male vs Female Reference group: Female
Location of adolescents' residence	Rural or urban locality as designated by the National Population Commission	Study questionnaire	Rural vs Urban Reference group: Rural
Parental history of cardio-metabolic disease	History of hypertension or diabetes in the adolescents' father and mother.	We categorised an adolescent as having a parental history of cardio-metabolic disease if either the father or the mother is known to have hypertension and/or diabetes.	The parental history of cardio-metabolic disease is categorised as absent or present. Reference group: No CMR
Sleep Health Variables			
Sleep Quality	Pittsburgh Sleep Quality Index (PSQI),	19 questions which lead to 7 components (sleep duration, sleep onset latency, sleep efficiency, sleep quality, daytime function, sleep quality, sleep medications) each scored on a Likert scale from 0 to 3 (0: not during the past week, 1: less than once a week 2: once or twice per week, 3: 3 or more times per week) Global score out of 21, higher scores indicate poorer sleep quality, PSQI>5 is considered poor quality sleep	PSQI global score taking values from 0-21(higher score: poorer sleep quality)[25,26]
Daytime Sleepiness	Epworth Sleepiness Scale for Children and Adolescents (ESS CHAD)	Measured with the Epworth Sleepiness Scale for Children and Adolescents (ESS CHAD). It has 8 components investigating the likelihood of falling asleep in various scenarios (0: never,	ESS CHAD global score taking values 0-24 (higher score reflects higher daytime sleepiness).[27]

		1: slight chance, 2: moderate chance 3: high chance). Global score out of 24 Higher scores indicate higher daytime sleepiness, ESS>10 indicate likelihood of a sleep disorder.	
Risk of Sleep Apnea	Teen STOP-BANG questionnaire	Evaluates the presence of : **S**noring Ever feeling **T**ired **O**bserved apnea High blood **P**ressure **B**MI> 95th percentile **A**cademic performance **N**eck circumference >95th percentile Male **G**ender.[28] If presence of 3 or more of those 8 symptoms, then the participant is at risk of sleep apnea. Final score : risk of sleep apnea vs low risk of sleep apnea	Risk of sleep apnea or Low risk of sleep apnea Reference group: Low risk
Sleep Duration	Sleep duration	This is the self-reported duration of sleep obtained from the Pittsburgh Sleep Quality Index (PSQI) questionnaire	A continuous variable reflecting hours spent asleep, as reported by the participant
Cardio-metabolic Risk Measures			
Weight	Weight of the respondent	The anthropometric data obtained by trained research assistants from each body weight (kg) was noted on a standard weighing scale to the	Weight (kg)

		nearest 0.1 kg with the adolescent dressed in minimal clothing.	
Height	Height of the respondent	Adolescents’ standing height (cm) to the nearest 0.1 cm with a standard calibrated stadiometer using the standard protocol.	Height (cm)
Body Mass Index	Body mass index (BMI)	Calculated as weight (kg) divided by height (m) squared.	BMI (kg/m^2)
Body Mass Index z-score	BMI z-score	The age- and sex-specific z-scores were calculated using the WHO Anthroplus software.	BMI z-score
Physical Activity (PA)	Modified Physical Activity Questionnaire for Adolescents (PAQA)	We asked about the frequency of the adolescents’ engaging in various physical activities in the past 7 days based on PAQA.	We categorized the PA into three categories based on the cumulative frequency of PA in the past week. The three categories are Low if the score is <4 (coded 0), Moderate if the score is 4-11 (coded 1) and vigorous if > 11 (coded 2). In the analysis, we used the PA variable as an ordinal categorical variable (taking values 0, 1 and 2). We assumed a linear relationship between the different categories and the CMR variables of interest. The Beta estimate from the regression model thus represents the change in CMR variable when moving from category 0 (low PA) to category 1 (moderate PA) or from category 1 to category 2 (high PA). Moving from category

			0 to category 2 thus would be represented by Beta x 2.
Waist circumference	Waist circumference	Measured with non-elastic measuring tape using the landmark midway between the pubic symphysis and the xiphisternum.	Waist circumference (cm)
Waist circumference z-score		The age- and sex-specific z-scores were calculated using age- and sex- specific mean (SD). Each participant's waist circumference (WC)'s z score was calculated as follows: $(WC_{participant}$-mean $WC_{age\ \&\ sex\ specific})$ /standard deviation $WC_{age\ \&\ sex\ specific}$	Waist circumference z-score
Neck circumference	Neck circumference	Measured with a non-elastic measuring tape using the landmark of the mid-cervical spine and mid-anterior neck at the level of the most prominent part of the thyroid cartilage. We instructed the participants to stand with their heads held erect, eyes looking straight ahead and their necks in the horizontal plane.	Neck circumference (cm)
Neck circumference (NC) z-score		The age- and sex-specific z-scores were calculated using age- and sex- specific mean (SD). Each participant's neck circumference's z score was calculated as follows: $(NC_{participant}$- mean $NC_{age\ \&\ sex\ specific})$ /standard deviation of $NC_{age\&sex\ specific}$	Neck circumference z-score
Blood pressure	Systolic and Diastolic Blood pressure (SBP and DBP) of the respondents	Measured on the right arm in the sitting position using an appropriate-sized cuff. We used the average blood pressure out of the measured three readings per participant.	SBP (mm Hg) DBP (mm Hg)

DBP z-score and SBP z-score		The age-, sex-, and height-specific percentile for DBP and SBP were calculated according to WHO reference data.[34]	DBP z-score SBP z-score
Mean Arterial Pressure	Mean Arterial Pressure (MAP) of the respondents	MAP = DBP + 1/3(SBP – DBP)	MAP (mm Hg)
MAP z-score	determined the mean and standard deviation of MAP for the whole sample to calculate the MAP z-score	($MAP_{participant}$- mean MAP_{sample})/ standard deviation of MAP_{sample}	MAP z-score
Random blood glucose (RBG)	Glucometer-derived RBG	To measure the RBG of each participant, we used a BGCheck BS-201 Blood glucose meter which utilizes the glucose dehydrogenase method. The accuracy of the glucometer is 100% (within±0.83mmol/L) for glucose concentrations <5.55mmol/L and 99.7% (within±15% for values ≥5.55mmol/L.	Plasma glucose concentration (mmol/L)
RBG z-score		Each participant's RBG z score was calculated as follows: ($RBG_{participant}$- mean RBG_{sample})/ standard deviation of RBG_{sample}	RBG z-score
CMR score	Continuous CMR score	Generated from the combination of four CMR measures namely: i) blood pressure (BP) = MAP z-score, ii) body mass index (BMI) z-score, iii) waist circumference (WC) z-score, iv) random blood glucose (RBG) z-score.[31] We used these simple non-laboratory measures based on earlier reports of non-laboratory risk prediction methods for cardiovascular risk being as accurate as the methods requiring laboratory information.[33]	We calculated the continuous CMR score by obtaining the mean of the z-scores of the CMR factors such that each factor was equally weighted. CMR score = (MAP z-score+BMI z-score+ WC z-score + RBG z-score)/4

5.8 Results

In total, 900 adolescents (459 rural; 59% female; average age 15.1±1.4; 49.1% of lower social class) were included in this study. In previously published results on the same sample, we showed that there was no statistically significant difference in the sex composition of the adolescents based on their type of residence (rural or urban).[23] The rural adolescents were older, were more in the middle and late adolescence category than early adolescence, more in the lower social class, more from polygamous family settings, and were more in the public schools. Despite being older, the rural adolescents were more likely to be in junior secondary school (vs Senior secondary school) than the urban adolescents.[23] The urban adolescents reported significantly higher parental cardiometabolic disease ($p < 0.001$) while there was no significant difference in the physical activity levels between the rural and urban adolescents ($p=0.195$) as shown in Table 5.3.

5.8.1 Sleep health of the adolescents

The rural and urban distribution of the sleep health variables of the adolescents is shown in Table 5.3. All markers of sleep health were worse in urban compared to rural adolescents. Sleep quality was lower ($p < 0.001$) (PSQI score higher), sleep duration was lower ($p < 0.001$) and daytime sleepiness was higher ($p = 0.033$) in the urban adolescents when compared to the rural adolescents. Similarly, urban adolescents had a higher prevalence of risk of sleep apnea than rural adolescents ($p=0.006$), as measured by having 3 components or more present out of 8 possible of the Teen STOPBANG. The average number of components of the Teen STOPBANG present was higher in the urban compared to the rural adolescents (unpaired t-test, $p<0.001$).

5.8.2 Cardiometabolic risk outcomes

BMI ($p=0.004$), WC ($p<0.001$) and neck circumference (NC) ($p=0.007$) were significantly higher in the urban compared to rural adolescents. Conversely, random blood glucose (RBG) was higher among the rural compared to urban adolescents ($p<0.001$). There was no statistically significant difference between the systolic blood pressure (SBP), diastolic blood pressure (DBP) and MAP of the urban versus rural adolescents as shown in Table 5.3.

5.8.3 Relationship between sleep health and cardiometabolic risk outcomes of the adolescents:

There was a statistically significant association between higher CMR and lower sleep quality, lower sleep duration, and risk of sleep apnea, using the raw values of the cardiometabolic risk measures (Table 5.4). Using the simple linear regression (unadjusted), lower sleep quality (β=0.02, $p<0.001$) and Teen STOPBANG continuous score (β=0.08, $p<0.001$) were associated with higher CMR scores. Lower sleep duration was associated with a higher CMR score (β=-0.04, p=0.001) (Table 5.5). Lower sleep quality (higher PSQI score) was associated with a higher BMI (p=0.001), WC (p=0.018), and NC z-scores ($p<0.001$). Higher Teen STOPBANG continuous score was associated with a higher BMI (p=0.028), SBP ($p<0.001$) and DBP (p=0.001); and higher WC, NC, MAP z-scores (p=0.001). Longer sleep duration was associated with a lower BMI ($p<0.001$), WC (p=0.001) and NC (all $p<0.001$). There was no statistically significant relationship between daytime sleepiness and any of the CMR variables measured.

In the multivariable linear regression models adjusting for parental history of cardiometabolic disease and physical activity, when comparing the urban to the rural adolescents, BMI, WC, and NC were all higher, while random blood glucose (RBG) was significantly lower; and there was no difference in blood pressure measurements and CMR score. In these adjusted models, we found the following associations of sleep health variables with CMR variables. Lower sleep quality (higher PSQI score) was associated with a higher CMR score (β=0.18), BMI z-score (β=0.04), WC z-score (β=0.03) and NC z-score (β=0.04). A higher Teen STOPBANG continuous score was associated with a higher CMR score (β=0.09), MAP z-score (β=0.2), WC z-score (β=0.14), and NC z-score (β=0.18). Conversely, longer sleep duration was associated with lower CMR score (β= -0.04), BMI z-score (β= -0.09), WC z-score (β= -0.06), and NC z-score (β= -0.07) (Table 5.6).

Table 5.4: Comparison of the participant characteristics, sleep and cardio-metabolic risk variables between rural and urban-dwelling adolescents

Participant Characteristics	Whole Population Mean ± SD Or N (%)	Rural Mean ± SD Or N (%)	Urban Mean ± SD Or N (%)	p-value
Gender				
Female	531 (59.0)	274 (59.7)	257 (58.3)	0.665*
Male	369 (41.0)	185 (40.3)	184 (41.7)	
Age in years				
Mean ± SD	15.1 ± 1.4	15.4 ± 1.4	14.8 ± 1.4	**<0.001**
Parental history of cardiometabolic disease				
Absent	857 (95.2)	449 (97.8)	408 (92.5)	**<0.001***
Present	43 (4.8)	10 (2.2)	33 (7.5)	
Physical activity level (N=858)				
Low	210 (24.5)	108 (24.9)	102 (24.0)	0.195*
Moderate	489 (57.0)	255 (58.9)	234 (55.1)	
Vigorous	159 (18.5)	70 (16.2)	89 (20.1)	
Sleep health variables				
Sleep quality (PSQI)	2.7 ± 2.6	2.3 ± 2.4	3.1 ± 2.8	**<0.001**
Daytime sleepiness score (ESS)	5.3 ± 3.9	5.0 ± 3.8	5.5 ± 4.0	**0.033**
Risk of sleep apnea¥				
Low risk	805 (90.2)	422 (92.9)	383 (87.4)	**0.006***
Risk of apnea	87 (9.8)	32 (7.1)	55 (12.6)	
Teen STOPBANG continuous (0-8)	1.20 ± 0.98	1.08 ± 0.93	1.32 ± 1.01	**<0.001**
Sleep Duration (h: mm)	7h10 ± 1h40	7h23 ± 1h34	6h55 ± 1h44	**<0.001**
Cardiometabolic risk variables				

CMR score	-0.2± 0.6	-0.2± 0.5	-0.1± 0.7	0.392
Weight (kg)	48.4 ± 9.5	46.5 ± 7.8	50.3 ± 10.7	**<0.001**
Height (m)	1.59 ± 0.1	1.57 ± 0.1	1.61 ± 0.1	**<0.001**
BMI in kg/m^2	18.9 ± 2.8	18.7 ± 2.3	19.2 ± 3.3	**0.004**
BMI z-score	-0.6 ± 1.0	-0.7 ± 0.9	-0.5 ± 1.2	**<0.001**
Waist Circumference (cm)	68.9 ± 6.5	68.1 ± 5.5	69.6 ± 7.3	**0.001**
WC z-score	0.0	-0.1 ±0.9	0.1 ±1.1	**<0.001**
Neck Circumference (cm)	30.1± 4.0	29.7 ± 4.4	30.5 ± 3.6	**0.007**
NC z-score	0.00	-0.2 ± 0.9	0.2 ± 1.0	**<0.001**
SBP in mmHg	113.5 ± 12.1	113.2 ± 11.7	113.7 ± 12.5	0.453
DBP in mmHg	69.9 ± 9.2	69.6 ± 9.0	70.2 ± 9.4	0.398
MAP in mmHg	84.4 ± 9.0	84.1 ± 8.7	84.7 ± 9.3	0.360
MAP z-score	0.0 ± 1.0	-0.1 ± 1.0	0.1 ± 1.0	0.360
Random blood glucose (RBG) (mmol/L)	7.3 ± 1.9	7.72.1	6.8 ± 1.7	**<0.001**
RBG z score	0.0 ± 1.0	0.2 ± 1.1	- 0.2 ± 0.9	**<0.001**

Abbreviations: PSQI = Pittsburgh Sleep Quality Index, ESS = Epworth Sleepiness Scale, BMI = Body Mass Index, SBP = Systolic Blood Pressure, DBP = Diastolic Blood Pressure, NC= Neck circumference, WC = Waist Circumference, MAP=Mean arterial pressure, CMR = Cardiometabolic risk, RBG = Random Blood Glucose . [¥] Low risk: presence of <3 out of 8 components of the Teen STOPBANG. Risk of sleep apnea: presence of ≥3 components out of 8 of the Teen STOPBANG. *Chi-square test. Other analyses were with independent t-tests.

Table 5.5: Unadjusted relationship of sleep characteristics with cardiometabolic risk factors and neck circumference (non-z-scores)

	BMI		**WC**		**NC**		**SBP**		**DBP**		**RBG**	
	Beta estimate (crude) 95%CI	***P-value***	**Beta estimate (crude) 95%CI**	***P-value***	**Beta estimate (crude) 95%CI**	***P-value***	**Beta estimate (crude) 95%CI**	***P-value***	**Beta estimate (crude) 95%CI**	***P-value***	**Beta estimate (crude) 95%CI**	***P-value***
Sleep Quality $^{\alpha}$	0.13	**<0.001***	0.24	<**0.001**	0.11	**0.003**	0.11	0.469	-0.01		-0.02	
	0.06, 0.20		0.13, 0.36		0.04, 0.18		-0.19, 0.42		-0.24, 0.22	0.929	-0.08, 0.02	0.290
Daytime Sleepiness $^{\beta}$	-0.01	0.604	0.01	0.91	0.02	0.568	0.04	0.732	-0.14		-0.01	
	-0.06, 0.04		-0.10, 0.12		-0.05, 0.09		-0.17, 0.24		-0.29, 0.02	0.084	-0.05, 0.02	0.444
Teen STOPBANG continuous	0.21	**0.028**	0.55	**0.015**	0.7	<**0.001**	2.58	**<0.001**	1.04		-0.06	
	0.02, 0.40		0.11, 0.99		0.52, 0.88		1.79, 3.38		0.43, 1.65	**0.001**	-0.19, 0.07	0.373
Sleep Duration $^{\gamma}$	-0.31	**<0.001**	-0.47	<**0.001**	-0.26	**0.001**	-0.38	0.122	-0.01		0.04	
	-0.42, -0.20		-0.72, -0.21		-0.42, -0.11		-0.85, 0.10		-0.37, 0.35	0.960	-0.04, 0.11	0.338

BMI= Body Mass Index in (kg/m^2), WC= Waist Circumference in cm, NC = Neck Circumference in cm SBP = Systolic Blood Pressure in mmHg, DBP = Diastolic Blood Pressure in mmHg, RBG = Random Blood Glucose. $^{\alpha}$ Based on the Global PSQI score: higher scores indicate lower sleep quality. $^{\beta}$ Measured with the Epworth Sleepiness Scale – higher scores indicate higher daytime sleepiness. $^{\gamma}$ As determined by the sleep duration question on the PSQI.

Table 5.6: Unadjusted relationship between sleep characteristics and cardiometabolic risk factors (z-scores)

	CMR Score		**BMI z-score**		**WC z-score**		**NC z-score**		**MAP z-score**		**RBG z-score**	
	Beta estimate (crude) 95%CI	***P-value***	**Beta estimate (crude) 95%CI**	***P-value***	**Beta estimate (crude) 95%CI**	***P-value***	**Beta estimate (crude) 95%CI**	***P-value***	**Beta estimate (crude) 95%CI**	***P-value***	**Beta estimate (crude) 95%CI**	***P-value***
Sleep quality $^{\alpha}$	0.02 0.01, 0.03	**0.034**	0.04 0.02, 0.07	**0.001**	0.03 0.01, 0.06	**0.018**	0.05 0.02, 0.07	**<0.001**	0.01 -0.02, 0.03	0.790	-0.01 -0.04, 0.01	0.257
Daytime sleepiness $^{\beta}$	-0.01 -0.01, 0.01	0.490	0.01 -0.02, 0.02	0.869	-0.01 -0.18, 0.16	0.927	0.01 -0.01, 0.02	0.791	-0.01 -0.03, -0.01	0.305	0.01 0.02, 0.01	0.444
Teen STOP BANG continuous	0.08 0.04, 0.12	<**0.001**	0.04 -0.03, 0.11	0.246	0.14 0.07, 0.21	**<0.001**	0.18 0.11, 0.25	<**0.001**	0.17 0.11, 0.24	**<0.001**	-0.03 -0.10, 0.04	0.373
Sleep duration (h) $^{\gamma}$	-0.04 -0.07, -0.02	**0.001**	-0.11 -0.14, -0.06	**<0.001**	-0.65 -0.10, -0.03	**0.001**	-0.08 -0.11, -0.04	**<0.001**	-0.15 -0.05,-0.02	0.465	0.02 -0.02, 0.06	0.338

CMR= Cardiometabolic risk, BMI= Body Mass Index, WC= Waist Circumference, NC =Neck Circumference, MAP = Mean Arterial Blood Pressure, RBG = Random Blood Glucose; $^{\alpha}$ Based on the Global PSQI score: higher scores indicate lower sleep quality. $^{\beta}$ Measured with the Epworth Sleepiness Scale – higher scores indicate higher daytime sleepiness. $^{\gamma}$ As determined by the sleep duration question on the PSQI.

Table 5.7: Adjusted multivariable linear regression models assessing the relationship between sleep health variables (independent variable) and cardiometabolic risk factors as z-scores (dependent variable).

Dependent variable ➔ / **Independent variables ⬇**	**CMR Score** Beta estimate (adjusted) 95%CI	*P-value*	**BMI z-score** Beta estimate (adjusted) 95%CI	*P-value*	**WC z-score** Beta estimate (adjusted) 95%CI	*P-value*	**NC z-score** Beta estimate (adjusted) 95%CI	*P-value*	**MAP z-score** Beta estimate (adjusted) 95%CI	*P-value*	**RBG z-score** Beta estimate (adjusted) 95%CI	*P-value*
Sleep quality $^{\alpha}$	0.18 0.01, 0.03	**0.026**	0.04 0.02, 0.07	**0.001**	0.03 0.02, 0.05	<**0.001**	0.04 0.02, 0.07	**0.001**	-0.01 -0.03, 0.03	0.944	-0.01 -0.03, 0.02	0.702
Residence (urban-rural)*	0.03 -0.06, 0.11	0.545	0.23 0.09, 0.37	**0.001**	0.23 0.09, 0.37	**0.001**	0.41 0.28, 0.55	**<0.001**	0.06 -0.08, 0.20	0.395	-0.44 -0.57, -0.31	**<0.001**
Parental history of CMR†	0.15 -0.04, 0.35	0.128	0.30 -0.02, 0.61	0.069	-0.01 -0.32, 0.32	0.830	-0.18 -0.49, 0.12	0.242	0.25 -0.06,0.57	0.119	0.03 -0.28, 0.33	0.855
Physical activity$^{¥}$	-0.07 -0.14, -0.01	**0.024**	-0.25 -0.36, -0.15	**<0.001**	-0.02 -0.12, 0.08	0.715	-0.10 -0.20, 0.07	0.064	-0.07 -0.17, 0.04	0.208	0.05 -0.05, 0.15	0.332
Daytime sleepiness $^{\beta}$	-0.01 -0.01, 0.01	0.456	0.01 -0.02, 0.02	0.988	-0.01 -0.02, 0.02	0.911	-0.01 -0.02, 0.02	0.941	-0.01 -0.03, 0.01	0.118	-0.01 -0.02, 0.02	0.873
Residence (urban-rural)*	0.04 -0.04, 0.12	0.351	0.26 0.12, 0.40	<**0.001**	0.27 0.12, 0.40	**<0.001**	0.44 0.31, 0.58	<**0.001**	0.07 -0.07, 0.21	0.311	-0.45 -0.58, -0.32	<**0.001**
Parental history of CMR†	0.17 -0.02, 0.37	0.082	0.34 0.02, 0.66	**0.038**	0.026 -0.29, 0.35	0.872	-0.14 -0.45, 0.17	0.370	0.26 0.05, 0.58	0.102	0.02 -0.28, 0.32	0.873
Physical activity$^{¥}$	-0.07 -0.13, -0.01	**0.036**	-0.24 -0.35, 0.14	**<0.001**	-0.01 -0.12, 0.09	0.792	-0.08 -0.18, 0.02	0.115	-0.07 -0.17, 0.04	0.199	0.05 -0.05, 0.15	0.345

Dependent variable ➔ / Independent variables ⬇	CMR z-score Beta estimate (adjusted) 95%CI	CMR z-score *P-value*	BMI z-score Beta estimate (adjusted) 95%CI	BMI z-score *P-value*	WC z-score Beta estimate (adjusted) 95%CI	WC z-score *P-value*	NC z-score Beta estimate (adjusted) 95%CI	NC z-score *P-value*	MAP z-score Beta estimate (adjusted) 95%CI	MAP z-score *P-value*	RBG z-score Beta estimate (adjusted) 95%CI	RBG z-score *P-value*
Teen STOPBANG continuous	0.09 0.05, 0.14	<**0.001**	0.05 -0.02, 0.12	0.176	0.14 0.07, 0.21	<**0.001**	0.18 0.11, 0.25	<**0.001**	0.20 0.13, 0.27	<**0.001**	-0.01 -0.08, 0.05	0.674
Residence (urban-rural)*	0.01 -0.07, 0.10	0.790	0.23 0.11, 0.39	**<0.001**	0.23 0.10, 0.37	**0.001**	0.40 0.27, 0.53	<**0.001**	0.01 -0.14, 0.13	0.970	-0.44 -0.57, -0.31	<**0.001**
Parental history of CMR[†]	0.16 -0.04, 0.35	0.113	0.33 0.01, 0.65	**0.043**	0.01 -0.31, 0.32	0.979	-0.16 -0.47, 0.14	0.285	0.22 -0.09, 0.53	0.160	0.03 -0.27, 0.33	0.860
Physical activity[¥]	-0.09 -0.15, -0.02	**0.008**	-0.26 -0.36, -0.15	<**0.001**	-0.04 -0.15, 0.06	0.434	-0.12 -0.22, -0.02	**0.017**	-0.10 -0.21, -0.01	0.047	0.05 -0.05, 0.15	0.287
Sleep duration (h)[γ]	-0.04 -0.65, -0.02	**0.002**	-0.09 -0.14, -0.05	<**0.001**	-0.06 -0.10, -0.02	**0.004**	-0.07 -0.11, -0.03	**0.001**	-0.01 -0.05, 0.03	0.686	0.01 -0.04, 0.04	0.839
Residence (urban-rural)*	0.02 -0.07, 0.11	0.624	0.22 0.08, 0.35	**0.002**	0.24 0.10, 0.38	**0.001**	0.42 0.28, 0.55	<**0.001**	0.06 -0.08, 0.20	0.391	-0.45 -0.58, -0.31	<**0.001**
Parental history of CMR[†]	0.15 -0.05, 0.34	0.133	0.29 -0.03, 0.61	0.072	-0.01 -0.32, 0.31	0.977	-0.18 -0.48, 0.13	0.261	0.24 -0.07, 0.56	0.134	0.03 -0.28, 0.33	0.870
Physical activity[¥]	-0.07 -0.13, -0.01	**0.028**	-0.25 -0.35, -0.15	<**0.001**	-0.02 -0.12, 0.09	0.730	-0.09 -0.19, 0.01	0.092	-0.07 -0.17, 0.04	0.203	0.05 -0.05, 0.15	0.341

CMR= Cardiometabolic risk, BMI= Body Mass Index, WC= Waist Circumference, NC =Neck Circumference, MAP = Mean Arterial Blood Pressure, RBG = Random Blood Glucose; *reference group= rural †reference group= no risk; ¥physical activity was entered as an ordinal categorical variable coded 0 (low PA), 1 (moderate PA) or 2 (high PA) with an assumption of linearity between PA and the cardiometabolic outcome variables; α Based on the Global PSQI score: higher scores indicate lower sleep quality. β Measured with the Epworth Sleepiness Scale – higher scores indicate higher daytime sleepiness. γ As determined by the sleep duration question on the PSQI.

5.9 Discussion

In this cross-sectional study of 900 Nigerian in-school adolescents, urban compared to rural dwellings, and poorer sleep health were associated with higher cardiometabolic risk. Urban adolescents had higher BMI, WC and NC while rural-dwelling adolescents had higher random blood glucose levels; the CMR score combining z-scores of the 4 clinical CMR factors (BMI, WC, RBG and MAP) was not different between the urban and rural adolescents. Urban adolescents also had poorer sleep health measures than their rural counterparts. Overall, lower sleep quality was associated with higher BMI, WC and NC, and a higher CMR score. A higher risk of sleep apnea was associated with higher CMR scores, and higher WC, NC and MAP z-scores. Higher sleep duration was associated with lower CMR scores, and lower BMI, WC and NC z-scores.

Our study is unique among earlier studies on the association between sleep and cardiometabolic risk due to its comparison of an urban and a rural population of adolescents in a low and middle-income country. This study highlights the important contribution of urban versus rural type of residence to the relationship between sleep health and cardiometabolic health in line with previous publications.[2,11] Among the social determinants of sleep health, racial and neighbourhood factors are important contributors to the sleep health of adolescents.[2,35] Our study shows how the urban lifestyle may contribute independently to both poorer cardiometabolic health, and poorer sleep health, respectively. In addition, poorer sleep health was independently associated with increased cardiometabolic risk.

The higher cardiometabolic risk in urban adolescents concerned anthropometric measures of adiposity (WC, NC, BMI). This finding may be associated with dietary lifestyles in urban areas (higher availability of high sugar, high fat processed foods).[31] In contrast, the RBG of rural adolescents in our study was higher than that of urban adolescents. We excluded adolescents with known diabetes from our study. It is possible that the lower access to healthcare facilities in the rural communities[36] meant a lower rate of diabetes detection and thus we may have included unwittingly more rural than urban adolescents with undiagnosed pre-diabetes or diabetes. Measures of blood pressure were not significantly different between rural and urban adolescents. This finding is contrary to the report of higher SBP and DBP among urban adolescents in a study among 500 urban vs 500 rural Nigerian adolescents in the same senatorial district as our study though conducted ten years before our study and involved adolescents aged 10-19 years.[37] However, a higher level of adiposity was reported among urban adolescents in their study, similar to the findings from our study.

We utilized multiple dimensions of sleep health in assessing the association between sleep health and CMR. We found poorer sleep health overall in the urban compared to the rural adolescents. Hypotheses for poorer sleep health in urban adolescents include higher access to electricity and thus light at night (which may disrupt circadian rhythms) and overall poorer sleep habits, which may be multifactorial. The industrialized lifestyle in urban communities has been shown to predispose adolescents to greater access to screen and bedtime screen use (driven by larger night access to electricity compared to rural areas). This in turn leads to higher levels of artificial light at night (ALAN) which causes circadian rhythm disruption and delayed bedtimes.[22,38] The delayed bedtimes, while school start times and thus wake times cannot be delayed, would lead to the lower sleep duration observed in urban adolescents, but also may create a chronic circadian misalignment resulting in the poorer sleep quality observed. Furthermore, there is possible higher exposure to sleep disruptors in urban settings, in particular noise. It has also been suggested that reduced parental supervision, due to busy urban lifestyles, is another possible explanation for urban adolescents' poorer sleep.[21,22,19]

The first marker of sleep health that we studied was overall sleep quality measured by the PSQI global score. Urban adolescents reported poorer sleep quality than rural adolescents. Poorer sleep quality was associated with higher CMR scores and higher measures of adiposity (BMI, WC and NC) among the study adolescents. This suggests that poorer quality sleep may contribute to worse cardiometabolic health of adolescents. The association between lower sleep quality and higher CMR (including measures of central adiposity like WC and BMI) has been discussed in previous research works.[7,12] In a US adolescents' cross-sectional study by Feliciano *et al,* poor sleep quality based on actigraphy measurements was associated with central adiposity and an increased aggregate metabolic score.[5] Similarly, Gohil *et al,* in a review article, reported that poor sleep and obesity were concurrent epidemics based on the association between sleep quality, sleep duration and obesity among adolescents.[6] Conversely, a study conducted among 1078 Chinese children and adolescents, aged 9-18, reported a lack of significant association between PSQI-derived sleep quality and CMR measured with BMI, WC and serum lipids.[8] The inclusion of pre-adolescents and early adolescents in their study may account for this difference. Interestingly, the same study found a significant association between sleep irregularity and CMR, showing the contribution of other components of sleep health to CMR.[8] The mechanisms involved in the association between sleep quality and adiposity may be linked with the effect of sleep disruption on energy balance and the hormones regulating satiety and appetite, and a dysregulation of the hypothalamic-pituitary-adrenal axis.[6]

The second marker of sleep health measured in our study was sleep duration, as derived from the PSQI's question on sleep duration. Urban adolescents reported shorter sleep duration than rural adolescents, while shorter sleep was associated with higher CMR. Short sleep is a well-established risk factor for adverse cardiometabolic health in adolescents.[39] The association between short sleep duration and CMR has been described in both adult[40] and pediatric populations,[5,40] while a lack of association has also been reported.[7] In our study, shorter sleep duration was associated with higher CMR scores and higher measures of adiposity after controlling for confounders. Similar to our findings, longer sleep duration has been reported as being protective against CMR[7], while others reported a U-shaped association, whereby both short sleep duration and extremely long sleep duration were associated with CMR in both children and adults**.**[40] In our study, because only eight participants had a sleep duration >10h (threshold) for long sleep duration in children and adolescents)[41] We may not have had the power to detect an association between long sleep duration and CMR.[23]

Our third measure of sleep health was the risk of sleep apnea as assessed by the Teen STOPBANG. Urban adolescents had a higher risk of sleep apnea than rural adolescents while a higher risk of sleep apnea (as shown by a higher Teen STOPBANG score) showed a significant association with a higher CMR score. We found a similar association between a higher risk of sleep apnea and measures of adiposity, specifically WC and NC. The second feature of the association between the risk of sleep apnea and CMR was the association with SBP and DBP at the bivariable level and the MAP at the multivariable level. It is noteworthy that the risk of sleep apnea was the only sleep health variable associated with MAP in our study. This may be due to the disturbances in the autonomic nervous system and endothelial dysfunction that can result from recurrent hypoxia with sleep apnea.[42]However, the low sensitivity of the Teen STOPBANG (64%) means that some adolescents with OSA could have been missed, underestimating the cardiometabolic effects of having sleep apnea. Most diagnostic tests for OSA have low sensitivity, emphasizing the need for polysomnography even in low-resource settings.

Our fourth measure of sleep health, daytime sleepiness, as measured by the Epworth Sleepiness Score, did not show any association with cardiometabolic health in adolescents.

There are some limitations to this study. First, the cross-sectional nature of our study design does not allow for the determination of causality. Secondly, the sleep health variables were self-reported and we could not calculate sleep regularity, another important sleep health variable, which is best determined with the use of actigraphy. Thirdly, we were unable to include more sophisticated measures of CMR such as cardiorespiratory fitness, skinfold thickness, homeostatic model assessment of insulin resistance and blood lipid measures due to the existing regulations forbidding blood collection in the school setting in the study location. However, the strong association between sleep and CMR in this adolescent population shows the need for longitudinal research on the relationship between sleep and CMR in adolescents. Such studies will help to build on the findings from our study if the use of objective sleep measures and expanded measures of CMR are included.

Our study has the major strength of studying the rural versus urban disparities in the associations between sleep health and CMR using a combination of sleep measurements (sleep quality, sleep duration, risk of sleep apnea and daytime sleepiness). Thus, it provides, first, a better understanding of the association between the multi-dimensions of sleep health with cardiometabolic health. Secondly, our findings add to the existing body of evidence on the need to study sleep from its multiple dimensions rather than focus on a single measure such as sleep duration or quality. Third, our large sample size gave us the power to show associations of poor sleep health with simple clinical measures of cardiometabolic risk.

In conclusion, poor sleep health, assessed with multiple sleep variables, showed a significant association with higher cardiometabolic risk in this sample of 900 Nigerian adolescents; with urban adolescents showing poorer sleep health and higher adiposity-related cardiometabolic risk than rural adolescents. Interventions to prevent CMR in adolescents should thus involve the promotion of good sleep health of adolescents across its multiple domains especially in resource-limited settings, having adolescents living in urban communities as important targets of such interventions. Further research using longitudinal and/or experimental designs is also necessary to better understand the causal relationships underlying the association between poor sleep health and cardiometabolic risk in adolescents.

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Chapters 4 and 5 focused on a large sample of urban and rural adolescents (n=900) and presented sleep health characteristics (as self-reported through validated questionnaires), their determinants and their association with cardiometabolic risk. The next chapter (Chapter 6) now focuses on actigraphy-measured sleep characteristics and their associated factors among a sub-sample (n=170) of the original 900 rural and urban in-school Nigerian adolescents.

CHAPTER 6

Objectively-measured Sleep Characteristics and the Associated Factors among Rural and Urban In-school Nigerian Adolescents

6.1 Publication details

This chapter is presented as a manuscript on objectively measured sleep characteristics and the associated factors among rural and urban in-school Nigerian adolescents. The information about the journal where the work was submitted is presented in Table 6.1

Table 6.1. Journal information and publication status

Title	**Objectively-measured Sleep Characteristics and the Associated Factors among Rural and Urban In-school Nigerian Adolescents**
Journal	**Sleep Medicine**
Manuscript ID	**SLEEP-D-24-02321**
Manuscript type	Original research article
Authors	Oluwatosin Eunice Olorunmoteni,[1,2] Adesegun O. Fatusi,[3,4] F Xavier Gómez-Olivé,[5] Karine Scheuermaier.[2]
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Publication status	Under Peer-review
Journal impact factor	3.8
Keywords	Keywords: Sleep health, Actigraphy, Sleep determinants, Teenagers, Sleep epidemiology

6.2 Author Contributions

Table 6.2 shows the contributions to the manuscript made by each author

Table 6.2: Author Contributions to the paper titled Objectively-measured Sleep Characteristics and the Associated Factors among Rural and Urban In-school Nigerian Adolescents

	Olorunmoteni	Fatusi	Gómez-Olivé	Scheuermaier
Conceptualisation	√	√	√	√
Project administration	√			√
Methodology	√	√	√	√
Initial data analysis	√			
Writing – original draft	√			
Writing – reviewing and editing	√	√	√	√
Visualization	√	√	√	√
Supervision		√	√	√

6.3 Associated Documentation:

The documentation associated with this publication are included as appendices and are labelled as follows:

- Appendix 5: Ethical Clearance Certificate from the Health and Research Ethics Committee of the University of Witwatersrand

- Appendix 6: Ethical Clearance Certificate from the Health Research Ethics Committee of the Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria-

- Appendix 7: Permission from the Osun State Ministry of Education

- Appendix 9: Participant Information and Informed Consent forms

- Appendix 12: Sleep diary

- Appendix 13: Standard Operating Procedure for Actigraphy Data Scoring

6.4 Manuscript: Objectively-measured Sleep Characteristics and the Associated Factors among Rural and Urban In-school Nigerian Adolescents

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6.4.1 Abstract

Purpose: Poor sleep is an important cause of morbidity among adolescents. Earlier studies of the sleep characteristics (SC) of Nigerian adolescents have used sleep questionnaires but are lacking studies using objective measures such as actigraphy and prospective sleep diaries. Thus, this study compared the sleep characteristics of rural and urban-dwelling Nigerian in-school adolescents using actigraphy plus a sleep diary, and it determined the factors associated with their sleep characteristics. Methods: This comparative, quantitative study involving 170 in-school adolescents aged 13-19 years was conducted in six rural and six urban schools in southwestern Nigeria. Participants were given an actigraphy device to wear for one week and were asked to fill in their sleep diary during the same period. Data analysis was done using the Stata SE 15 software. We ran a mixed model analysis with each sleep characteristic as a dependent variable in each model and the fixed effects of age, weekday versus weekend, rural versus urban residence, sex, and religion.

Results: The mean age of the adolescents was 15.6±1.3 years with 54.1% being females. Overall, adolescents' mean bedtime was 22.50±0.85, mean wake time was 5.73±0.68 and mean total sleep time (TST) was 06.07±0.95 hours. We found significantly later bedtimes, earlier mean wake times, shorter time-in-bed (TIB) and shorter TST among urban adolescents on weekdays and weekends ($p<0.05$ for each sleep characteristic). Rural adolescents had lower sleep efficiency ($p=0.016$), higher WASO ($p=0.005$), and more frequent awakenings ($p=0.012$) than urban adolescents on weekdays and weekend days. In mixed-model analyses, older adolescents had later bedtimes ($p=0.035$) and shorter TST ($p=0.047$), urban adolescents had earlier bedtimes, earlier wake times, shorter TIB and TST than rural adolescents (all $p<0.05$), and on weekdays, all adolescents had earlier bedtimes, wake times, shorter TIB and TST than on weekends (all $p<0.05$).

Conclusion: We found insufficient sleep duration among adolescents. This is especially important among urban adolescents with a catch-up sleep on weekends, likely caused by delayed bedtimes, while wake times remained constant. Multipronged interventions, including delaying school start times and better controlling the causes of delay in bedtimes are needed to improve sleep, especially among older adolescents in urban communities.

6.4.2 Background:

Poor sleep is widely recognized as an important cause of morbidity. Short sleep duration has been associated with such morbidities as adverse physical health and behavioural problems among adolescents in high-income countries.[1,2,3] Other sleep characteristics such as sleep quality, daytime sleepiness, sleep apnoea and regularity have also been well-studied in high-income settings using objective sleep measures. Though some reports on adolescent sleep exist in the African setting, most of these studies utilized retrospective sleep questionnaires.[4,5] Furthermore, these studies utilized different forms of sleep questionnaires which may not always have the same validity/cultural sensitivity for the African populations.

While sleep questionnaires are quite useful for the collection of large population data, studies in the field of adolescent sleep health have utilized a wide variety of methodologies. These diverse sleep measures have different strengths and weaknesses based on the ease of utilization, cost, availability duration of use required, level of expertise needed for their administration, and the reliability of the data obtained. The use of questionnaires in sleep research helps to capture a large population of respondents for cross-sectional studies[6,7,8] but entails a retrospective recollection of sleep-wake rhythms with a likely recall bias. The data derived from studies in high-income countries, suggests that information from sleep questionnaires is not as reliable as data obtained when objective measures are utilised.[6] These more reliable measures include the use of actigraphy and/or polysomnography.[6,9] Though the PSG provides accurate and reliable measures of sleep architecture, it has the disadvantage of not being feasible for large population studies and its conduct outside the natural sleep environment may make the measured sleep-wake rhythms of a once-off night atypical.

Actigraphy involves the use of actiwatches, a wristwatch-like device to measure sleep-wake rhythm, together with sleep diaries.[10,11] It provides a prospective and objective measurement of sleep characteristics in the home setting, usually over a three to fourteen-day period. Hence, the use of sleep questionnaires is useful and feasible for large population studies. Nevertheless, objective sleep measures using actigraphy or polysomnography provide stronger evidence for both research and clinical decisions. In Nigeria, there are a few questionnaire-based reports of sleep insufficiency and poor sleep quality in adolescents, especially in the last decade.[12–16] None of the sleep studies conducted in Nigerian adolescents utilized sleep diaries, actigraphy or polysomnography. Hence there is a need for an objective measurement of the sleep characteristics of Nigerian adolescents.

The sociodemographic factors associated with adolescent sleep health need to be more explored. Studies done among African adolescents have shown conflicting findings on the effect of individual and societal factors on adolescents' sleep health. While some studies have reported a lack of sex difference in sleep health,[13,15] some have found poorer sleep among boys,[12,17] and a few others reported a shorter sleep duration[18] and higher nighttime awakenings among girls than boys.[19] The sleep duration and quality of adolescents have been reported to worsen as their age increases.[20] Adolescents tend to have later bedtimes with increasing age with resultant shorter sleep duration as they have to wake up early to meet school demands.[21] Among African adolescents, many studies have found similar worsening of sleep health as adolescents' age increases,[12,13,22,23] though a few studies have reported a lack of association between age and sleep characteristics[15,24] as well as short sleep duration among younger adolescents compared to older ones.[25] Hence, there is a need for further studies to improve the understanding of the individual factors affecting adolescent sleep health.

There are very few studies on the association between religion and sleep health.[26] Types of religious affiliations and the belief system associated with religion have been shown to have an association with sleep but the direction of the association is yet to be well understood.[26,27] Studies have found that religious beliefs could act as stress moderators which may either enhance[28,29] or impede[27] good sleep health. However, most of the available studies have been in adult populations. A qualitative study among Muslim and Jewish participants in Israel reported early wake times and short sleep duration due to the need to rise for morning prayers.[29] Similar findings were reported among Muslim adolescents compared to Christian adolescents in a quantitative study in Côte d'Ivoire.[22] In the United States, Catholics and Baptists were reported to have a shorter sleep duration than atheists.[27] Another important societal aspect is the rural-urban disparities in sleep health which have been shown among African adolescents in general.[22,23] We also reported this rural-urban disparity among Nigerian adolescents in our previous study using sleep questionnaires.[24] These rural-urban disparities in adolescent sleep health have been reported in other climes.[30–32] Finally, adolescents have been reported to have catch-up sleep over the weekends compared to weekdays,[12,21] with their weekday sleep duration often shortened by various school-related demands.[12,33] With the use of objective sleep measures in the current study, we hope to better understand those societal factors affecting adolescent sleep health.

Therefore, our study aimed to answer the following research questions: 1. What are the actigraphy-measured sleep characteristics of Nigerian in-school adolescents in rural versus urban communities? 2. What are the factors associated with the actigraphy-measured sleep characteristics of adolescents?

6.4.3 Methods:

This study utilized a quantitative approach with a cross-sectional design. It was conducted on a subset of the adolescents involved in an earlier study on the multi-dimensions of sleep health among rural versus urban adolescents.[24] (Chapter 4).

6.4.3.1. Study setting:

The study was conducted in the Osun East Senatorial District, Osun State Nigeria.

6.4.3.2. Study population:

A sample was recruited from the 900 adolescents who participated in the initial phase of the study. These participants were required to wear actigraphy-recording devices for a 7-day duration to give an objective measure of their sleep characteristics. At the same time, these adolescents were required to keep a diary of their sleep habits. The research assistants gave daily reminders to the adolescents through home visits or phone calls to ascertain that the actigraphs were consistently worn.

6.4.3.3. Ethical considerations:

The ethical approval for the proposed study was obtained from the Health and Research Ethics Committee of the University of Witwatersrand (Appendix 2) and the Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria (Appendix 3). Written informed consent was obtained from each parent of the adolescent while assent was obtained from the respective adolescents. The purpose of the study, its benefits, and any likely risks were explained to the participants. Also, it was clearly stated that their participation was voluntary and that they could stop their participation at any time during the study with no consequences for them. They were informed about the ways confidentiality was ensured and the likely uses of the data generated.

6.4.3.4 Data collection:

The sociodemographic characteristics of the adolescents were obtained via a previously pilot-tested questionnaire which contained questions on the age, sex, place of residence, religion and nature of school of the adolescents.

6.4.3.5 Actigraphy:

We used the Condor ActTrust 2, which measures and monitors activity and light exposure. The participants were given an actiwatch in the school at the beginning of the study. After adolescents had worn the actiwatch for 7 days, we downloaded the data and analysed them using the ActStudio Version 1.0.6.0 Model AT0503. We also extracted the sleep data using the Cole Kripke algorithm.[34] Participants simultaneously received a printed sleep diary to record their daily sleep-wake schedule over the 7 days (Appendix 13). The sleep variables included in the sleep diary include: bedtime, time to fall asleep (in minutes), time and length of night awakenings, number of awakenings, time of final awakening (wake time), and the time and duration of afternoon naps. We imported the sleep diary data into the ActStudio software for the Actigraphy scoring. We used the sleep diaries to help us confirm the sleep measures recorded on the actigraph, such that the sleep diaries were used to clean the actigraphy data and to correctly score the rest and sleep periods. The standard operating procedure (SOP) used for the data collection with the Actiwatches and the sleep scoring with actigraphs and sleep diaries are presented in Appendix 14. The definition of rest interval was based on the procedure described by Chow *et al*[35] and described in detail in Appendix 14. The analysis of the actigraphy recordings focused on the main sleep episodes. As we scrutinized the actigraphy files, we noticed a few episodes of possible naps (secondary sleep episodes) but we could not distinguish them from periods of low activity as the adolescents very rarely reported those potential secondary sleep episodes in their sleep diaries. Thus, we did not attempt to analyse naps in this study.

6.4.3. 5 Sleep variables:

From the actigraphs, after cleaning the sleep onset and sleep offset times using the sleep diaries, we used the Cole-Kripke algorithm[34] embedded within the ActStudio version 1.0.6.0 software to extract the following sleep characteristics: bedtime (BT), wake time (WT), time in bed (TIB), total sleep time (TST), sleep onset latency (SOL), sleep efficiency (SE), wake after sleep onset (WASO) and number of awakenings.

Data management and analysis: Data analysis was conducted with the Stata SE 15.1 software (Add reference). We presented the description of sociodemographic characteristics using frequencies and percentages and compared the rural-urban differences in these characteristics using the Chi-square test for categorical variables and the independent t-test for the continuous variables. The paired t-test was used to compare the sleep characteristics obtained over the weekdays from weekends.

We ran mixed model analyses where we included each sleep variable (as described above) as a dependent variable in each model and we added the fixed effects of age, time of week (weekday vs weekend; with weekend including the nights from Friday to Saturday and from Saturday to Sunday while all other nights were considered weekdays), rural versus urban residence, sex, and religion.

6.5 Results

We recruited 244 adolescents (among the initial larger study involving 900 participants)[24] for the study to wear actiwatches for a 7-day period. We excluded from the analysis 13 adolescents who did not use the actiwatches correctly and 61 adolescents who used the actiwatches for ≤ 3 days. At the end, we included in the analysis of this sub-study the 170 participants with usable data.

Among the 170 adolescents analysed, there was no statistically significant difference in sex distribution, though there was a female preponderance (54.12%) in the total cohort. The mean age of the respondents was 15.55±1.34 years. The rural-dwelling adolescents had a significantly older mean age (15.75±1.33 years) than their urban-dwelling (15.33±1.33 years) counterparts (p<0.001). Furthermore, two-thirds of the adolescents (68.24%) were in the middle adolescent age group for the overall population. There was no statistically significant difference in the age category between urban and rural adolescents. There was a higher number of attending public schools among the rural adolescents (p<0.001). The majority of the adolescents were Christians, there was no statistically significant difference in the distribution of religion of the adolescents in both rural and urban schools. The other details on the sociodemographic characteristics of the adolescents were provided in Table 6.3.

6.5.1 Sleep characteristics of the adolescents in rural versus urban communities as measured by actigraphy (see Table 6.4.)

The mean bedtime of the urban adolescents (22.73±0.82 pm) was later than the rural adolescents (22.41±0.85) ($p=0.012$). Also, the urban adolescents had an earlier mean waketime (5.54±0.74) than their rural counterparts (5.89±0.58) ($p=0.001$). Furthermore, this study showed a shorter actigraphy-measured mean TST (5.85±0.84 hours) among urban adolescents compared to rural adolescents (6.26±1.01 hours) ($p<0.001$). Similarly, the urban adolescents had a lower actigraphy-measured mean TIB (6.81±1.02 hours) than their rural counterparts (7.49±0.99 hours) ($p=0.004$). Conversely, the mean sleep efficiency of the urban adolescents (86±6%) was significantly higher than that of the rural adolescents (84±8%) ($p=0.016$). The rural adolescents had higher mean wake-after-sleep-onset (WASO) and frequency of awakening than their urban counterparts ($p=0.005$ and 0.012).

6.5.2 Weekday-weekend difference in the sleep characteristics of the overall participants as measured by actigraphy (See table 6.5.)

Our study showed an overall significantly shorter actigraphy-measured mean TST (5.97±0.94 hours) on weekdays compared to weekends (6.26±1.39 hours) ($p=0.028$). The mean bedtime was earlier on weekdays (22.50±2.89) than on weekends (22.73±1.18) ($p=0.048$). Similarly, the adolescents had earlier mean wake times on weekdays (5.58±0.65) than at weekends (6.09±1.04) ($p<0.001$). The mean TIB of 7.08±1.08 hours obtained on weekdays was shorter than the mean of 7.36±1.52 hours on weekends ($p<0.045$). In summary, the adolescents had significantly later mean bedtimes, earlier mean wake times, significantly shorter mean TIB and shorter TST on weekdays. The other sleep characteristics were not significantly different among the adolescents on weekdays versus weekends. Using actigraphy, the mean bedtime of all the adolescents for the entire days of the study was 22.62±1.05, while their mean wake time was 5.84±0.90 and the mean TST was 6.11±1.20 hours.

6.5.3 Weekday-weekend difference in the sleep characteristics of the adolescents in rural versus urban communities as measured by actigraphy (See table 6.6.).

On weekdays, the urban adolescents had significantly later mean bedtimes, than the rural adolescents (p=0.019). Also, they presented earlier mean wake times, shorter mean TIB and shorter TST (all p<0.001). On the other hand, rural adolescents had more frequent awakenings than their urban counterparts on weekdays (p=0.006).

On weekends, the mean TIB of the urban adolescents was significantly shorter than that of the rural adolescents (p=005), while the rural adolescents had significantly lower sleep efficiency (p=0.005), higher wake-after-sleep onset (WASO) (p=0.004), and a higher mean frequency of awakening (p=0.004) than the urban adolescents. Mean bedtimes, mean wake times, mean TST, and sleep onset latency, were not different in urban vs. rural adolescents.

6.5.4 Multivariable analysis of the factors associated with sleep characteristics of rural vs urban adolescents.

Using the mixed-model analysis to determine the factors associated with sleep characteristics of rural versus urban adolescents, we found that the adolescents' sleep characteristics differed significantly based on their age, weekday versus weekend period and place of residence, but not their sex or religion. The older adolescents had later bedtimes (p=0.035) and shorter TST (p=0.047) than the younger adolescents. In those adjusted analyses, on weekdays, adolescents had earlier bedtimes (p=0.003), earlier wake times (p=<0.001), shorter TIB (p=0.001), and shorter TST (p=0.001) compared to weekends. Furthermore, the urban adolescents had earlier bedtimes (p=0.020), earlier wake times (p=0.004), shorter TIB (p<0.001) and TST (p=0.031) compared to rural adolescents. On the other hand, the rural adolescents had significantly lower sleep efficiency (p=0.004), higher WASO (p=0.002) and more frequent awakenings (p=0.006) than urban adolescents. There were no significant differences in the adolescent sleep characteristics by sex or religion.

Table 6.3.: Socio-demographic characteristics of the respondents.

Sociodemographic characteristics	Rural (N=91) N (%)	Urban (N=79) N (%)	Overall (N=170) N (%)	Statistics
Sex				
Female	44(48.35)	48(60.76)	92(54.12)	χ2=2.622
Male	47(51.65.)	31(39.24)	78(45.88)	*p*=0.105*
Age in years				
Mean age (mean ±SD)	15.75±1.33	15.33±1.33	15.55±1.33	t=6.06 ***p*=<0.042**
Age categories				
13– 14 (early adolescence)	16(17.58)	24(30.38)	40(23.53)	χ2=3.851
15 – 17 (middle adolescence)	67(73.63)	49(62.03)	116(68.24)	*p*=0.146*
18 – 19 (late adolescence)	8(8.79)	6(7.59)	14(8.24)	
Religion (n=165#)				
Christianity	79(91.86)	75(94.94)	154(93.33)	χ2=11.822
Islam	7(8.14)	4(5.06)	11(6.67)	*p*=0.429
Social class				
Upper	3(3.30)	17(21.52)	20(11.76)	χ2=9.2291
Middle	28(30.77)	40(50.63)	68(40.00)	*p*<**0.001***
Lower	60(65.93)	22(27.85)	82(48.24)	
Nature of School				
Public	76(83.52)	21(26.58)	97(57.06)	χ2=55.946
Private	15(16.48)	58(73.42)	73(42.94)	*p*=<**0.001***
Class in school				
JSS1-JSS3	6(6.59)	1(1.27)	7(4.12)	χ2=3.040
SSS1-SSS2	85(93.41)	78(98.73)	163(95.88)	*p*=0.081

Table 6.4.: Rural-urban difference in the mean sleep characteristics for the entire study period.

Sleep variables	Rural Mean±SD	Urban Mean±SD	*t*/p*
Bedtime	22.41±0.85	22.73±0.82	t=-2.536 **p=0.012**
Wake time	5.89±0.58	5.54±0.74	t=3.460 p**=0.001**
Time-in-bed	7.49±.99	6.81±1.02	t=4.383 p**=<0.001**
Total sleep Time	6.26±1.01	5.85±0.84	t=2.919 **p=0.004**
Sleep efficiency (%)	84±8	86±6	t=-2.426 **p=0.016**
SOL	0.10±0.07	0.08±0.10	t= 1.247 p= 0.214
WASO	1.08±0.57	0.85±0.74	t=2.815 **p=0.005**
Awakenings (n/night)	12±5	10±5	t=2.554 **p=0.012**

All time variables are in decimal hours. *unpaired t-test

Table 6.5.: Difference in mean sleep characteristics of the whole sample between weekdays and weekends as measured with actigraphy

Sleep variables	**Weekend Mean±SD**	**Weekday Mean±SD**	**Overall Mean±SD**	*t*/p*
Bedtime	22.73±1.18	22.50±0.89	22.62±1.05	t=1.988 **p=0.048**
Wake time	6.09±1.04	5.58±0.65	5.84±0.90	t=5.170 p=**<0.001**
Time in bed`	7.36±1.52	7.08±1.08	7.22±1.33	t=2.015 **p=0.045**
Total sleep Time	6.26±1.39	5.97±0.94	6.11±1.20	t=2.201 p**=0.028**
Sleep efficiency (%)	85±9	85±7	85±8	t=0.328 p=0.743
SOL	0.08±0.10	0.09±0.11	0.09±0.10	t= -1.322 p= 0.187
WASO	0.98±0.64	0.97±0.54	0.97±0.59	t=0.142 p=0.661
Awakenings (n/night)	11±7	11±5	11±6	t=0.309 p=0.757

All time variables are in decimal hours *Paired t-test

Table 6.6.: Rural-Urban Difference in Mean Sleep Characteristics on Weekdays and Weekends.

Sleep variables	**Rural (n=91) Mean±SD**	**Urban (n=79) Mean±SD**	**Overall (n=170) Mean±SD**	**P value**
Week days				
Bedtime	22.36±0.84	22.67±0.10	22.50±0.89	***p*= 0.019**
Wake time	5.75±0.56	5.38±0.70	5.58±0.65	***p*<0.001***
Time in bed	7.39±0.96	6.71±1.11	7.07±1.08	***p*<0.001***
Total sleep Time	6.21±0.93	5.71±0.89	5.97±0.94	***p*<0.001***
Sleep efficiency (%)	84.18±7.46	85.73±6.83	84.90±7.19	*p*=0.163
Sleep onset latency	0.10±0.08	0.09±0.06	0.09±0.08	*p*=0.687
WASO	1.04±0.56	0.88±0.51	0.97±0.54	*p*=0.051
Awakenings (n/night)	12.19±5.34	10.01±4.63	11.18±5.13	***p*=0.006***
Weekend days				
Bedtime	22.56±1.19	22.92±1.15	22.73±1.18	*p*= 0.053
Wake time	6.23±0.92	5.93±1.14	6.09±1.04	*p*=0.063
Time in bed	7.67±1.52	7.02±1.46	7.36±1.52	***p*=0.005**
Total sleep time	6.41±1.51	6.08±1.22	6.26±1.39	*p*=0.129
Sleep efficiency (%)	83.45±9.48	87.18±7.22	85.19±15.56	***p*=0.005**
Sleep onset latency	0.09±0.11	0.07±0.08	0.98±0.10	*p*=0.174
WASO	1.11±0.68	0.82±0.56	0.98±0.64	***p*=0.004**
Awakenings (n/night)	12.34±6.77	10.27±6.07	11.38±6.52	***p*=0.004**

WASO: wake after sleep onset; unpaired t-tests were run to compare the rural and the urban adolescents; all time variables are in decimal hours.

Table 6.7: Factors associated with sleep characteristics of rural versus urban adolescents using mixed-models analysis

Dependent variable ➔ **Independent variables ⬇**	**Bedtime** **Beta estimate (adjusted)** **95%CI**	***P-value***	**Wake time** **Beta estimate (adjusted)** **95%CI**	***P-value***	**TIB** **Beta estimate (adjusted)** **95%CI**	***P-value***	**TST** **Beta estimate (adjusted)** **95%CI**	***P-value***	**SOL** **Beta estimate (adjusted)** **95%CI**	***P-value***	**SE** **Beta estimate (adjusted)** **95%CI**	***P-value***	**WASO** **Beta estimate (adjusted)** **95%CI**	***P-value***	**# Awak.** **Beta estimate (adjusted)** **95%CI**	***P-value***
Age in years	0.10	**0.035**	-0.01	0.798	-0.11	0.054	-0.11	**0.047**	-0.01	0.478	-0.11	0.784	-0.01	0.962	-0.28	0.349
	0.01, 0.19		-0.09, 0.07		-0.23, 0.01		-0.21, -		-0.01, 0.01		-0.93, 0.70		-0.06, 0.06		-0.86,0.30	
Weekday-	-0.23	**0.003**	-0.52	**<0.001**	-0.29	**0.001**	-0.28	**0.001**	0.02	0.153	-0.09	0.853	-0.02	0.512	-0.74	**0.023**
Weekend	-0.38, -		-0.63, -		-0.47, -		-0.43, -		-0.01, 0.05		-1.08, 0.89		-0.10, 0.05		-1.38,-	
Residence	0.34	**0.010**	-0.32	**0.002**	-0.66	**<0.001**	-0.39	**0.007**	-0.02	0.176	2.76	**0.014**	-0.24	**0.005**	-2.24	**0.006**
(urban-rural)	0.08, 0.60		-0.53, - 0.12S		-0.97, - 0.35		-0.67, - 0.11		-0.05, 0.01		0.55, 4.98		-0.40, - 0.07		-3.80,- 0.65	
Sex (Male-Female)	-0.02	0.891	0.17	0.102	0.18	0.237	0.24	0.096	-0.01	0.687	0.57	0.600	-0.02	0.832	-0.05	0.946
	-0.27, 0.24		-0.03, 0.36		-0.12, 0.49		-0.42, 0.51		-0.03, 0.02		-1.56, 2.69		-0.18, 0.14		-1.55, 1.44	
Religion	-0.08	0.751	-0.03	0.891	-0.11	0.721	0.02	0.943	0.01	0.798	1.85	0.382	-0.13	0.377	-1.38	0.356
(Christianity/Islam)	-0.41, - 0.01		-0.40, - 0.36		-0.69, 0.48		-0.51, 0.55		-0.05, 0.06		-2.29, 5.98		-0.45. 0.17		-4.32, 1.55	

TIB: Time in Bed; TST: Total sleep time, SOL: sleep onset latency, SE: sleep efficiency, WASO: wake after sleep onset, # Awak.: number of awakenings per night.

Beta estimates for bedtime, wake-time, time in bed, total sleep time, sleep onset latency and wake after sleep onset show decimal time, with -0.23 weekday compared to WE in bedtime meaning that all participants on average woke up 0.23x60=13.8 minutes earlier on weekdays compared to weekends.

All models were run using mixed model analysis specifying a normal distribution, except for the number of awakenings where we specified a Poisson distribution.

6.6 Discussion

This study provides data on the sleep characteristics of 170 rural and urban in-school Nigerian adolescents using actigraphy recordings. Overall, the adolescents had a short TST (sleep duration) of about 6 hours (Table 3) which is significantly lower than the recommended duration.[36] Also, their age, place of residence and weekday versus weekend measurements showed statistically significant associations with the sleep characteristics measured. The older adolescents had later bedtimes, similar wake times and shorter TIB and TST than the younger adolescents. On weekdays compared to weekends, adolescents had earlier bedtimes, earlier wake times shorter TIB and TST. Furthermore, urban adolescents had later bedtimes, earlier wake times, and shorter TIB and TST compared to rural adolescents. On the other hand, rural adolescents had significantly lower sleep efficiency and higher wake after sleep onset than urban adolescents

The adolescents studied had short sleep duration irrespective of their place of residence. As shown in Table 3, the overall mean sleep duration obtained by these adolescents was about 6 hours which is significantly below the recommended 8.5 – 9.3 hours.[36] This short sleep duration is due to their late bedtimes and early wake times. While the late bedtime is in keeping with the tendency to sleep late due to physiological phase delay during adolescence, their wake time is early rather than late. The early wake time may be due to school and societal pressures which result in early wake times, as reported in other settings.[36,37,38] It is therefore important to understand the factors associated with the adolescent's sleep deprivation to develop appropriate interventions.

6.6.1 Adolescent sleep characteristics and age

We found that older adolescents had significantly later bedtimes and shorter sleep duration than their younger counterparts. The mean TST of 6.1±1.2 hours obtained for the overall population worsens as the age of the adolescent increases with a mean of 6.2±1.4 hours for early adolescents, 6.1±1.5 hours for middle adolescents and 6.0±1.6 hours for late adolescence. On weekdays, the mean TST was 6.0±0.8 hours for early adolescents, 6.0±1.0 hours for middle adolescents and 5.8±1.0 hours for late adolescence. The shorter sleep duration observed in these older adolescents concurs with previous findings of shorter sleep duration among older adolescents in our setting using sleep questionnaires.[12] Being in the early adolescent age group was reported to be an independent predictor of sufficient sleep on weekends.[12] Similar findings have been reported in other societies.[36,39] The biological changes which begin at the onset of puberty and progress as the age of the adolescent increases are associated with progressively larger delayed sleep phase.[39,40] In our study, bedtime was more delayed as the age of the adolescent increased, which aligns with previous findings.[40] In addition to the biological explanations for delayed bedtimes in older adolescents, individual and social factors may also be contributory. Electronic device use at night has been associated with delayed bedtimes and short sleep duration.[12,38] It is possible that older adolescents are more likely to use electronic devices at bedtime than younger adolescents. Furthermore, the older the adolescent is, the lower the parental supervision of their bedtime and overall sleep schedule.[39] In an earlier study, we found that parental supervision of bedtimes showed a significant association with better sleep health.[24] In addition, the academic demands, after-school classes and homework burden of older adolescents may be more than that of younger adolescents and may likely contribute to a further delay in their bedtimes.[39] While bedtimes were more delayed with older age, we did not find more delay in the wake times with age, which may be due to fixed school start times. Thus the combination of delayed bedtimes and inability to delay wake times resulted in shorter sleep opportunity and duration with older age. This suggests that a simple intervention such as delaying school start times may help increase sleep duration during adolescence, as elsewhere in the world.[41,42]

6.6.2 Weekday versus weekend differences in adolescent sleep characteristics

The actigraphy measure of the adolescents' sleep characteristics provided an objective differentiation of weekend versus weekday values. The significantly later wake times of the adolescents on weekends support the previous reports of a tendency for adolescents to have catch-up sleep on weekends.[43] This is attributed to insufficient sleep on school days such that the adolescents utilize the sleep opportunity provided by a free weekend to pay back the previous sleep debt. As shown in Table 3, the adolescents had a shorter sleep duration on weekdays compared to weekends, supporting the reasons for a tendency to catch up on lost sleep hours on weekdays. Also, the adolescents' later bedtime on weekends suggests that the adolescents tended to sleep according to their physiologic sleep drive and phase delay when the pressure of school demands is removed. It is also possible that they tended to sleep late on weekends because of their increased use of electronic devices. However, there was no statistically significant difference in the weekday versus weekend SE, SOL, WASO and number of awakenings. Despite evidence for catch-up sleep on weekends by delaying wake times, the sleep duration on weekends remained under the recommended 8.5 hours for adolescents.

6.6.3 Rural versus urban differences in actigraphy-measured adolescent sleep characteristics

This study showed later bedtimes among urban adolescents compared to their rural counterparts when investigated in multivariable analyses. Also, urban adolescents had earlier wake times and shorter sleep duration than their rural counterparts. Thus, urban adolescents had poorer sleep characteristics than their rural counterparts. The likely factors contributing to the poor sleep characteristics among urban adolescents include exposure to artificial light at night (ALAN) due to electricity supply which may not be available in rural settings.[44] Furthermore, urban adolescents are likely to use electronic devices at bedtime which further causes a shift in bedtime.[45] In a previous paper[24], we found no significant difference in the school start time of rural versus urban adolescents but we found a difference in the school end times with the urban adolescents closing later (p=0.021). Also, every later hour in the school end (closing) time showed a 1-fold increase in the odds of having poor sleep quality and excessive daytime sleepiness.[24] Interventions targeting urban adolescents will need to explore further the factors contributing to their sleep health at home and in school.

Conversely, the rural adolescents in the present study had a lower sleep efficiency and a higher WASO. The urban adolescents likely had lower WASO and lower number of awakenings than rural adolescents due to the higher homeostatic sleep pressure built across time. According to the two-process model (Borbely et al, 1982), higher sleep pressure due to larger time spent awake in the 24-hour day would lead to a higher amount of slow wave sleep during the sleep episode, which in turn would make waking during sleep less likely. Conversely the relatively lower sleep pressure in rural adolescents, in particular on weekends, may translate into a lower amount of slow wave sleep, which in turn may make awakenings from external signals more likely. From a previous study, we found that a bit more than two-thirds of the adolescents living in rural settings in this region of Nigeria were from a low social class[24], so their sleeping environment may be poorer than that of urban adolescents. Sleeping in poor sleeping environments may lead to a higher number of awakenings and WASO, and thus impair their sleep efficiency. Poor sleeping conditions as well as living in a disadvantaged neighbourhood have been reported to contribute to poor sleep health.[46,47] Thus, the external signals which can interrupt sleep may be more frequently encountered in rural adolescents' environments than in urban adolescents' environments. In rural Nigeria, poor heat control in rural dwellings, the presence of mosquitoes, and overcrowding may all contribute to sleep disruption. It is also possible that urban adolescents may have more access to air conditioning which would both help with heat control and lower amount of mosquitoes that can disrupt sleep. Interventions focused on improving adolescent sleep must reduce factors contributing to later bedtimes and earlier wake times among urban adolescents while targeting improving sleep efficiency among rural adolescents.

6.6.4 Strengths and Limitations

This study is the first, to the best of the investigators' knowledge, to compare actigraphy-measured sleep characteristics among urban and rural African adolescents. The scoring of the actigraphy data with a concurrent sleep diary recording further strengthens the quality of the data. However, 74 of the 244 adolescents did not use the actigraphs correctly or for enough number of days within the 7-day period. As a result, only the 170 adolescents who used the actigraphs correctly for at least 4 days were included in the final analysis. We explored the reasons for poor use of the actigraphs among adolescents who did not use the actigraphs correctly. We found that some forgot to wear the actigraphs after bathing or washing, some were skeptical of the safety of the watch especially because the "black colour" of the actiwatch was associated with "evil", while one adolescent stopped using the actiwatch because she had allergic dermatitis after wearing it for a few days. Future studies involving the use of actiwatches in our setting will need to counsel adolescents and their parents on their safety and possibly exclude those with allergic skin conditions. In addition, we did not analyze naps due to the challenges reported in the methods section, but we recommend the use of phone recalls to document daily nap periods to aid analysis of secondary sleep episodes.

6.6.5 Conclusions

Objective measurement of adolescent sleep characteristics showed significant insufficient sleep duration and poor sleep efficiency. Among urban adolescents, insufficient sleep was mainly from delayed bedtimes and early wake times with a catch-up sleep on weekends, similar to reports in other climes. Adolescents in rural settings had lower sleep efficiency which also needs to be explored to understand the contributors and provide the appropriate interventions. Multipronged interventions are needed to improve sleep health, especially among older adolescents in urban communities.

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CHAPTER 7

DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

7.1. Introduction

This chapter highlights the key findings from each of the study objectives as presented in the thesis. It discusses the study findings and their implications, providing explanations and lines of future studies. It also provides the strengths of the study, the limitations, as well as the recommendations from the study. The aims and objectives of the study in this thesis address some of the research gaps recently compiled by technical experts in the field of child and adolescent sleep.[1] The experts highlighted the need for studies using objective methodologies to address child and adolescent sleep health, the need to explore disparities that may be associated with sleep in children and adolescents, and the need for studies to identify the potential risk and protective factors that may be associated with sleep health of children and adolescents as well as the need to further understand the link between sleep health and cardiometabolic risk (CMR).[1]

The study aimed to map the studies on adolescent sleep in Africa, identify knowledge gaps, and determine the differences in the sleep characteristics among rural versus urban adolescents. It alos aimed to define the determinants of the sleep health of in-school adolescents in southwestern Nigeria, and to stablish the association between their sleep health and their CMR factors. I utilised multiple methodologies to answer each of the four objectives of this work. The first objective was to map out adolescent sleep health in Africa using a scoping review methodology, describing the patterns, determinants, and associated factors with adolescent sleep health in the continent. The second objective was to determine the differences in the sleep characteristics of Nigerian in-school adolescents in rural versus urban communities. The third objective was to determine the association between sleep health and CMR factors of rural and urban in-school Nigerian adolescents. The fourth objective (involving a subset of the in-school adolescent participants for objectives 2 and 3) was to determine the sleep characteristics obtained with a sleep diary and the factors associated with their sleep characteristics. The summary of the key findings from this thesis against initial objectives and the key implications of these findings are presented in Table 7.1.

Table 7.1. Summary of research findings and implications

S/No	Objectives	Chapters	Key Findings	Implications
1	To map out the studies on adolescent sleep health in Africa using a scoping review methodology, describing the patterns, determinants and associated factors with adolescent sleep health in the continent.	2 (scoping review protocol, published) 3 (scoping review)	• Very few studies are available on adolescent sleep in Africa. We identified 31 that met our inclusion criteria. • The most studied sleep variables are sleep duration and quality with limited studies on other dimensions of sleep health. Inadequate sleep duration during weekdays was common among adolescents, with compensatory longer weekend sleep durations. • There is increasing attention to adolescent sleep health in Africa but there is inconsistent use of terminologies and standardised tools, as well as limited rigour in study designs (use of convenience sample, no validation of the questionnaire tools, sparse/no use of actigraphy or polysomnography). • Younger age and parental setting of bedtimes serve as a protective factor for good sleep health. • Screen use at bedtime was a major risk factor for sleep disturbances among urban-dwelling adolescents while poor sleeping conditions impaired sleep, especially among	• Need for more studies on the multi-dimensions of adolescent sleep health in Africa. • Challenges with using diverse forms of questions /questionnaires to measure sleep show the need for unified sleep questionnaires and their validation, as well as cultural adaptation of available tools to measure adolescent sleep in Africa. It is important to understand the causes of sleep disturbance to be captured in the questionnaires such as the role of mosquitoes, the effect of dysmenorrhea among adolescent girls and gender roles. • Need for well-designed studies using multiple methods (qualitative, longitudinal, multisite) to further understand adolescent sleep health and its determinants. • More resources for objective measurement of sleep characteristics in adolescents in Africa.

			adolescents in rural communities. Other risk factors identified were substance use, caffeine intake and adverse childhood experiences. • Findings on the sex differences and the rural-urban differences in sleep characteristics are conflicting. • Less explored factors include religion, family dynamics, neighbourhood factors as well school-related factors.	• Multi-level interventions to improve adolescent sleep health in Africa by addressing the various risk factors and exploring the protective factors.
2.	To compare the multi-dimensions of sleep health of in-school adolescents in rural versus urban communities in southwestern Nigeria.	4	• 900 adolescents (461 rural) had analysable data for this study. • The majority (79%) of the adolescents had short self-reported sleep duration (< 8.5 hours). • Other sleep health problems were less prevalent as 14.9% had poor sleep quality, 9.6% had excessive daytime sleepiness and 9.8% had a risk of sleep apnea. • Urban adolescents had a higher prevalence of poor sleep quality (p=0.004), short sleep duration (p<0.001), daytime sleepiness (p=0.044), and risk of sleep apnea (p=0.006) compared to rural adolescents. With adjusted analysis, urban adolescents had about 2-fold higher odds of having poor sleep quality (p=0.008) and daytime sleepiness (p=0.007) compared to rural adolescents.	• Adolescents have an idea of their poor sleep health and self-report of their sleep health can be useful in large population studies and to guide adolescents' sleep hygiene, and their seeking of appropriate help or treatment for their sleep problems. • Protective factors for sleep health to be promoted: - Parent-setting of bedtimes • Risk factors to be mitigated: - Urban residence - Family dynamics - Sleep disruptors in rural settings • Urban adolescents' poor sleep health needs to be explored more to develop appropriate interventions.

			• Protective factors for good sleep health included living in a rural community and having parents set bedtimes. • The risk factors for having poor sleep health in adolescents were living in an urban community, later school end time, and having single/separated parent(s).	• Sleep disruptors in rural communities need to be identified to provide tailored interventions and improve their sleep quality. • Which school factors should be considered: school start time, school end time or both?
3.	To determine the association between sleep health and markers of CMR in rural and urban in-school Nigerian adolescents.	5	• We included the same 900 adolescents as in Chapter 4. • Poor sleep health was associated with higher cardio-metabolic risk. • Urban adolescents had higher BMI, WC and NC while rural-dwelling adolescents had higher random blood glucose levels. • CMR score combining z-scores of the 4 clinical CMR factors (BMI, WC, RBG and MAP) was not different between the urban and rural adolescents. • Urban adolescents also had poorer sleep health measures than their rural counterparts • Poorer sleep quality was associated with higher BMI, WC and NC, and a higher CMR score. • A higher risk of sleep apnea was associated with higher CMR scores, and higher WC, NC and MAP z-scores.	• Our study showed a significant association between adolescent sleep health and CMR though there are considerations of the right sleep questionnaire for measuring the association between risk of sleep apnoea and CMR. • Challenges of measuring CMR in resource-constrained settings. • Improving sleep and CMR in urban adolescents to prevent present and future multi-morbidities.

			• Lower sleep duration was associated with higher CMR scores, and higher BMI, WC and NC z-scores.	
4.	To determine the sleep characteristics obtained with a sleep diary and actigraphy using a subset of the adolescents, and the factors associated with their sleep characteristics	6	• A subset of 170 adolescents (91 rural) from the 900 adolescents of Chapters 4 and 5. • Overall, both rural and urban adolescents had a very short total sleep time of 06.07±0.95 hours. • On both weekdays and weekends, urban adolescents had significantly later bedtimes, earlier wake times, shorter time-in-bed (TIB) and TST (all p<0.05) than rural adolescents. In mixed models analysis, urban adolescents had later bedtimes, earlier wake times, shorter TIB and TST than rural adolescents (all p<0.05) • Rural adolescents had lower sleep efficiency, more frequent awakenings and WASO (all p<0.05). • Older adolescents had later bedtimes (p=0.035) and shorter TST (p=0.047). • On weekdays, all adolescents had earlier bedtimes, wake times, and shorter TIB and TST than on weekends (all p<0.05).	• Objective sleep measures show worse short sleep duration among all adolescents with similar rural-urban pattern • Worse insufficient sleep on weekdays suggests the influence of school-related factors • Risk factors to be mitigated: - Challenges of urban residence - School factors • Protective factors for sleep health to be promoted: - Young age - Habits in rural areas that are associated with better sleep health.

7.2. Integrated Discussion

7.2.1. Scope of Adolescent Sleep Health in Africa

Our scoping review revealed that there are very few studies on adolescent sleep health in Africa. The gaps identified from the study were the need for more studies on adolescent sleep health in Africa to have the entire scope of sleep issues in African adolescents. Secondly, there is a need to have the contexts of Africa well considered, taking into consideration the differences in infrastructure in rural versus urban communities, and how these affect the sleep health of adolescents. The role of poor sleep hygiene, electricity or artificial light at night and the effect of screen use on adolescent sleep as well as the impact of cultural norms such as gender roles need to be further explored. Furthermore, the causes of sleep disruptions in rural settings need to be well-considered to identify the extent to which the sleeping environment in rural settings affects sleep and how to mitigate these factors. I also identified the need to explore other factors that have not been given adequate attention in the African context such as the role of religion, the family environment and parent-adolescent relationships, neighbourhood safety and school-related factors, especially the school start and end times.

The sleep duration on weekdays obtained from the various studies included in this review was overall <8 hours which is below the recommended 8.5 hour sleep duration for adolescents.[2] The few studies where the mean sleep duration of adolescents was reported to be above the minimum recommended duration of <8.5 hours were those in which the weekday versus weekend sleep duration was not disaggregated. Since adolescents will typically have a catch-up sleep on weekends[3] as shown also in the studies among African adolescents,[4–7] it is likely that the longer sleep duration on weekends contributed to a seemingly normal range of sleep duration in those studies without disaggregated weekday-weekend sleep duration. Furthermore, the high prevalence of poor sleep quality among African adolescents shows that sleep duration is not the only sleep characteristic with poor indices. Though there are limited findings on other aspects of sleep health, the available studies show the need to study the different dimensions of sleep in African adolescents and to also give attention to the factors that may be associated with adolescent sleep health in Africa. There is also the need for more studies on adolescent sleep health from the East and Central regions of Africa.

The findings obtained on determinants of adolescent sleep health highlighted some risk and protective factors that can be looked into. African adolescents, especially those in urban areas may be exposed to similar risk factors as the adolescents in high-income countries due to the effects of rapid urbanization such as screen use, artificial light at night and the higher demands of school-related schedules such as commuting time, school start time and possibly the school end time. However, among adolescents in Morocco, urban adolescents had better sleep quality than rural adolescents.[8] There may be sleep disruptors in the sleeping environment for rural adolescents but this needs to be explored. Rural adolescents may be more exposed to mosquito bites. There may be links between sleep and mosquitoes since mosquito bites are more common at night. The noise or pain caused by the bites may cause sleep disruptions. Additionally, the lack of electricity in rural settings can result in hot sleeping environments that can contribute to frequent nighttime arousals from mosquito bites and heat.[9] Hence, there is a need for studies to further explore the rural-urban disparities in sleep health among African adolescents.

It is impressive to see that studies on adolescent sleep health in Africa showed a gradually rising trend in the last 10 years. This trend in the right direction provides a huge opportunity for coordination and direction for adolescent sleep research in Africa. African researchers must use the right tools and questions to answer the gaps identified in adolescent health. The use of non-validated or random questions to measure sleep reduces the validity and reliability of the results. Also, there is a need to use the right terminologies when describing sleep-related concepts or variables to allow for comparison of results and generalization of findings. Sleep disturbances were sometimes used interchangeably with sleep disorders or sleep quality, making the interpretation of results difficult (Chapter 3). Therefore, African researchers and collaborators need to pay attention to the study design and data quality on sleep research in the continent.

7.2.2. Multi-dimensions of sleep health among in-school adolescents in rural and urban areas

In the studies I conducted in Nigeria, I used basic validated self-report questionnaires to measure the various sleep characteristics, giving a general sleep health overview. I found poor sleep health in some of the adolescents with the majority (79%) sleeping less than the recommended 8.5 hours' while varying degrees but lesser prevalence were obtained for other sleep quality, daytime sleepiness and the risk of sleep apnoea (Chapter 4). The poor sleep health found in adolescents using sleep questionnaires was confirmed when actigraphy with sleep diaries was used on a subset of randomly selected adolescents from the larger sample (Chapter 6). This suggests that adolescents recognize their poor sleep health but may be underestimating its extent. Thus, objective measures need to be more deployed to study adolescent sleep in Africa.

Furthermore, adolescents presenting with sleep problems in clinical settings may need to be further evaluated with objective measures to establish the type and extent of the sleep problems and to diagnose sleep disorders in them. The lack of resources for polysomnography (PSG) studies in Africa is exemplified by the paucity (4/31) of studies with PSG in the scoping review (Chapter 3). Due to the scarcity of resources for sleep evaluation in Africa, a model of screening with validated questionnaires in large populations followed up with detailed assessments with objective methods for high-risk persons identified from the sleep questionnaires may be practicable. Investment in improving sleep health in the African continent will be an important public health investment.

The rural-urban disparities shown in the two studies on sleep characteristics (Chapter 4 and Chapter 6) point attention to sleep health inequalities even in Africa. Urban adolescents had poorer sleep health than rural adolescents which may be due to their exposure to more socially-determined risk factors such as screen and internet use, better access to electricity and higher nightlife. Urban adolescents had significantly delayed bedtime in both questionnaire and actigraphy measurements and either the same (questionnaires, Chapter 4) or earlier (actigraphy, Chapter 6) waketime than the rural adolescents. This finding is consistent with the use of light-emitting devices at night, most likely at bedtime, in urban adolescents. It is also possible that the parents of urban adolescents are less available to regulate their children's bedtime and help minimise distractions. Conversely, the rural adolescents showed lower sleep efficiency, more frequent awakenings and longer wake after sleep onset, supporting the hypothesis that rural adolescents are exposed to some sleep disruptors that need to be further explored.

7.2.3. Risk and protective factors associated with sleep health among rural and urban-dwelling in-school Nigerian adolescents

Our study (chapters 3, 4 and 6) explored some of the risk and protective factors that may be associated with adolescent sleep health. A study by Grandner has used the socioecological model to explain the risk and protective factors associated with sleep health.[10] I have adapted the socioecological model of sleep and health to illustrate the risk and protective factors found to be associated with adolescent- sleep health in this thesis as shown in Figures 7.1. and 7.2.

The risk factors identified to be associated with adolescent sleep health are multilevel. They can be grouped as individual, family/household-related, neighbourhood-related and school-related. The individual-level risk factors identified in the literature include older age, screen use, poor sleep hygiene, and substance use. Though age was not associated with any of the sleep health variables in the questionnaire study (Chapter 4), the actigraphy study showed a significant association between older age and later bedtime as well as lower sleep duration (total sleep time) (Chapter 6). Our finding of older adolescents having later bedtimes and shorter sleep duration is similar to earlier reports from studies in Côte d'Ivoire,[11] Tunisia[12] and Nigeria.[6,13] The older the adolescent, the more likely they will be susceptible to the social factors that can result in delayed bedtimes and short sleep duration. Older adolescents are more likely to have independence with less parental setting of bedtimes, more school/homework load, afterschool lessons or jobs and more access to smartphones and other electronic devices. The effects of these social factors are worsened by biological delay in the circadian phase which is likely to be more established in older adolescents[14] giving what has been described as the "pubertal storm".[15,16]

Other individual factors identified are poor sleep hygiene such as caffeine use, substance use and the use of electronic devices at bedtime (Scoping review, Chapter 3). These factors need to be further explored in greater detail in subsequent studies. In addition, the association of sex and religion with adolescent sleep health is not well understood. Though, the type of religious affiliation did not show a significant association with sleep health in the Nigerian adolescents I studied, the religious practices of the adolescents may be more contributory to their sleep health. Amongst the 900 adolescents who filled in the PSQI, 34 had answered 'other' to question 5 about sleep disturbances. Our unpublished data showed that two adolescents out of those 34 who had other reasons for sleep disturbance aspect of the PSQI reported praying at night as the other reason they had trouble sleeping as part of the Pittsburgh Sleep Quality Index. Also, 5 out of 34 who had other reasons for sleep disturbance aspect of the PSQIreported menstrual cramps as the other reason they had trouble sleeping . Furthermore, the scoping review (Chapter 3) showed conflicting directions of sex differences in adolescent sleep health, with girls sleeping better or sometimes worse than boys. Hence, further studies, probably with qualitative design will help provide better undesrtanding of the association between adolescent sleep health and sex/gender roles as well as religion.

At the family and household level, some factors were associated with adolescent sleep health. These factors included: adverse childhood experiences such as family violence, parental abuse or divorce (Chapter 3), and having single or separated parents (Chapter 4). These family factors can serve as stressors that may affect adolescent sleep health. Adolescents with single parents have been found to have lower weekday sleep efficiency as well as shorter weekend sleep duration than adolescents living with both parents.[17,18] Future studies should utilise longitudinal designs and/or qualitative approaches to study adolescent sleep health and family dynamics.

Neighbourhood risk factors were also important in affecting adolescent sleep health. In urban communities, the factors that delay bedtimes in adolescents are diverse. These factors have been identified as the consequences of urbanisation such as the effect of electricity giving artificial light at night,[19] and screen exposure,[20] internet use, intense nighttime social life and high burden of academic workload, especially in private schools.[6,21] In a previous study among Nigerian adolescents, private school attendance was associated with poorer sleep health,[21] and the sociodemographics of the adolescents in our studies (Chapters 4 and 6) showed more private school attendance among urban adolescents. While the risk factors of poor sleep health identified in urban adolescents affected bedtimes, shortened sleep duration, and poor sleep quality (Chapters 4 and 6), the factors in rural adolescents affected their sleep quality[8] (Chapters 3), sleep efficiency and night awakenings (Chapter 6). In a comparative study comparing two communities (one urban and one rural) in Mozambique, people in the rural community had poorer sleep quality probably because of their involvement in vigorous and exhausting physical labour and their sleeping in uncomfortable environments.[19] In our unpublished work, I found that 41% (14 out of 34) of adolescents who reported other factors of having trouble sleeping on the PSQI, complained of mosquitoes or mosquito bites. It is unclear whether the sleep disturbance they experienced was from the pain of the mosquito bites or the noise made by the mosquitoes which can be a disturbing high-pitched buzzing sound or a low-pitched humming sound. Future studies should explore these factors in greater detail, probably with qualitative research, and eventually adding those elements to an Africa-adapted PSQI. Furthermore, interventions aimed at improving sleep health among rural adolescents need to give attention to sleeping arrangements and other causes. Some other neighbourhood factors previously studied in relation to sleep health include neighbourhood safety/crime levels,[20] violence exposure[20] and housing quality.[22] There were also reports of sex differences in the association between neighbourhood disadvantages and sleep.[20] These factors need to be studied in more detail among African adolescents.

School schedules and sleep health have been well-studied in other climes but not in Africa. We found school-end time to be associated with poorer sleep quality and higher daytime sleepiness (Chapter 4). This finding may not diminish the effect of school start times as there was minimal variability in the start times of the schools studied (standard deviation = 0:12 hour) while school-end showed more variability (standard deviation = 1:06 hour). In an earlier study in Ile-Ife, southwestern Nigeria, school end time (p = 0.039) and school type (p = 0.005) were associated with poor sleep quality with the odds of having poor sleep quality being 2-fold higher among adolescents in private schools compared to those in public schools.[21] Using actigraphy, I identified a significant weekday-weekend disparity in adolescent sleep health (Chapter 6). The worse sleep health found on weekdays is probably a result of the burden of school schedules (later end times and early start times) but this need to be further explored. Therefore, further studies are needed to consider the effect of school schedules on the sleep health of adolescents. Other African countries may also take a clue from Rwanda where school start was changed from 7/8 am to 8:30 am in January 2023.[23]

We identified very few protective factors of adolescent sleep health (Figure 7.2.). At the individual level, younger age was identified as a protective factor for good sleep duration (Chapter 6) while at family level, parental setting of bedtimes was protective of good sleep quality (Chapter 4). Younger adolescents are less likely to have begun to experience the pubertal storm from biological and social influences of sleep.[16,24] However, these same adolescents may develop poor sleep health as they grow older if not helped, as evidenced by the findings from longitudinal studies.[25,26] The age-related changes around the onset of puberty affect both the circadian process (Process C) and the homeostatic process (Process S) of sleep regulation (Chapter 1), causing the worsening of sleep as adolescents increase in age.[24] At the neighbourhood level, our findings (Chapters 3, 4, and 6) support previous evidence that urban adolescents may have better sleep efficiency and fewer night awakenings due to their having a better sleeping environment[19] while rural adolescents may have earlier bedtimes and longer sleep duration due to their limited access to electricity, internet and screen use.[27] However, further studies are needed to understand the mechanisms through which the identified protective factors improve adolescent sleep and to develop targeted interventions.

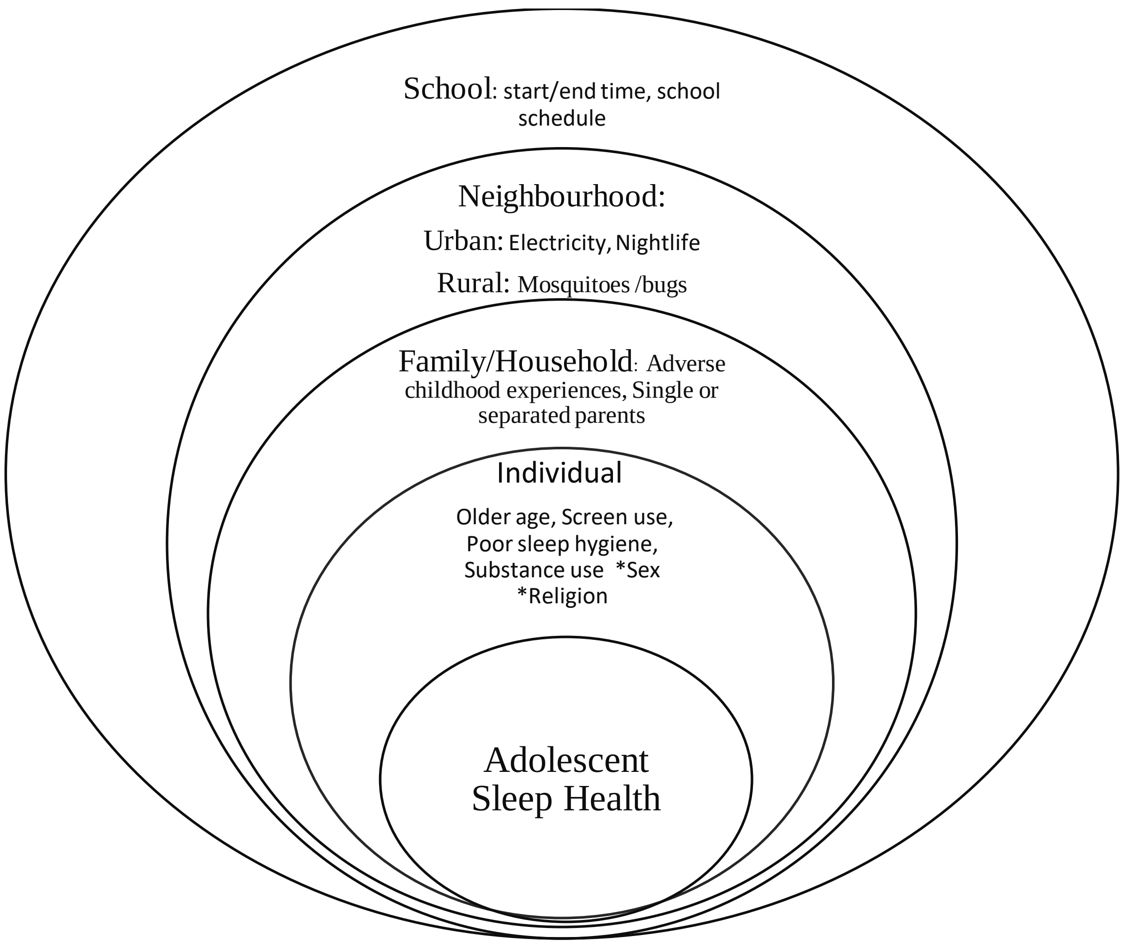

Figure 7.1. Risk factors associated with adolescent sleep health. *Inconclusive associations from the scoping review suggesting the need for further studies.

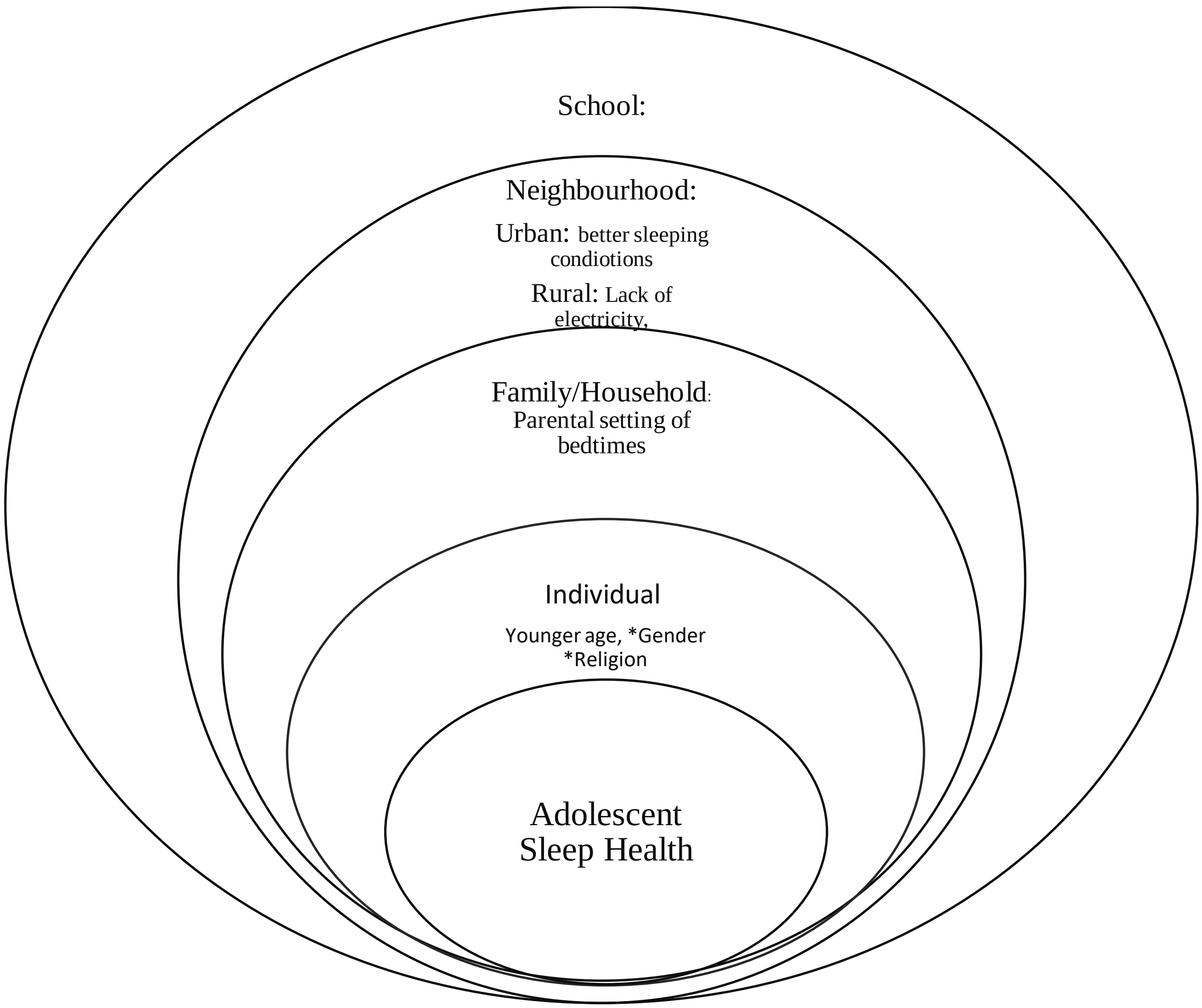

Figure 7.2. Protective factors for adolescent sleep health. *Inconclusive associations from the scoping review suggesting the need for further studies.

7.2.4. Sleep health and cardio-metabolic risk among rural and urban-dwelling in-school Nigerian adolescents

Poor sleep health showed a significant association with higher cardiometabolic risk in our study (Chapter 5). Also, urban adolescents showed worse association between their sleep health and the markers of cardiometabolic risk than rural adolescents, though the associations were more with adiposity-related markers. These findings from our present study corroborate the previous reports from different studies in Africa where short sleep duration was associated with higher adiposity, indicated by higher body mass index (BMI),[8,12,28,29], higher waist circumference,[12,29] and metabolic syndrome (Chapter 3).[8] However, all these studies measured sleep duration as the only sleep health variable. Hence, our study is the only study, to the best of our knowledge, where multiple dimensions of sleep health have been studied with multiple markers of CMR. In a study in the United States, adolescents with longer sleep duration and higher sleep efficiency had better CMR scores. Thus, having good sleep health in adolescents may be protective of cardiometabolic disease.

Our findings also bring to the fore the need to include sleep health promotion among public health efforts aimed at reducing cardiometabolic diseases. This is especially important among urban adolescents who seem more predisposed to developing poor sleep health. Interestingly, a number of the factors that lead to poor sleep health can also result in increased adiposity through other mechanisms. Excessive screen use has been linked to a sedentary lifestyle, reduced physical activity and eventually obesity. In our present study (Table 5.4.), higher physical activity was associated with lower CMR. Therefore, interventions are needed to prevent the double burden of poor sleep health and CMR in adolescents, especially those living in urban communities. Further research using longitudinal and/or experimental designs is also necessary to better understand the causality and directions of association between the multidimensions of poor sleep health and cardiometabolic risk in adolescents, and the rural versus urban differences in the associations.

7.3. Strengths and limitations of the study

Chapter 3 of this dissertation presents a detailed overview of the available literature on adolescent sleep health in Africa. This helped to identify the research gaps that need to be filled to provide direction for adolescent sleep in the continent. I also attempted to fill some of these gaps by studying multiple dimensions of sleep health first with multiple self-report questionnaires (Chapter 4) and later with the use of actigraphy augmented with sleep diaries (Chapter 6) as an objective measure of sleep in adolescents. In addition, I determined some multilevel risk and protective factors associated with adolescent sleep health, providing important targets for intervention aimed at improving the sleep health of African adolescents. Furthermore, I reported on one of the likely consequences of poor sleep health in adolescents through our findings of associations between multidimensions of sleep health variables and markers of cardiometabolic risk in adolescents (Chapter 5). I also showed a rural-urban difference in the association between adolescent sleep and CMR, presenting a further need for interventions for both rural and urban African adolescents. Therefore, I have provided important data on the burden of sleep health in Africa using a cohort of in-school adolescents in the southwestern Nigeria.

The studies in this thesis have a few limitations. First, the validation of the sleep quality questionnaire used; the Pittsburgh Sleep Quality Index (PSQI), showed a moderate Cronbach Alpha of 0.63 in the urban communities and 0.54 in the rural communities. It is important to further explore which components of the PSQI need to be reviewed in the African context. Qualitative studies can help to explore the factors that typically cause trouble sleeping in African adolescents such as mosquitoes, religious aspects, or gender biases in the division of chores in the household (we had incidental reports of girls having to wake up early to prepare food for the male members of the family). Another limitation of this study is our inability to measure more blood-related markers of CMR. The measurement of other blood lipid markers may have helped to substantiate the association observed between sleep and CMR, especially with the possible interaction between the STOPBANG and the blood pressure markers of CMR.

7.4. Conclusion

1. Adolescents in Africa have a high burden of sleep health problems as shown in the scoping review presented in this thesis and exemplified by the findings I obtained from in-school adolescents in southwestern Nigeria.

2. Overall, rural-urban disparities exist in the pattern of the multidimensional adolescent sleep health characteristics, the determinants of adolescent sleep health across multiple levels and the association between sleep health and CMR variables. While urban adolescents have delayed bedtimes and short sleep duration, the rural adolescents have lower sleep efficiency and higher frequency of nighttime awakening probably from sleep disruptors.

3. There is a wide disparity between the adolescent sleep characteristics on weekdays and weekends with many adolescents having catch-up sleep on weekends. The factors affecting adolescent sleep on weekdays which are likely to be related to school schedule and artificial light exposure at night need to be further explored to develop appropriate interventions.

4. The risk and protective factors affecting adolescent sleep health cut across multiple levels. These factors are promising targets for improving the sleep health of adolescents if further explored and understood.

5. Poor sleep health is associated with cardiometabolic risk among adolescents, especially those in urban communities. These adolescents may be the more exposed to artificial light at night, the internet, and screen use, lack of parental supervision as well as a huge burden of school-related demands.

6. There is a growing interest in adolescent sleep health on the African continent. There is a need for coordination and collaboration among various sleep researchers on the African continent to develop indigenous tools, validate the already existing tools for local use and design more quality studies that can generate strong and reliable data towards improving Adolescent Sleep Health on the continent.

7.5. Recommendations

7.5.1. Recommendations for research

1. Validated tools need to be developed and made culturally adaptable to measure the multiple dimensions of sleep health in the African context.

2. The factors associated with adolescent sleep health need to be well understood across multiple levels. Therefore, qualitative studies, using focused group discussions and/ or in-depth interviews involving adolescents, their parents and their teachers as well as related stakeholders will help to further explore the risk and protective factors associated with adolescent sleep health.

3. Future researchers should also consider longitudinal studies, possibly with experimental designs to improve understanding of the causal relationships, between sleep health and cardiometabolic risk.

4. Implementation research is needed to develop and implement interventions that can improve the sleep health of African adolescents in urban as well as rural settings.

7.5.2. Policy Recommendations

1. Routine screening for sleep health and cardiometabolic risk should be instituted in schools, primary health care facilities, and general Paediatric clinics where adolescents are seen on a regular pathway.

2. Adolescents identified to have poor sleep health indices should have more objective assessments with actigraphy augmented with sleep diary and/or polysomnography. Thus, there is a need for policymakers to develop policies and implement programs that can help provide appropriate diagnosis and treatment for adolescents with sleep problems.

3. Stakeholders in the Ministries of Education, Health, Transportation and Labour need to collaborate towards reviewing school schedules, possibly delay start times, reduce variability in end times and improve afterschool distractions in adolescents, especially those in urban and private schools. The official working

hours may also need to be regulated so as to enable parents to drop their children at school. A well-coordinated transportation system will be very important to achieve this change.

4. Rural community development programs should be targeted towards improving living conditions and reducing environmental disruptors while urban adolescents should be helped to avoid the risks associated with urbanization through appropriate sleep health awareness programs and regulations.

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APPENDIX

APPENDIX 1: TURNITIN REPORT

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Adolescent sleep health in Africa: a scoping review protocol

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ABSTRACT

Introduction Problematic sleep is a major threat to health and quality of life among adolescents. Hence, to provide directions for research and interventions, there is a need to examine the literature on adolescent sleep health in Africa. However, available studies on adolescent sleep health in Africa have not been properly mapped. Thus, this scoping review aims to investigate the extent and type of available evidence concerning sleep health among adolescents in Africa and to highlight the relationship of adolescent sleep health with adverse mental health outcomes and cardiometabolic risk factors. The review will further highlight areas of agreement and controversies on adolescent sleep health, and identify evidence gaps that require research attention across the continent.

Methods and analysis This scoping review will be conducted using Arksey and O'Malley's six-step procedure. Thus, we have prepared this protocol according to the framework for scoping reviews developed by the Joanna Briggs Institute. To identify eligible studies, we will search MEDLINE, Scopus, PsycINFO, AJOL, JSTOR, HINARI and Google Scholar. The review will include all published articles in English, French, Spanish, Portuguese and Italian languages on adolescent sleep health in Africa from the inception of the databases, while relevant information will be extracted from included studies using an adapted data extraction tool. The results will be presented using tables and charts as appropriate.

Ethics and dissemination The scoping review does not require ethical approval because the publications to be used for the review are publicly available and the study does not involve contact with humans or other animals as research participants. Furthermore, clinical records will not be used for the study. Upon completion, findings from the study will be disseminated through presentations at scientific meetings and publication in a relevant peer-reviewed journal.

Scoping review registration Open Science Framework (https://osf.io/5sjwq/).

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ By interrogating the association of adolescent sleep health with mental health and cardiometabolic risk (CMR) in the wide cultural and geographical context of Africa, the review will provide the needed evidence to elicit action for improved adolescent health in Africa.
- ⇒ The scoping review will capture studies published in the major languages spoken on the African continent to ensure inclusivity.
- ⇒ As a limitation, the review will not analyse the size of the effects of the relationship between adolescent sleep health, mental health and CMR factors.

INTRODUCTION

Sleep health is an important component of overall health. It was first defined in 2014 by Buysse[1] as 'a multidimensional pattern of sleep-wakefulness, adapted to individual, social, and environmental demands, that promotes physical and mental well-being'. Good sleep health is characterised by subjective satisfaction, appropriate timing, adequate duration, high efficiency and sustained alertness during waking hours.[1] Sleep health has since evolved as a concept that explains the role of sleep as a cause or determinant of adverse health outcomes and morbidity rather than just a consequence or symptom of ill health.[2–4] Furthermore, the understanding of the concept of sleep health is widening the focus of sleep medicine beyond seeing poor sleep as a cause of sleep disorders to identifying sleep health as a predictor of overall health.[1 5] Thus, sleep health has emerged as a holistic view of sleep and its multiple characteristics: duration, quality, alertness, timing and continuity.[4] Sleep variability or regularity is being considered as an additional characteristic.[4] While earlier studies have focused on the concept of sleep health as it relates to the adult population, there is growing evidence of its applicability to child and adolescent health.[4 5] Hence, it is important to investigate the available evidence on the sleep health of adolescents in Africa.

While poor sleep is widely recognised as an important cause of morbidity, research on the subject is lacking both in quantity and quality in Africa.[6 7] Studies in high-income countries (HICs) have associated short sleep duration (SD) with increased physical and behavioural problems.[4 8 9] Nevertheless, evidence on the role, extent and scope of the various aspects of sleep health characteristics such as SD, sleep quality, sleep chronotype (SC) and bedtime variability (BV) of adolescents in Africa has not been well reviewed or synthesised. Thus, there is a need for a review to examine the available evidence on adolescent sleep health, and the determinants and possible outcomes for adolescent sleep health in Africa.

Furthermore, existing studies have highlighted racial and social disparities in sleep health.[10–12] Some disparities have been described among people living in urbanised communities when compared with dwellers of rural communities. This suggests that differences may exist in the sleep health dynamics of adolescents in Africa when compared with adolescents in other low/middle-income countries as well as those in HICs. Similarly, there may be similarities or differences in the sleep health of adolescents dwelling in the various regions of the African continent. The sleep characteristics of adolescents in sub-Saharan Africa may be different from that of their counterparts in North Africa. Conversely, the sleep characteristics of adolescents within the entire African continent may be similar due to similarities and overlap of cultures, including the nomadic culture which cuts across the countries in North and West Africa. Furthermore, there may be disparities in the sleep health of rural-dwelling versus urban-dwelling adolescents in Africa. Thus, a detailed review of existing studies on African adolescents' sleep patterns and the sleep problems among adolescents residing in all the regions of the continent may help understand the effects of culture, religion, natural light exposures and electricity on adolescent sleep health.

In addition, there is a need to collate the available evidence on the contributory factors and outcomes associated with poor sleep health. The social determinants of sleep problems in adolescents have been well described in HICs using various models, especially the socioecological model.[13–15] The leading factors identified by these studies were excessive screen use, early school start times, the burden of homework, caffeine use and parental influences.[16–18] However, the available studies on the social determinants of sleep health in Africa have not been well explored among the adolescent population.

Many studies of adolescent sleep are based on SD as the main sleep variable measured. Other variables such as BV, sleep quality and SC have not been well explored.[19 20] However, emerging evidence suggests that SC and BV may be more important measures of sleep health.[21–23] Thus, there is a need to synthesise the mechanisms by which other sleep health variables such as SC contribute to adolescent sleep problems. This will bring more understanding of the concept of sleep health as it relates to adolescent sleep, particularly in the context of Africa.

Aside from the sociodemographic variables, emerging pieces of evidence have shown links between cardiometabolic diseases and poor sleep.[23 24] This suggests a possible association between cardiometabolic risk (CMR) and sleep health. CMR refers to an increased predisposition to cardiovascular disease, diabetes and metabolic syndrome.[25] The markers of CMR include cardiovascular risk factors such as weight–height ratio, body mass index, blood pressure, heart rate and measures of adiposity such as waist circumference, waist–hip ratio, body fat percentage and superficial fat thickness.[26 27] Others include fasting blood sugar, homeostatic model of insulin resistance, Matsuda index, lipid profile and inflammatory markers, among others.[26–28] These factors have been linked to various sleep parameters such as short or long SD, poor sleep quality, SC, bedtime irregularity and intra-individual variability (IIV) in bedtime.[13 21] Also, a high CMR in adolescence has been associated with a higher risk of cardiovascular disorders in adulthood, in particular young adulthood.[29]

However, inconsistencies in findings limit the generalisability of many suggested associations between sleep and CMR. The majority of these studies are cross-sectional in design and suggest a bidirectional relationship between poor sleep and CMR.[13 30] Furthermore, a gender disparity was observed between short SD and increased adiposity in females suggesting the need for an improved understanding of the mechanisms of the association.[28 31] The postulated mechanisms for the adverse effects of sleep disruption on CMR include inflammation, increased oxidative stress and endothelial dysfunction, elevated ghrelin and leptin levels, etc.[24 32 33] However, the types of sleep disruption associated with CMR are mainly those with altered circadian rhythms such as IIV or bedtime irregularity.[19 21 28] Thus, the collation of evidence from existing studies is needed to identify research gaps and suggest the direction for future research.

Studies in HICs suggest an association between poor sleep and adverse health outcomes.[31 34 35] In some African countries, there is an already worrisome increase in non-communicable diseases (NCDs).[36 37] This is mainly due to changes in lifestyles and the consequent increase in the risk factors for NCDs.[38] Sleep problems in adolescents, especially circadian misalignment or BV, have been linked with NCDs such as diabetes, cardiovascular diseases and cancers.[26 39 40] In addition, the presence of risk factors for the development of NCDs such as obesity has been linked to sleep problems.[26 27 31] Furthermore, obesity and poor sleep have been recognised as dual epidemics in adolescents worldwide.[26] However, the attention of researchers appears skewed towards obesity, while sleep problems and health outcomes have not been well explored.

The association between sleep health and the mental health of adolescents needs to be well studied. Sleep problems have been reported to result in adverse mental health outcomes such as anxiety, depression and behavioural disorders.[41–44] Many mental health disorders have sleep disturbances as a component of their symptomatology.[22] In addition, sleep problems can be an early pointer to the existence of a mental health disorder and sleep is a modifiable factor that can be targeted in mental health promotion programmes.[44] Furthermore, many of the medications used in treating mental health conditions have significant effects on sleep architecture and quality.[45] Thus, the relationship between sleep and mental health is multidimensional. According to the WHO, 'mental health is more than the absence of mental health disorders'.[46] Mental health problems occur for one in seven adolescents.[47] Also, many of the determinants of mental health in adolescents contribute to sleep health.[44] These determinants would be worth exploring among African adolescents. Thus, this scoping review will include studies on the relationship between sleep health variables and the mental health of African adolescents.

After conducting preliminary searches on MEDLINE, the Cochrane Library of Systematic Reviews and Joanna Briggs Institute (JBI) Evidence Synthesis, no existing or underway systematic or scoping review on the topic was identified. Thus, the objective of this scoping review will be to assess the extent of the literature on adolescent sleep health in Africa. We present here the methods proposed for this scoping review.

Review questions

1. What are the key concepts, beliefs and cultural practices on sleep health in adolescents in Africa?
2. How have publications in adolescent sleep health evolved in Africa?
3. What are the geographical distribution, trends, sources and types of evidence available on adolescent sleep health in Africa?
4. What disparities exist in sleep health among rural versus urban-dwelling African adolescents?
5. What are the barriers and facilitators to good sleep health among rural and urban-dwelling adolescents in Africa?
6. What relationship exists between sleep health and mental health among adolescents in Africa?
7. What relationship exists between sleep health and CMR among adolescents in Africa?
8. What association exists between sleep health and school schedule among adolescents in Africa?
9. What interventions have been implemented for improving the sleep health of adolescents in Africa and how effective have they been?

METHODS AND ANALYSIS

Study design

This scoping review will be used to map out literature on the topic 'Adolescent sleep health in Africa'. We will be using the six-step procedure described by Arksey and O'Malley.[48] Thus, we have written this protocol according to the framework for scoping reviews developed by the JBI and the proposed scoping review will be conducted following the JBI methodology for scoping reviews.[49] The result will be presented following the Preferred Reporting Items for Systematic Reviews and Meta-analyses extension for scoping review (PRISMA-ScR).[50]

Search strategy

The search strategy will aim to locate published studies. An initial limited search of MEDLINE (via PubMed) and CINAHL will be undertaken to identify articles on the topic. The text words identified in the titles and abstracts of relevant articles, and the index terms used to describe the articles will thereafter be used to develop a full search strategy for MEDLINE (PubMed), Scopus, CINAHL, AJOL, HINARI Summons and PsycINFO. The search strategy, including all identified keywords and index terms, will be adapted for each included database and/or information source. Aside from database searching, a reference snowballing approach will be deployed to identify more studies from the reference lists of screened and eligible articles. The initial search strategy developed for the study is presented in table 1.

Planned start and end dates

The study is planned to start in July 2023 and end by August 2023.

Inclusion criteria

The scoping review will include all published articles on the various sleep characteristics of adolescents, aged 10–19 years living in Africa from the inception of the databases. We will include peer-reviewed publications in English, French, Spanish, Portuguese, Italian and Arabic languages since the official languages in most African countries are anglophone, francophone, lusophone and Arabic. This will enable appropriate inclusion and evaluation of the evolution of publications over the years on adolescent sleep health in Africa.

Exclusion criteria

Studies published in languages other than English, French, Spanish, Portuguese, Italian and Arabic languages and those based on geographical location outside Africa will not be included in the review. Blogs, web pages, books, conference presentations and other grey literature will also be excluded from the review.

Types of sources

For comprehensive coverage of available evidence, the scoping review will include analytical observational studies (epidemiological studies) including prospective and retrospective cohort studies, case–control studies and analytical cross-sectional studies. In addition, the review will consider descriptive observational study designs including case series, individual case reports and descriptive cross-sectional studies for inclusion. In addition, studies from experimental and quasi-experimental study designs including randomised controlled trials, non-randomised controlled trials, before and after studies and interrupted time-series studies will be included. Qualitative studies that focus on qualitative data including, but not limited to, designs such as phenomenology, grounded theory, ethnography, qualitative description, action research and feminist research will be considered for inclusion. In addition, relevant systematic reviews that meet our inclusion criteria will also be for inclusion in the review. Only studies available in the full text will be included in the review.

Table 1 Initial search strategy for MEDLINE (via PubMed)

	Search strategy
#1	Sleep[Mesh] OR "Sleep quality"[Mesh] OR "Circadian rhythm"[Mesh] OR "Sleep hygiene"[Mesh] OR "Sleep duration"[tw] OR "sleep chronotype*"[tw] OR "Bedtime variabilit*"[tw] OR "Sleep pattern*"[tw] OR "Total sleep time"[tw] OR "Sleep efficienc*"[tw] OR "Sleep sufficienc*"[tw] OR "Sleep habit*"[tw] OR sleep[tw] OR "Sleep Deprivation"[Mesh] OR "Sleep Deprivation/complications"[Mesh] OR "Sleep Initiation and Maintenance Disorders"[Mesh] OR "Sleep Wake Disorders"[Mesh] OR "Disorders of Excessive Somnolence"[Mesh] OR Parasomnias[Mesh] OR "Sleep disorder*"[tw] OR "Sleep insufficienc*"[tw] OR "Sleep difficult*"[tw] OR Insomnia[tw] OR Hypersomnia[tw] OR "Excessive daytime sleepiness"[tw] OR "Sleep-related movement disorder*"[tw] OR "Sleep-related breathing disorder*"[tw] OR "Sleep apnoea"[tw] OR "Sleep apnea"[tw] OR "Obstructive sleep apnoea"[tw] OR "Obstructive sleep apnea"[tw] OR "Daytime sleepiness"[tw] OR "sleep deprivation"[tw]
#2	Adolescent[Mesh] OR Youth[tw] OR "Young people"[tw] OR Teenager*[tw] OR adolescent[tw]
#3	"Africa, Western"[Mesh] OR "Africa, Southern"[Mesh] OR "Africa south of the Sahara"[MeSH] OR "Africa, Eastern"[Mesh] OR "Africa, central"[MeSH] OR "Africa, Northern"[Mesh] OR Cameroon[tiab] OR "Central African Republic"[tiab] OR Chad[tiab] OR Congo[tiab] OR "Democratic Republic of the Congo"[tiab] OR "Equatorial Guinea"[tiab] OR Gabon[tiab] OR "Sao Tome and Principe"[tiab] OR Burundi[tw] OR Djibouti[tiab] OR Eritrea[tiab] OR Ethiopia[tiab] OR Kenya[tiab] OR Rwanda[tw] OR Somalia[tiab] OR "South Sudan"[tiab] OR Sudan[tiab] OR Tanzania[tiab] OR Uganda[tiab] OR Angola[tiab] OR Botswana[tiab] OR Eswatini[tiab] OR Lesotho[tiab] OR Malawi[tiab] OR Mozambique[tiab] OR Namibia[tiab] OR "South Africa"[tiab] OR Zambia[tiab] OR Zimbabwe[tiab] OR Benin[tiab] OR "Burkina Faso"[tiab] OR "Cabo Verde"[tiab] OR "Cote d'Ivoire"[tiab] OR Gambia[tiab] OR Ghana[tiab] OR Guinea[tiab] OR Guinea-Bissau[tiab] OR Liberia[tiab] OR Mali[tiab] OR Mauritania[tiab] OR Niger[tiab] OR Nigeria[tiab] OR Senegal[tiab] OR "Sierra Leone"[tiab] OR Togo[tiab] OR Algeria[tiab] OR Egypt[tiab] OR Libya[tiab] OR Morocco[tiab] OR Tunisia[tiab] OR "cape verde"[tiab]
#4	#1 AND #2 AND #3

Study/source of evidence selection

Following the search, all identified citations will be collated and uploaded into the Mendeley citation management software for deduplication. Following this, titles and abstracts will then be screened by two independent reviewers for assessment against the inclusion and exclusion criteria for the review. The full text of selected citations will be assessed in detail against the inclusion criteria by two or more independent reviewers. Reasons for the exclusion of studies whose full text does not meet the inclusion criteria will be recorded and reported in the scoping review. Any disagreements that arise between the reviewers at each stage of the selection process will be resolved through discussion, or with an additional reviewer. The results of the search and the study inclusion process will be reported in full in the final scoping review and presented in a PRISMA-ScR[50] flow diagram (figure 1).

Patient and public involvement

None.

Data extraction

Data will be extracted from studies included in the scoping review by two independent reviewers using a data extraction tool developed by the team (table 2), adapted from a previous scoping review on adolescent reproductive health in Africa.[51] The data extracted will include specific details about the participants, concept, context, study methods and key findings relevant to the review questions. A draft extraction form will be provided in the report of the scoping review. The draft data extraction tool will be modified and revised as necessary during the process of extracting data from each included evidence source. Modifications will be detailed in the scoping review. Any disagreements that arise between the reviewers will be resolved through discussion or with an additional reviewer. Where required, authors of papers will be contacted to request missing or additional data.

Data analysis and presentation

We intend to map available evidence on adolescent sleep health in Africa. For this, we will characterise sources of evidence through the descriptive presentation of the yearly publication rates of adolescent sleep studies included in the scoping review and the countries of publication of the studies included in the review. Furthermore, extracted data from included publications will be presented according to the study design and sleep themes investigated by performing a basic qualitative content analysis of the publications. By using the thematic content analysis, pertinent qualitative data (texts) extracted from all studies included in the review will be synthesised and descriptively presented under themes that address the review questions.

Specifically, the review will use the three phases of qualitative content analysis described by Pollock *et al*.[52] In the preparation phase, the deductive approach will be used to map the data to established frameworks (sleep quality, SD, presence of sleep disorders, sleep as a comorbid condition with mental health) within the literature. The second phase, the organising phase, will involve open coding to allocate concepts or characteristics in the mapped data into overall categories. Thereafter, we will organise the categories of data into themes, based on the

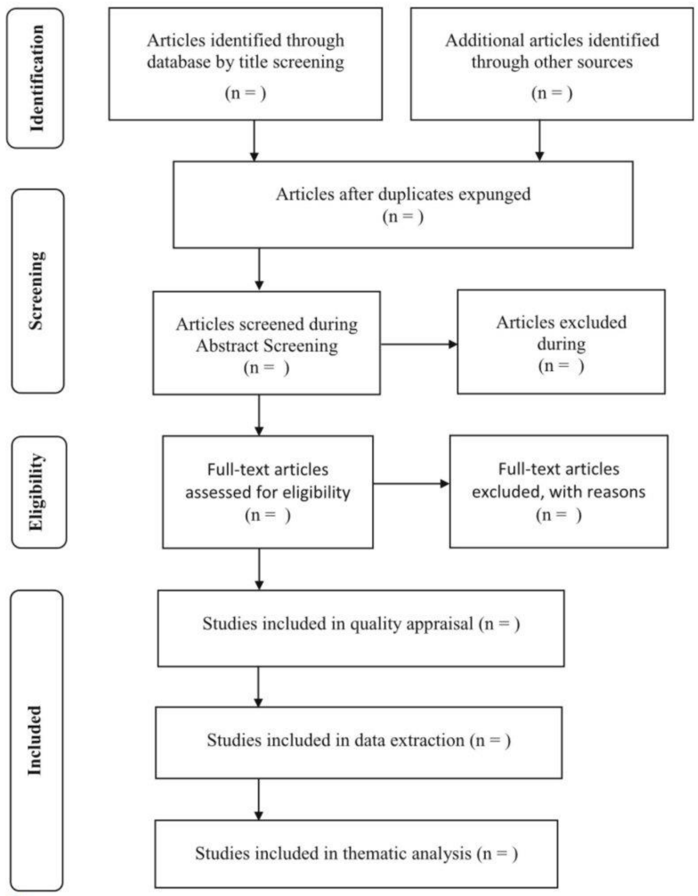

Figure 1 Flow chart.[50] The PRISMA-ScR flow diagram shown will be used to illustrate the processes involved in conducting this scoping review. These processes are (1) identification: to state the number of articles identified and the respective sources. The number of the duplicates found and removed will also be provided; (2) screening: the total number of articles screened will be provided here; (3) eligibility: the details of the number of full-text articles assessed for eligibility, the number of eligible studies and the number of studies that were excluded; (4) included: this section provided the number of studies included following quality appraisal, data extraction and thematic analysis, respectively. PRISMA-ScR, Preferred Reporting Items for Systematic Reviews and Meta-analyses extension for scoping review.

review questions, to draw appropriate conclusions from the findings. For these steps, we will use the NVivo V.12 software. Using the NVivo software, the primary author will chart the results obtained from the publications and identify the main themes, while other authors will give feedback and review the synthesised results. These results will include themes and conclusions relating to adolescent sleep in Africa, rural versus urban disparities, the association between sleep and CMR and the association between sleep and mental health. The final results will be validated by the last author who is a specialist in sleep research and the third author who is a librarian. We will conduct the validation of sources using a test set of pre-identified relevant publications that should be captured using the database search. Following the first database search, we will check the identified publications based on our predetermined strategy to ascertain the comprehensiveness of the search. We will use the information obtained to make the appropriate changes to the search strategy if needed. In the reporting phase, the bibliographical characteristics of studies included in the review will be presented through the use of tables and charts. These tables and charts will describe the publication year, country of publication, authorship information, study design and settings, funders, sample size and other available relevant information about the articles. Visual

Table 2 Data extraction tool (adapted from a scoping review by Ajayi *et al*[51])

Main category	Subcategory	Description
Author Lead author		Indicate where the lead author is based (we will determine if a lead author is African or non-African by the institutional affiliation of the author)
Funder(s)		Indicate the funder (eg, Africa, European, USA, other North America)
Title		
]Journal		
Year of publication		
Aim/objectives		Describe the stated aim and objectives of the study
Year of research		
The country where the study was conducted		Indicate the country(ies) where the study was conducted
Study setting		Specify the location of study sites (eg, district(s))
Subregion where the study was conducted		Indicate the subregion study was conducted
Type of study		Indicate the study type (eg, primary research, secondary analysis, review, commentary, document analysis or discourse analysis)
Type of source		Indicate the type of publication (eg, journal article, book chapter, report, thesis)
Is the study an intervention study or focusing on describing the problem		Indicate whether the study described a problem or examine the effect of an intervention
Thematic focus	If describing a problem	Identify the area of focus (eg, sleep pattern, sleep duration, sleep quality, sleep hygiene/habits, sleep apnoea, other sleep problems, sleep chronotype, risk and protective factors, association with CMR factors, association with other health outcomes)
	If an intervention study	Describe the nature of the intervention
Methodology		
	Study design	Specify the study design adopted (eg, cross-sectional design, case study, prestudy, post-study design, longitudinal study, mixed methods, randomised controlled trial, qualitative study, review study)
	Population	Describe the characteristics of the target population
	Sampling strategy	Describe how sampling was done if applicable
	Data collection	Specify the methods of data collection
	Outcome measures	Indicate the outcome measures for quantitative studies
	Data analysis	Indicate method of data analysis
Results		
	Reported outcomes	Indicate the prevalence reported Highlight the determinants reported
	Key findings	Summarise the key findings
Conclusion		Highlight the main conclusion of the study
Limitations		Describe the study limitations

CMR, cardiometabolic risk.

presentation tools such as word clouds, tree graphs and waffle charts will also be used in presenting the results as appropriate. The key findings and gaps will thereafter be presented in a narrative summary within the text of the review.

ETHICS AND DISSEMINATION

The scoping review does not require ethical approval because the publications to be used for the review are publicly available and the study does not involve contact with humans or other animals as research participants.

Furthermore, clinical records will not be used for the study. Upon completion, findings from the study will be disseminated through presentations at scientific meetings and publication in a relevant peer-reviewed journal.

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APPENDIX 3: Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	57
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	57-58
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	58-60
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	60-61
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	61
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	61-62
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	62
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	65-67
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	62,64
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	63
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	63
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	N/A

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	63
RESULTS			
Selection of sources of evidence	14	Give number of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	63-64
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	68-70
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	N/A
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	71-91
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	92-102
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	103-108
Limitations	20	Discuss the limitations of the scoping review process.	109
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	110
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	111

JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

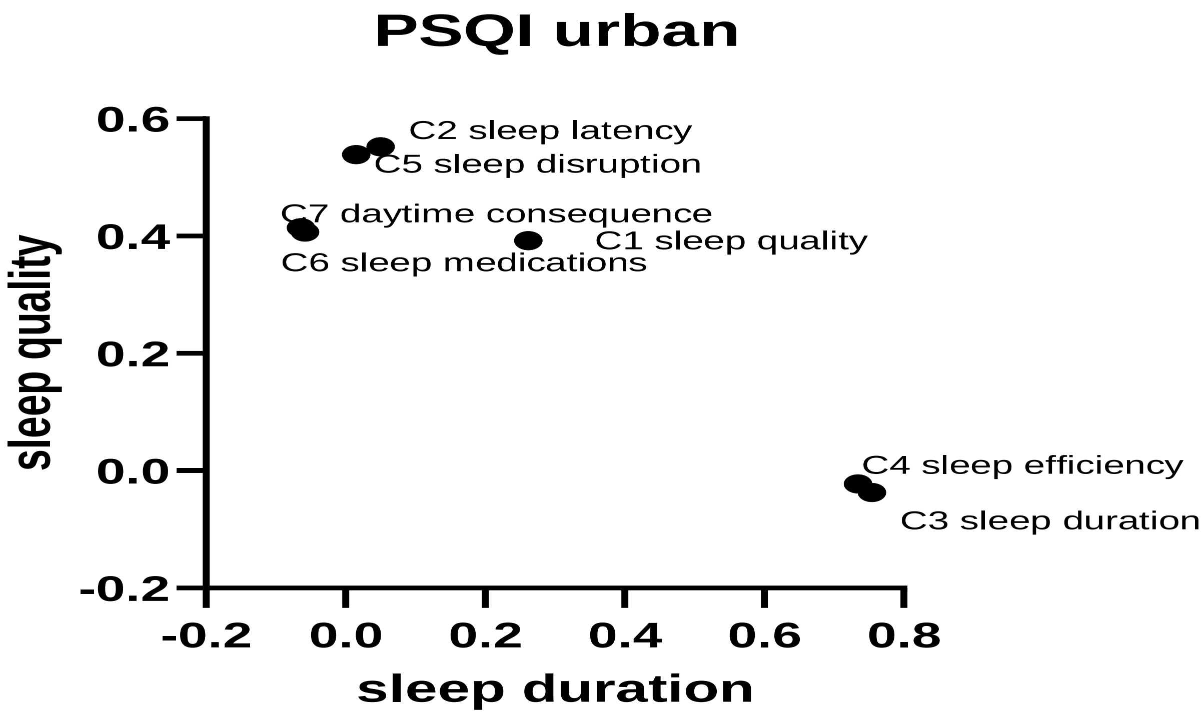
From: Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMAScR): Checklist and Explanation. Ann Intern Med. 2018;169:467–473. doi: 10.7326/M18-0850.

APPENDIX 4: CRONBACH ALPHA AND FACTOR ANALYSIS FOR SLEEP QUESTIONNAIRES

The Cronbach's alpha was 0.62 (urban, raw variables) and 0.54 (rural) when analyzing the internal consistency of the PSQI in the 900 adolescents (Table I). Factor analysis revealed that the questionnaire had a three-factor structure (see Figure A4.1 below).

Table I: Cronbach Coefficient Alpha for the Sleep Questionnaires (Pittsburgh Sleep Quality Index (PSQI)

	Urban Schools	**Rural Schools**
PSQI		
Component 1:		
Subjective sleep quality	0.564567	0.526278
Component 2:		
Sleep latency	0.628816	0.505323
Component 3:		
Sleep duration	0.565953	0.449939
Component 4:		
Sleep efficiency	0.567442	0.438391
Component 5:		
Sleep disturbances	0.590095	0.525749
Component 6:		
Use of Sleep medications	0.656093	0.560372
Component 7:		
Daytime dysfunction	0.617460	0.499858
Cronbach's alpha	**0.628816**	**0.544188**



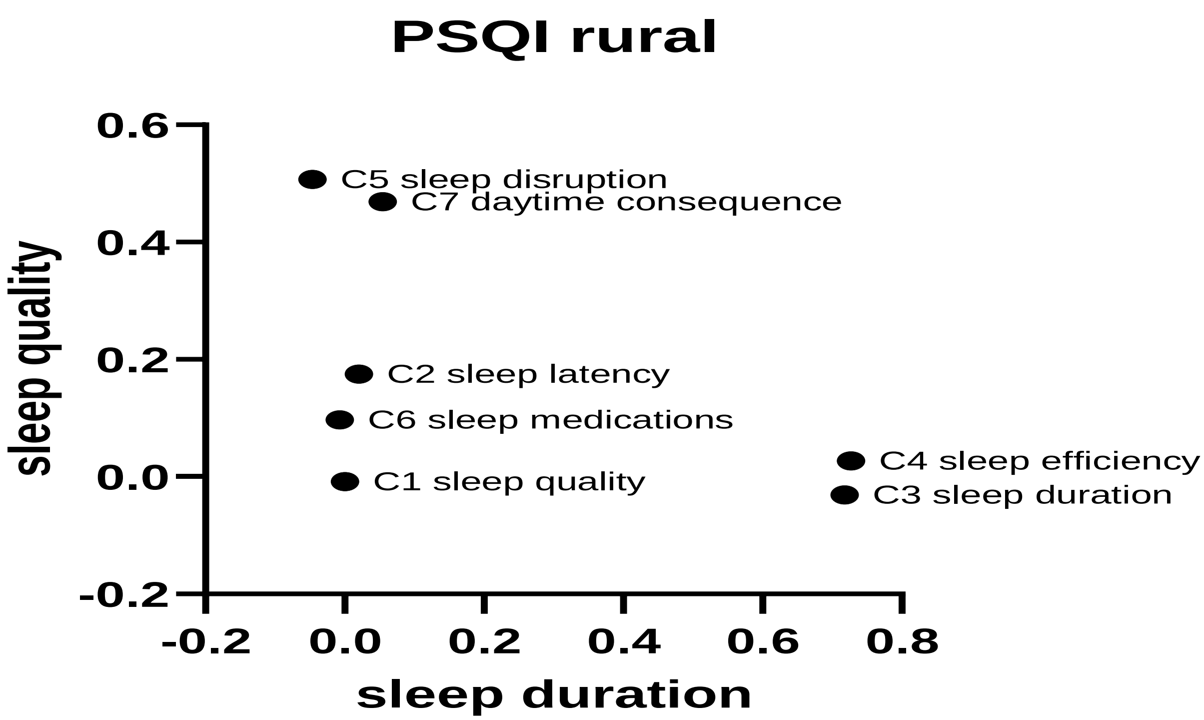


Figure A4.1: Representation of the construct validity of the PSQI in urban and rural adolescents, as obtained in the factor analysis. The PSQI in rural adolescents did not have the same construct validity as in the urban adolescents.

APPENDIX 5: ETHICAL CLEARANCE CERTIFICATE FROM THE HEALTH AND RESEARCH ETHICS COMMITTEE OF THE UNIVERSITY OF WITWATERSRAND

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG	HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

Office of the Deputy Vice-Chancellor (Research and Innovation)

TO:	Dr OE Olorunmoteni School of Physiology Medical School University E-mail: 2482237@students.wits.ac.za
CC:	Supervisor: Profs K Scheuermaier, XFG-O Casas & A Fatusi <Karine.Scheuermaier@wits.ac.za> and <HREC-Medical Research Office@wits.ac.za>
FROM:	Mr Iain Burns Human Research Ethics Committee (Medical) Tel: 011 717 1252 E-mail: Iain.Burns@wits.ac.za
DATE:	2021/11/24
REF:	R14/49
PROTOCOL NO:	**M210745** (This is your ethics application reference number. Please quote it in all enquiries, oral or written, relating to this study.)
PROJECT TITLE:	*Sleep characteristics amongst in-school adolescents in South-Western Nigeria: pattern, determinants and association with cardio-metabolic risk factors*

Please find attached the Clearance Certificate for the above project. I hope it goes well and that an article in a recognized publication comes out of it. This will reflect well on your professional standing and contribute to Government funding of the University.

MSWorks2000/Iain0007/Clearscan.wps

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

R49 Dr OE Olorunmoteni

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M210745

NAME: **(Principal Investigator)**	Dr OE Olorunmoteni
DEPARTMENT:	School of Physiology Medical School University
PROJECT TITLE:	*Sleep characteristics amongst in-school adolescents in South-Western Nigeria: pattern, determinants and association with cardio-metabolic risk factors*
DATE CONSIDERED:	2021/07/30
DECISION:	Approved unconditionally
CONDITIONS:	
NOTE:	If contact information regarding student study participants is required, please contact the Registrar's office - <Nicoleen.Potgieter@wits.ac.za>
SUPERVISOR:	Profs K Scheuermaier, XFG-O Casas & A Fatusi
APPROVED BY:	CB Penny Dr CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	2021/11/24

This Clearance Certificate is valid for 5 years from the date of approval. An extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office secretariat on the 3rd floor, Phillip Tobias Building, Parktown, University of the Witwatersrand, Johannesburg.

I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated from the research protocol as approved, I/we undertake to submit details to the Committee. **I agree to submit a yearly progress report**. When a funder requires annual re-certification, the application date will be one year after the date when the study was initially reviewed. In this case, the study was initially reviewed in July and therefore reports and re-certification will be due in the month of **July** each year. Unreported changes to the study may invalidate the clearance given by the HREC (Medical).

Signature of Principal Investigator ____________ Date ____________

APPENDIX 6: Ethical clearance certificate from the Health and Research Ethics Committee of the Obafemi Awolowo University, Ile-Ife, Osun State

HEALTH RESEARCH ETHIC COMMITTEE (HREC)
INSTITUTE OF PUBLIC HEALTH
OBAFEMI AWOLOWO UNIVERSITY, ILE-IFE, NIGERIA.

Our Ref: HREC NO: IPH/OAU/12/1850

Date: Nov. 26th, 2021

Your Ref: ______

Notice of Full Approval after Full Committee Review

SLEEP CHARACTERISTICS AMONG IN-SCHOOL ADOLESCENTS IN SOUTH-WESTERN NIGERIA: PATTERN, DETERMINANTS AND ASSOCIATION WITH CARDIO-METABOLIC RISK FACTORS.

Health Research Ethics Committee assigned number: IPH/OAU/12/1850

Applicant's Name: OLORUNMOTENI OLUWATOSIN EUNICE

Name/Status of Co- Researcher: ASSOC. PROF. KARINE SCHEUERMAIER, ASSOC. PROF. F. XAVIER GÓMEZ-OLIVÉ, PROF. ADESEGUN O. FATUSI

Applicant's Address: Dept. of Paediatrics and Child Health, OAU, Ile-Ife.

Date of receipt of valid application: 8th October, 2021

Date of meeting when final determination of research was made: November 25th, 2021

This is to inform you that the research described in the submitted protocol (HREC No: IPHOAU/12/1850), the consent forms and other participant information materials have been reviewed and given full approval by the Health Research Ethics Committee.

This approval dates from Nov. 25th, 2021 to Nov. 24th, 2022. If there is delay in starting the research, please inform the HREC so that the dates of approval can be adjusted accordingly. Note that no participant accrual or activity related to this research may be conducted outside of these dates. All informed consent forms used in this study must carry the HREC assigned number and duration of HREC approval of the study. In multiyear research, endeavor to submit your annual report to the HREC early in order to obtain renewal of your approval to avoid disruption of your research.

The National Code for Health Research Ethics requires you to comply with all institutional guidelines, rules and regulations and with the tenets of the Code including ensuring that all adverse events are reported promptly to the HREC. No changes are permitted in the research without prior approval by the HREC except in circumstances outlined in the Code. The HREC reserves the right to conduct compliance visit to your research site without previous notification.

HEALTH RESEARCH ETHICS COMMITTEE, O.A.U, ILE-IFE

SIGN: ______ DATE: 30-11-2021

Chairman, HREC

Web-site: www.iphoau.org // E-mail: iph@oauife.edu.ng, iphhoauife@gmail.com

APPENDIX 7: PERMISSION FROM THE MINISTRY OF EDUCATION

...IPINLE OMOLUABI

Osun A Dara

MINISTRY OF EDUCATION

PUBLIC SCHOOLS DEPARTMENT

P.M.B. 4418 OSOGBO, STATE OF OSUN, NIGERIA

***Your Ref. No.:* ....**

All communication should be
Addressed to "The Permanent Secretary"
Ministry of Education quoting
Our Ref. No.:

Date: 7th ***January, 2022***

The Principal,

----

u,f,s

The Local Inspector of Education,
Ife North Local Education Office,
Ipetumodu.

LETTER OF INTRODUCTION

I am directed to introduce Dr. Olorunmoteni, a Consultant Paediatric Neurologist in the Department of Paedratics Obafemi Awolowo University Teaching Hospitals' Complex (OAUTHC), Ile Ife.

2. She is on her research project titled; "Sleep Characteristics among In-school Adolescent in South-Western Nigerians: Pattern, Determinants and Association with Cardio-metabolic risk factors".

3. The Permanent Secretary, Ministry of Education has graciously approved her visit to your school for his research work and other necessary assistance you can render to make his research a success. However, it should be noted that: -

- *No scratch should be made on the skin of students*
- *No blood should be extracted from the students*
- *No virginity test should be carried out on students*
- *The consent of the parents of the students must be gotten before any screening exercise.*

4. Your co-operation is highly essential.

5. Thank you.

Dr. Mrs. T. T. Adeagbo
for; Coordinating Director

...IPINLE OMOLUABI
Osun A Dara

MINISTRY OF EDUCATION
PUBLIC SCHOOLS DEPARTMENT
P.M.B. 4418 OSOGBO, STATE OF OSUN, NIGERIA

9

Your Ref. No.: ....
All communication should be Addressed to "The Permanent Secretary" Ministry of Education quoting
Our Ref. No.:

Date: 7th ***January, 2022***

The Principal,

----

u,f,s

LOCAL INSPECTOR OF EDUCATION
IFE CENTRAL LOCAL EDUCATION OFFICE
ILE - IFE,
Sign............ Date 27/01/22.

The Local Inspector of Education,
Ife Central Local Education Office,
Ile – Ife.

LETTER OF INTRODUCTION

I am directed to introduce Dr. Olorunmoteni, a Consultant Paediatric Neurologist in the Department of Paedratics Obafemi Awolowo University Teaching Hospitals' Complex (OAUTHC), Ile Ife.

2. She is on her research project titled; "Sleep Characteristics among In-school Adolescent in South-Western Nigerians: Pattern, Determinants and Association with Cardio-metabolic risk factors".

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4. Your co-operation is highly essential.

5. Thank you.

Dr. Mrs. T. T. Adeagbo
for; Coordinating Director

...IPINLE OMOLUABI

Osun A Dara

MINISTRY OF EDUCATION

PUBLIC SCHOOLS DEPARTMENT

P.M.B. 4418 OSOGBO, STATE OF OSUN, NIGERIA

Your Ref. No.: ....
All communication should be Addressed to "The Permanent Secretary" Ministry of Education quoting
Our Ref. No.:

Date: 7th ***January, 2022***

The Principal,

----

u,f,s

The Local Inspector of Education,
Atakunmosa West Local Education Office,
Osu.

LETTER OF INTRODUCTION

I am directed to introduce Dr. Olorunmoteni, a Consultant Paediatric Neurologist in the Department of Paedratics Obafemi Awolowo University Teaching Hospitals' Complex (OAUTHC), Ile Ife.

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- *No virginity test should be carried out on students*
- *The consent of the parents of the students must be gotten before any screening exercise.*

4. Your co-operation is highly essential.

5. Thank you.

Dr. Mrs. T. T. Adeagbo
for; Coordinating Director

LOCAL INSPECTOR OF EDUCATION
ATAKUNMOSA WEST, OSU
SIGN 25-1-2022

Dear Principal/Proprietor,
Kindly give the bearer all necessary assistance they need.

Awoyera S.O
LIE
25/1/22

APPENDIX 8: PUBLISHED ARTICLE ON THE MULTIDIMENSIONS OF SLEEP HEALTH AMONG IN-SCHOOL ADOLESCENTS IN RURAL AND URBAN AREAS IN SOUTHWESTERN NIGERIA

ARTICLE IN PRESS

Sleep Health: Journal of the National Sleep Foundation xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Sleep Health: Journal of the National Sleep Foundation

journal homepage: www.sleephealthjournal.org

Multidimensions of sleep health among in-school adolescents in rural and urban areas in southwestern Nigeria

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Keywords:
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Rural
Urban

ABSTRACT

Introduction: Previous studies have focused on sleep inequities among disadvantaged populations in high-income countries. However, little is known about the differences in sleep health among adolescents in Africa. We aimed to compare the multidimensions of sleep health in adolescents living in rural vs. urban communities in Nigeria.

Methods: This cross-sectional study enrolled adolescents aged 13-19 in six rural and six urban schools in Osun State, Nigeria. We measured the prevalence of poor sleep quality (Pittsburgh Sleep Quality Index score > 5), daytime sleepiness (Epworth Sleepiness Scale for Children and Adolescents score > 10), and risk of sleep apnea (Teen STOPBANG). We compared the sleep health variables between the rural and urban populations using multivariable logistic regression.

Results: Of the 900 participants (51% rural; 59% female; average age (SD) = 15.1(1.4) years), 79% had short sleep duration (< 8.5 hours), 14.9% poor sleep quality, 9.6% excessive daytime sleepiness and 9.8% risk of sleep apnea. Urban adolescents had a higher prevalence of poor sleep quality (p = .004), short sleep duration (p < .001), daytime sleepiness (p = .044), and risk of sleep apnea (p = .006) compared to rural adolescents. The adjusted odds of having poor sleep quality (p = .008) and daytime sleepiness (p = .007) were about 2-fold higher among urban compared to rural adolescents. Later school end time, having single/separated parent(s), absence of parental setting of bedtime were independently associated with poorer sleep health.

Conclusion: Adolescents in rural communities had better sleep health than adolescents in urban communities. There is a need to develop interventions to improve the sleep quality and overall sleep health of urban-dwelling adolescents.

Introduction

Poor sleep constitutes a public health issue as it affects about half of the global population,[1] and is of particular concern among adolescents.[2-7] The period of adolescence is characterized by changes in physical, physiological, and psychological functions,[8] a physiological delay in adolescents' circadian and sleep phases with shorter sleep duration during weekdays.[4,9] Poor sleep in adolescents has been associated with risky behavior, poor academic performance, adverse mental health, and adverse cardiometabolic health.[10-12] Therefore,

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E-mail addresses: karine.scheuermaier@wits.ac.za (K. Scheuermaier).

https://doi.org/10.1016/j.sleh.2023.11.006
2352-7218/

adolescent sleep issues can be linked to other aspects of their health and well-being.

In 2014, Buysse[13] defined sleep health as "a multidimensional pattern of sleep-wakefulness, adapted to individual, social, and environmental demands, that promotes physical and mental well-being." This definition has improved the understanding of poor sleep health as a "cause of adverse health outcomes, rather than just a consequence or symptom of ill health."[14-16] Sleep health, as defined by Buysse, comprises the following sleep characteristics: duration, quality, timing, variability or regularity, efficiency, and continuity.[13,14] Sleep apnea is also a notable contributor to poor sleep and adverse health outcomes,[17,18] including cardiovascular health, especially among obese adolescents.[19,20] Sleep health disparities reflect socioeconomic inequities at the family, school, community levels. Addressing sleep health disparities, by intervening on those socioeconomic inequities could in turn improve overall health.[14,21]

In high-income countries, the problems associated with poor sleep among adolescents have been studied across racial, social and ethnic groups. Reports indicate that poor sleep exists among both rural and urban-dwelling adolescents,[22,23] but the determinants of poor sleep are not the same in these populations. In urban populations, adolescent sleep-related problems include sleep deprivation and excessive daytime sleepiness,[22,24] with shorter sleep duration and later bedtimes among urban-dwelling adolescents compared to rural-dwelling adolescents.[25-27] In urban settings, technology use at bedtime, artificial light exposure at night (ALAN), environmental noise, school-related demands, and family dynamics were the major determinants of sleep health.[22,24,28] In rural communities, poor sleep has been linked to poverty, low access to public - including health - amenities, and adverse mental health.[25,27,29] However, lack of access to electricity - more prevalent in rural communities - has been associated with earlier bedtimes.[30,31] Thus, there seems to be a disparity in the determinants of sleep health problems among rural and urban-dwelling adolescents.

In Africa, the few available studies on adolescent sleep have focused on urban communities. In South Africa, Reid et al reported insufficient sleep among urban-dwelling adolescents on weekdays with 40% reporting excessive daytime sleepiness.[32] In Nigeria, rural-urban migration has led to the rural population decreasing from 70% to 46% of Nigeria's total population between 2000 and 2022.[33,34] Urban communities in Nigeria have better access to social amenities,[34] the internet,[35] technology and electricity as well as alternative energy sources which are lacking in the rural communities.[34-36] In 2020, the World Bank reported a 55.4% electricity access rate in Nigeria with a wide disparity in urban (83.9%) compared to rural areas (24.6%).[37] Technology use, electricity and ALAN disrupt the natural light-dark cycle and are associated with short sleep duration and later bedtimes.[38] These factors may contribute to a difference in sleep health characteristics between rural and urban dwellers in Nigeria.

The existing Nigerian studies also have additional limitations, including a concentration on only sleep quality or sleep duration components of adolescent sleep health.[5-7] The other components of adolescent sleep health such as daytime sleepiness and the risk for sleep apnea have not been studied individually or in combination. Therefore, this research aimed to compare the different components of sleep health, encompassing both sleep quantity and quality, between rural and urban in-school adolescents in Osun State, Nigeria. We hypothesized that adolescents living in rural communities have earlier bedtimes, earlier wake times, longer sleep duration, better sleep quality, and lower daytime sleepiness than those living in urban communities.

Participants and methods

Study design

This comparative cross-sectional study was conducted in six rural and six urban schools in Osun State, southwestern Nigeria. All data were collected between May and June 2022, among a representative sample of 900 adolescents who were selected using a stratified, multistage sampling technique.

Study setting

The site for the study is the Osun East Senatorial District, one of the three senatorial zones (regions) in Osun State, Nigeria. Osun State is one of the most populated southern Nigerian states with an estimated population of 5,521,901 and an estimated adolescent population of 810,558. Three local government areas (LGAs), namely Atakumosa West (representing rural), Ife North (representing rural) and Ife Central (representing urban), were selected from the 10 LGAs within the zone. We selected 3 LGAs out of the 10 LGAs in the district based on their geographical proximity and ethno-religious similarities. Thus, the communities are only different based on their rural vs. urban features. The rural and urban classification is based on the Osun State government categorization of the communities. One school was selected from each rural community since most of these communities had only one or two secondary schools. Six schools were selected for the study in Ile-Ife, the urban community, using the proportion-to-population approach.

Study participants

The study participants were apparently healthy adolescents aged 13-19 years attending secondary schools in the selected rural and urban communities. Adolescents using sedative medications, anti-epileptics or narcotic preparations for any acute or chronic medical condition were excluded from the study using a screening questionnaire at the first school visit.

Adolescents in the final class (senior secondary school 3 [SSS 3]) were not available for the data collection process due to their final examinations and were excluded. We also excluded boarding students due to the controlled day and night schedules in the school boarding facilities. As per ethics regulations, adolescents whose parent did not sign the consent form were not enrolled (see flow chart in Fig. 1).

Sampling procedures

The multistage sampling method was used for the selection of study participants. In the first stage, the list of secondary schools in each community was obtained from the Education Office of the Osun State Ministry of Education. A stratified sampling technique was used to select six schools in the urban community and six schools in rural communities. For the second stage, we obtained the list of classes in each selected school and a class was selected from each stratum of the classes from Junior Secondary School (JSS) 1 (age range is 10-13 years old in urban areas, 10-16 years old in rural areas) to Senior Secondary School (SSS) 2 (age range urban areas 14-16 years old; age range rural areas 14-19 years old) using the stratified sampling technique. In the third stage, the simple random sampling technique was used to select a predetermined number of students per class. This was done using a proportionate-to-population approach to ensure that the number of students selected per class was proportional to the class population.

Ethical considerations

We obtained approval for the study from the Health and Research Ethics Committee of the University of Witwatersrand, Johannesburg, South Africa (Reference number M210745) and the Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria (Reference number HREC NO: IPHOAU/12/1850). We also obtained permission to conduct the study from the State Education Authority, the School

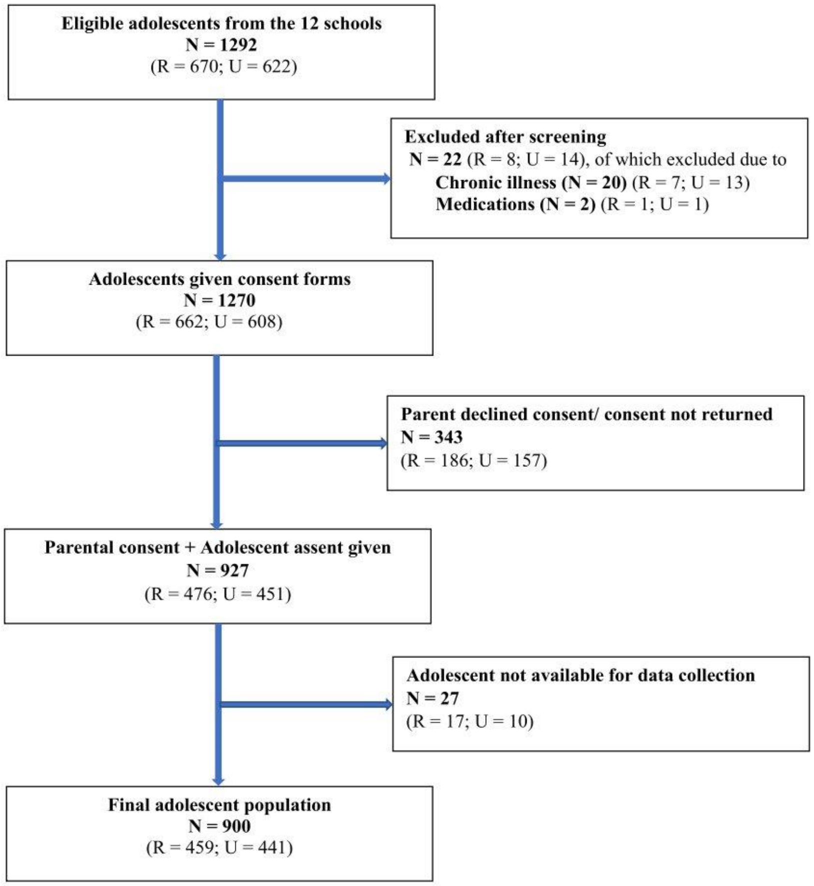

Fig. 1. Flow chart of participant recruitment process from the rural and urban communities in Osun State, Nigeria. R, rural; U, urban

Principals and the Proprietors. We conducted the study in accordance with the Declaration of Helsinki. Written informed consent was obtained from each parent of the adolescents aged less than 18 years, and the adolescents also gave signed assent. Adolescents aged 18-19 years gave written informed consent. During the first contact with the students, the lead researcher (OEO) provided general information about the study on the assembly ground in each school. Thereafter, the adolescents were given an information sheet about the study for delivery to their parents. The completed parental consent forms were collected from the adolescents the following day. Once parental consent and the adolescent's assent were obtained, we arranged for fully trained research assistants to be present at the school in the afternoons for 1-2 weeks for the data collection.

Data collection tools and measures

We used a pilot-tested questionnaire to obtain a self-report of information about the sociodemographic features, covariates and sleep characteristics of the rural and urban-dwelling adolescents. The questions on the sociodemographic information and other covariates were compiled by the research team based on earlier reported factors contributing to sleep characteristics,[5-7] while the sleep health variables were obtained using standardized sleep questionnaires. Each adolescent was interviewed in the school setting to gather self-reported sociodemographic and sleep characteristics and school schedule variables. The sociodemographic information obtained included the adolescent's age, sex, ethnicity, family type, nature of school (public or private) and class (grade) they were in (the variable was dichotomized into the junior secondary school classes JSS 1-3 and senior secondary school classes SSS 1-2). For analyses, we split age into 3 categories: Early adolescence: 13-14, Middle adolescence: 15-17, and Late adolescence: 18-19. We asked questions about the type of family, parental setting of bedtimes, bed sharing, ethnicity, nature of school, school start times, home-to-school commuting time, and the class in school.

Social class

We determined the social class of the respondents using the method described by Ibadin.[39] The occupation and the highest educational attainment of each parent were given a score from 1 to 6 based on the rating scale. The aggregate score for the respondents' social class was computed by dividing by four the score obtained from the occupation and the highest educational attainment of each parent (two, where only one parent or caregiver was available) and the derived value was approximated to the nearest integer. The resultant score range of 1-6 was further used to classify the social classes into Upper class (scores 1-2), Middle class (scores 3-4) and Lower class (scores 5-6).

Sleep quality

The Pittsburgh Sleep Quality Index (PSQI) was used to assess sleep over a 1-month time interval. It has been validated among a Nigerian population of late adolescents and older young people in a university setting.[40] It comprises 19 items, which are used to generate component scores across the seven domains: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. A total score of 21 is obtainable from the composite scores from each domain. A cumulative score with Global PSQI > 5 (out of 21) is considered poor sleep quality.

Sleep pattern

We used the components of the PSQI which contained questions about the adolescents' usual bedtime, wake time, total time in bed, self-reported sleep duration and sleep efficiency. For the logistic regression analysis, we dichotomized sleep duration in adolescents who slept < 8.5 hours/night (insufficient sleep duration) and those who slept ≥8.5 hours per night (sufficient sleep duration). Only eight (8) adolescents were in the long sleep duration category (sleep duration > 10 hours). Therefore, we decided to merge the adolescents who had a sleep duration of ≥8.5 hours in the sufficient sleep duration category.

Daytime sleepiness

It was assessed using the Epworth Sleepiness Scale for Children and Adolescents (ESS-CHAD, a modified form of the Epworth Sleepiness Scale [ESS] for children and adolescents). ESS-CHAD comprises 8 items and has been validated in children and adolescents aged 12-18 years of age.[41] It assesses the presence and degree of daytime sleepiness in more or less active situations, on a Likert scale of 0-3 per item (with 0 representing the least chance of dozing and 3 representing the worst). The participant is asked to recall their situations over the past month in answering the questions, and a composite score is obtained from the sum of the score for each domain. A score of > 10 for the ESS-CHAD is considered excessive daytime sleepiness.

Risk of sleep apnea

A modified STOP-Bang (teen STOP-Bang) questionnaire was used for assessing the risk of sleep apnea in adolescents.[42] A score of "1" was given for a "Yes" answer to each of the parameters which include snoring, tiredness, observed apnea, blood pressure ≥95th percentile for height and age, body mass index (BMI) > 95th percentile, academic problems and male gender. To calculate BMI (weight (kg)/(height (m))^2), we measured the adolescents' standing height (cm) to the nearest 0.01 cm with a standard calibrated stadiometer, and the body weight (kg) using a standard weighing scale to the nearest 0.1 kg with the adolescent dressed in minimal clothing. BMI was then subclassified into > 95th percentile or not, using the growth chart of the World Health Organization (WHO).[43] We measured each adolescent's blood pressure on the right arm in the sitting position using an appropriate-sized cuff. Blood pressure was then classified as ≥95th percentile for the sex and age in this population, or < 95th percentile. The total score obtained with the Teen STOPBANG was classified as "no risk" if < 3, while a total score of ≥3 being classified as risk of sleep apnea.

Data analysis

The data obtained were analyzed using Stata-15 software (StataCorp. 2017. Stata Statistical Software: Release 15. College Station, TX: StataCorp LLC). Descriptive analysis was used for the sociodemographic characterization of the study participants and other relevant variables, such as age, sex, class, place of residence, and ethnicity. We categorized the adolescents based on their place of residence since the factors that may affect the adolescent's sleep go beyond the school, to the environment where they live and sleep. At the bivariate level, a Chi-square test was used to assess the association between the category of residence (urban and rural) and the categorical adolescent sleep health variables (sleep quality, excessive daytime sleepiness, sleep duration < 8.5 hours, and risk of sleep apnea). An independent Student *t* test was used to assess the relationship between the category of residence and the continuous adolescent sleep health variables (bedtime, wake time, time in bed, sleep duration and sleep efficiency). Multivariable analysis was undertaken using the binary logistic regression model to assess the relationship between urban-rural location and sleep health, with the following sociodemographic variables controlled for: sex, age, social class, family type, ethnicity, parental setting of bedtimes, bed-sharing, nature of the school, class in school, school start and end times, and commuting time. A *p*-value < .05 was considered significant for all statistical analyses.

Results

Sociodemographic characteristics

Nine hundred adolescents participated in the study, with a mean ± SD age of 15.1 ± 1.4. Fifty-one percent were rural-dwelling adolescents, 59% were female, and 77.9% were in senior secondary school. Most respondents were of Yoruba ethnicity – the dominant ethnic group in southwest Nigeria (Table 1). School start time did not differ between the rural and urban-dwelling adolescents however school end time was later while their commuting time was shorter for the rural-dwelling adolescents.

Sleep quality

Overall prevalence of poor sleep quality was 14.9%. The urban-dwelling adolescents had statistically significant higher prevalence of poor-quality sleep (18.4%) compared to rural-dwelling adolescents (11.6%) ($p = .004$) (Table 2).

Excessive daytime sleepiness

Excessive daytime sleepiness was present in 86 (9.6%) of the in-school adolescents. Urban-dwelling adolescents had a significantly higher prevalence of excessive daytime sleepiness compared to rural-dwelling adolescents (11.6% vs. 7.6%, $p = .044$).

Sleep patterns

The mean ± SD sleep duration of the adolescents was 7:10 ± 1:40 hours while their mean total time in bed was 7:40 ± 1:29 hours (Table 2 and Fig. 2). The mean sleep duration and total time in bed were shorter among the urban-dwelling adolescents (both $p \leq .001$) while the sleep efficiency was not different. The urban-dwelling adolescents also had later bedtimes compared to their rural-dwelling counterparts; while there was no difference in their wake times (Table 2 and Fig. 2).

Risk of sleep apnea

Risk of sleep apnea was recorded in 87 (9.8%) adolescents. Urban-dwelling adolescents had a significantly higher prevalence of risk of sleep apnea compared to rural-dwelling adolescents (12.6% vs. 7.1%, $p = .006$).

Table 1
Participant's characteristics in rural vs. urban communities

Sociodemographic characteristics	Overall (N = 900) N (%)	Rural (N = 459) N (%)	Urban (N = 441) N (%)	p
Sex				
Female	531 (59.0)	274 (59.7)	257 (58.3)	.665*
Male	369 (41.0)	185 (40.3)	184 (41.7)	
Age in years				
Mean ± SD	15.1 ± 1.4	15.4 ± 1.4	14.8 ± 1.4	**<.001#**
13-14 (early adolescence)	323 (35.9)	123 (26.8)	200 (45.3)	**<.001**
15-17 (middle adolescence)	535 (59.4)	308 (67.1)	227 (51.5)	
18-19 (late adolescence)	42 (4.7)	28 (6.1)	14 (3.2)	
Social class				**<.001**
Upper	127 (14.1)	8 (1.7)	119 (26.9)	
Middle	323 (35.9)	137 (29.9)	186 (42.2)	
Lower	442 (49.1)	310 (67.5)	132 (29.9)	
Unclassified (no response)	8 (0.9)	4 (0.9)	4 (0.9)	
Ethnicity				**.002**
Yoruba	814 (90.4)	429 (93.5)	385 (87.3)	
Others	86 (9.6)	30 (6.5)	56 (12.7)	
Family type				**<.001**
Monogamous	672 (74.7)	308 (67.1)	364 (74.7)	
Polygamous	193 (21.4)	131 (28.5)	62 (14.1)	
Has single parents	22 (2.4)	13 (2.8)	9 (2.0)	
Have separated parents	13 (1.4)	7 (1.5)	6 (1.4)	
Parental setting of bedtime				.892
Yes	296 (32.9)	150 (32.7)	146 (33.1)	
No	604 (67.1)	309 (67.3)	295 (66.9)	
Bed-sharing				**<.001**
Yes	456 (50.7)	262 (57.1)	194 (44.0)	
No	444 (49.3)	197 (42.9)	247 (56.0)	
School start time (hh:mm)[a]	07:45 ± 0:12	07:45 ± 0:12	07:45 ± 0:12	.289
School end time (hh:mm)[a]	15:30 ± 1:06	15:36 ± 1:18	15:24 ± 0:54	**.021#**
Home-to-school commuting time (min)	24 ± 15	22 ± 14	26 ± 15	**<.001#**
Nature of school				
Public	553 (61.4)	373 (81.3)	180 (40.8)	**<.001**
Private	347 (38.6)	86 (18.7)	261 (59.2)	
Class in school		127 (27.7)		**<.001**
JSS1-JSS3	199 (22.1)	127 (27.7)	72 (16.3)	
SSS1-SSS2	701 (77.9)	332 (72.3)	369 (83.7)	

*Chi-square test.
#Independent *t* test.
P values in bold indicate statistically significant differences between the urban and rural adolescent characteristics.
[a] Mean ± SD.

Table 2
Comparison of sleep characteristics of Nigerian in-school adolescents in rural vs. urban communities

Sleep variables	Overall N (%)	Rural N (%)	Urban N (%)	p
Sleep quality (n = 899)				**.004***
Good	765 (85.1)	406 (88.4)	359 (81.6)	
Poor	134 (14.9)	53 (11.6)	81 (18.4)	
Excessive daytime sleepiness (n = 900)				**.044***
Absent	814 (90.4)	424 (92.4)	390 (88.4)	
Present	86 (9.6)	35 (7.6)	51 (11.6)	
Risk of sleep apnea				**.006***
No risk	805 (90.2)	422 (92.9)	383 (87.4)	
Risk of apnea	87 (9.8)	32 (7.1)	55 (12.6)	
Self-reported:	Mean ± SD	Mean ± SD	Mean ± SD	
Sleep duration (h:mm)	7:10 ± 1:40	7:23 ± 1:34	6:55 ± 1:44	**<.001#**
Bedtime (hh:mm)	21:49 ± 1:11	21:34 ± 1:08	22:05 ± 1:11	**<.001#**
Wake time (hh:mm)	05:27 ± 0:47	05:29 ± 0:46	05:25 ± 0:50	.190#
Time in bed (h:mm)	7:40 ± 1:29	7:55 ± 1:23	7:24 ± 1:31	**<.001#**
Sleep efficiency (%)	92.1 ± 13.2	92.3 ± 12.5	91.9 ± 14.0	.570#

*Chi-square test.
#Independent *t* test.
P values in bold indicate statistically significant differences between the urban and rural adolescent sleep characteristics.

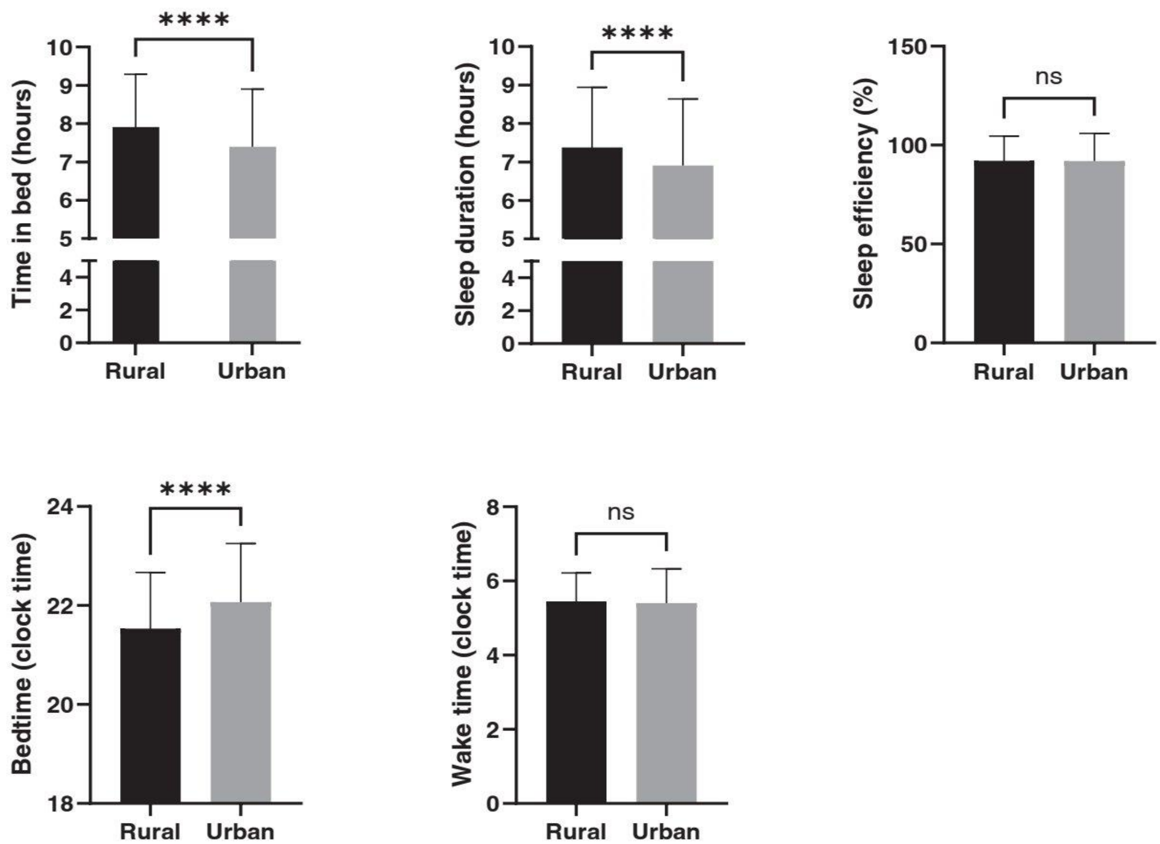

Fig. 2. Mean ± SD self-reported time in bed, sleep duration, bedtime, wake time and sleep efficiency extracted from the Pittsburgh Sleep Quality Index in rural vs. urban adolescents living in Osun State, Nigeria. ****p < .001, ns: nonsignificant, using an independent t test

Multivariable analysis

Table 3 shows the crude and adjusted relationship between the type of residence (rural-urban) and poor sleep quality, excessive daytime sleepiness, low sleep duration and the risk of sleep apnea in adolescents. The adjusted odds of having poor sleep quality and excessive daytime sleepiness were higher by almost 2-fold among the urban-dwelling adolescents compared to those living in the rural communities. Adjusted odds of reporting insufficient sleep duration (< 8.5 hours/ night) or risk of sleep apnea between the rural and urban communities were not significant (Table 3).

The full multivariable model of the rural-urban difference is shown in Table 4 and shows other factors associated with sleep health.

Female adolescents had higher odds of having poor sleep quality, but lower odds of having risk of sleep apnea than did male adolescents. Adolescents from lower and middle social classes had lower odds of having poor sleep quality and short sleep duration but

Table 3
Binary logistic regression analysis of the sleep health characteristics in Nigerian in-school adolescents in rural vs. urban communities in crude (cOR) and adjusted analyses (aOR)[a]

Variable name	Poor sleep quality		Excessive daytime sleepiness		Sleep duration < 8.5 h		Risk of sleep apnea	
Residence urban	Crude	Adjusted	Crude	Adjusted	Crude	Adjusted	Crude	Adjusted
OR95%CI	**1.73** **1.19-2.51** **0.004**	**1.95** **1.19-3.18** **0.008**	**1.58** **1.01-2.49** **0.046**	**2.25** **1.25-4.05** **0.007**	1.26 0.91-1.73 0.162	1.07 0.72-1.60 0.741	**1.89** **1.20-2.99** **0.006**	1.57 0.87-2.85 0.136

We modeled the odds of having poor sleep quality (PSQI > 5) over good sleep quality (PSQI ≤5), the odds of having excessive daytime sleepiness (ESS-CHAD > 10) over having normal daytime sleepiness (ESS-CHAD ≤10), the odds of having low sleep duration (< 8.5 hours) over the odds of having normal sleep duration (≥8.5 hours) and the odds of having risk of sleep apnea over the odds of having low risk of sleep apnea. Results (odds ratios and p values) in **bold** indicate a significant association between the independent variable (residence urban, compared to rural) and the sleep outcome variable tested.

[a] Binary logistic regression controlling for the confounders: sex, age, social class, family type, nature of the school, class in school, ethnicity, parental setting of bedtimes, bed-sharing, school start time, school closing time, and home-to-school commuting time.

Table 4
Multivariable analysis of the sleep health characteristics among the Nigerian in-school adolescents in rural vs. urban communities

Variable name	Poor sleep quality		Excessive daytime sleepiness		Sleep duration <8.5 h		Risk of sleep apnea	
	aOR (95% CI)	p	aOR (95% CI)	p	aOR (95% CI)	p	aOR (95% CI)	p
Residence[a]								.136
Urban	**1.95 (1.19-3.18)**	**.008**	**2.25 (1.25-4.05)**	**.007**	1.07 (0.72-1.60)	.741	1.57 (0.87-2.85)	
Sex[b]								**<.001**
Female	**1.60 (1.06-1.41)**	**.024**	1.11 (0.68-1.79)	.681	0.98 (0.70-1.39)	.928	**0.27 (0.16-0.44)**	
Age[c]								.846
Middle adolescence	0.99 (0.62-1.60)	.981	1.10 (0.61-1.96)	.758	1.40 (0.93-2.11)	.103	0.95 (0.54-1.66)	
Late adolescence	0.98 (0.36-2.67)	.965	1.57 (0.54-4.59)	.410	2.12 (0.80-5.63)	.133	2.78 (0.99-7.84)	.053
Social class[d]								.658
Middle	**0.46 (0.26-0.82)**	**.007**	**2.51 (1.08-5.83)**	**.028**	**0.29 (0.14-0.61)**	**.001**	1.17 (0.58-2.36)	
Lower	**0.46 (0.25-0.87)**	**.017**	**2.70 (1.09-6.69)**	**.032**	**0.28 (0.13-0.61)**	**.001**	0.85 (0.38-1.88)	.683
Ethnicity[e]								
Not Yoruba	1.16 (0.62-2.20)	.650	1.79 (0.91-3.53)	.091	1.58 (0.85-2.94)	.145	0.59 (0.24-1.46)	.256
Family type[f]								.428
Polygamous	1.59 (0.99-2.54)	.054	1.13 (0.68-1.99)	.681	1.47 (0.96-2.27)	.079	1.28 (0.69-2.37)	
Single	**2.80 (1.06-7.42)**	**.038**	1.61 (0.43-5.92)	.504	2.03 (0.56-7.40)	.284	**4.95 (1.59-15.40)**	**.006**
Separated	1.15 (0.23-5.88)	.863	——		2.83 (0.48-16.78)	.250	**5.97 (1.43-24.87)**	**.014**
Parent set[g] bedtime	**0.58 (0.37-0.91)**	**.018**	**0.36 (0.20-0.67)**	**.001**	0.79 (0.56-1.13)	.205	1.13 (0.68-1.85)	.643
Bed sharing[h]	0.82 (0.54-1.22)	.327	0.81 (0.50-1.31)	.383	0.78 (0.55-1.10)	.156	1.00 (0.61-1.65)	.989
Type of school[i]								.095
Private	**0.55 (0.31-0.97)**	**.040**	1.10 (0.57-2.12)	.782	0.94 (0.57-1.57)	.825	1.85 (0.90-3.82)	
Class in school[j]								.463
Senior	1.07 (0.62-1.87)	.805	0.70 (0.37-1.30)	.254	1.24 (0.81-1.90)	.322	0.78 (0.41-1.50)	
School start time (decimal time in hours)[k]	1.30 (0.55-3.08)	.556	0.57 (0.23-1.43)	.230	0.88 (0.43-1.83)	.748	0.54 (0.19-1.53)	.246
School end time (decimal time in hours)[l]	**1.29 (1.02-1.62)**	**.031**	**1.37 (1.03-1.83)**	**.032**	1.17 (0.97-1.41)	.097	0.99 (0.74-1.31)	.924
Commuting time (min)[m]	1.01 (0.99-1.02)	.170	1.00 (0.98-1.01)	.669	1.01 (0.99-1.02)	.174	1.01 (0.99-1.02)	.255

Reference categories: a: rural; b: males; c: early adolescence; d: social class: upper – missing social class for n = 8; e: Yoruba; f: monogamous; g: no parental setting of bedtime; h: no bed sharing; i: public; j: junior; k and l: the odds ratios show the odds of having the outcome for each later hour in the school start/school end times; m: the odds ratio shows the odds of having the outcome each incremental minute in commuting time. Results (odds ratios and p values) in **bold** indicate a significant association between the independent variable and the sleep outcome variable tested.

higher odds of daytime sleepiness relative to those in the upper class. The odds of reporting poor sleep quality increased almost 3-fold in adolescents from single-parent families compared to adolescents from monogamous family settings. Adolescents from families where the parents were separated or from single-parent families had higher odds of having risk of sleep apnea than adolescents from monogamous family settings. Furthermore, parental setting of bedtimes for adolescents was associated with lower odds of reporting poor sleep quality and excessive daytime sleepiness. Finally, every later hour in the school end (closing) time, was associated with about 1-fold increase in the odds of having poor sleep quality and excessive daytime sleepiness while school start times and commuting time were not associated with any sleep outcome.

Discussion

This study aimed to compare the sleep health of in-school adolescents in rural and urban communities within the Osun East Senatorial District, southwestern Nigeria using validated sleep questionnaires. About 15% of respondents reported poor sleep quality. The overall mean sleep duration was short (7 hours) for the general population of the participants. The odds of having poor sleep quality and excessive daytime sleepiness increased almost 2-fold among urban-dwelling adolescents compared to rural-dwelling students. Also, we found a shorter mean sleep duration, time in bed and later bedtimes among urban adolescents compared to rural adolescents.

The shorter sleep duration among urban-dwelling adolescents found in this study may be due to their later bedtime as they had similar wake times as the rural adolescents. Earlier studies have reported similar findings of a short sleep duration[6,7] and poor sleep quality[5] among urban-dwelling Nigerian adolescents. This may be due to some sleep stealers that reduce the sleep opportunities of urban-dwelling adolescents. Technology use at bedtime, artificial light exposure, environmental noise, school-related demands, and family dynamics were the major determinants of sleep health problems reported earlier in urban settings.[22,24,28] The active late-night life in urban communities is often enhanced by the availability of electricity and the increased access to artificial light at night. Artificial light in turn may chronically cause circadian phase delays in urban-dwelling adolescents, contributing to their later bedtimes. Also, adolescents in urban communities are more likely to stay up late at night watching TV or chatting at night on social media due to access to electricity.[7] The higher odds of poor sleep quality and excessive daytime sleepiness among the adolescents whose schools close late supports the contribution of school end time to adolescents' sleep health found in urban-dwelling adolescents in Ile-Ife.[44] However, the later school end time we found among the rural adolescents (who overall showed better sleep quality) shows that school end time alone does not explain the higher prevalence of poor sleep quality among urban vs. rural adolescents.

We found no association between school start times and sleep health outcomes. School start times did not differ in the urban vs. rural settings, nor did they vary substantially from one school to another (standard deviation = 0:12 hour). Conversely, school end times were more varied (standard deviation = 1:06 hours). The lack of variability in school start times in our sample may have precluded us from finding an effect of school start times on overall sleep health outcomes. Nevertheless, our findings suggest that at identical early school start times, later school end times may also be associated with poorer sleep health.

Sleep health of rural-dwelling adolescents has been reported to be adversely affected by poverty, poor amenities, poor access to health and adverse mental health.[25,27,29] However, the effect of these factors on the sleep of rural adolescents may not be as severe as the factors that limit the sleep of urban-dwelling adolescents. The higher odds of excessive daytime sleepiness among urban adolescents is probably a direct result of their poor sleep quality and lower sleep duration. Previously we showed that the pressure of schoolwork and extracurricular activities, was associated with a lower sleep opportunity of adolescents and lead to a worsened delay in bedtime.[7] The urban adolescents had shorter sleep duration compared to their rural counterparts. Therefore, the higher daytime sleepiness in urban adolescents is probably secondary to both poor sleep quality and short sleep duration. Parental setting of bedtimes was associated with lower odds of both poor sleep quality and excessive daytime sleepiness, possibly by mitigating the phase delay in bedtimes and allowing for longer time in bed.

The higher prevalence of risk of sleep apnea in the urban-dwelling adolescents in our study supports the multiple dimensions of sleep health disparities in adolescents. In addition, adolescents living in single-parent family settings had higher odds of poor sleep quality and risk of sleep apnea. These findings may be driven by lifestyle differences.[45,46] Hence, there is a need to further study the contributory factors to the overall sleep health of adolescents in urban and rural communities. There may be lessons to learn from rural-dwelling adolescents that can improve the sleep of their urban-dwelling counterparts.

The few comparative studies of urban vs. rural-dwelling adolescents have been focused on sleep duration. Boraita et al[47] found a higher sleep duration and better quality of life among adolescents in rural populations when compared to their urban-dwelling counterparts in Spain.

In another study, among adolescents aged 12-15 years, daytime somnolence and disorders of initiating and maintaining sleep were more prevalent in the urban compared to the suburban population.[48] Pereira et al[49] in a study of the sleep duration of rural adolescents in southern Brazil (Paraná) and its determinants concluded that “not all adolescents are sleep-deprived” because the rural adolescents had sufficient mean sleep duration of 9.6 hours on weekdays and 10.1 hours on weekends; however, they did not compare them with urban adolescents. In two Brazilian studies, urban dwellers had significantly later bedtimes and waketimes than rural-dwelling adolescents.[30,50] Within the rural population, adolescents with access to electricity and television had shorter sleep duration than their peers without such facilities.[28] Our findings suggest that rural adolescents in Nigeria may be experiencing some sleep enablers that are worth studying.

The higher odds of poor sleep quality among the female adolescents in our study are in accordance with other studies showing lower sleep quality in female vs. male adolescents.[43] Adolescents from the lower and middle classes had lower odds of poor sleep quality, short sleep duration but higher odds of excessive daytime sleepiness than those from the upper class. The higher number of rural-dwelling adolescents in the low and middle social class category may be contributory to this observation. However, the higher odds of daytime sleepiness in the same category require further studies. In one of our earlier studies among urban adolescents in Ile-Ife, we found low social class to be associated with short sleep duration.[7] The protective effect of low and middle social class in the present study may be more among the rural-dwelling adolescents who have other factors that enhance their sleep, possibly offsetting the adverse effects of low social class. These findings suggest the need to further study the factors predictive of the sleep health of adolescents.

Limitations

Our study has a few limitations: first, the sleep health characteristics of the adolescents were assessed with the use of self-report questionnaires, which can be subject to recall bias and social desirability bias. This limitation may have been mitigated by our use of multiple instruments, which have been previously validated. Secondly, we could not use an objective measure of the adolescents' sleep such as polysomnography due to its capital-intensive nature. However, the use of actigraphs and sleep diaries can be explored in our population where polysomnography is presently unavailable. Furthermore, the cross-sectional design of our study does not allow for cause-and-effect evaluations.

Strengths of the study

This present study has the following strengths: first, to the best of our knowledge this is the first study comparing the multi-dimensions of sleep health variables among rural and urban-dwelling adolescents in Africa. Secondly, we had a large sample size of adolescents in rural vs. urban communities. Thirdly, it employed the use of multiple instruments to measure the dimensions of sleep health, rather than the use of single measures such as sleep duration only.

Conclusions

This study showed that rural-dwelling adolescents living in Southwestern Nigeria have better sleep health than urban-dwelling adolescents. Further investigation of the risk and protective factors that affect the sleep health of adolescents in rural and urban communities can help guide the development of effective sleep health interventions. Therefore, we recommend further studies to better understand the sleep health of rural and urban–dwelling adolescents and the sleep health of out-of-school adolescents, including those living in slums. Qualitative surveys will be of help in exploring the perception of adolescents about their sleep and the consequences of their sleep health.

Dr. Czeisler's contributions to this work

Dr. Czeisler's research on the effects of circadian misalignment on sleep quality[51] and in turn on cognitive performance and health[52] has inspired us to investigate circadian and sleep health in African adolescents. Specifically, Dr. Czeisler showed that human circadian rhythms were entrained to the 24-hour Earth light-dark cycle by light.[53] With the rapid growth of urbanization[54] and concomitant higher access to artificial lighting and smartphones in Africa, the effects of light at night on adolescent circadian rhythms and sleep quality are of particular concern. As predicted from Dr. Czeisler's circadian and sleep research, our study shows that adolescents living in an urban area in Nigeria have lower sleep duration, worse sleep quality and later bedtimes than adolescents living in rural areas, where access to artificial lighting/smartphone technology is more limited. In addition, Dr. Scheuermaier is also grateful to Dr. Czeisler for his support through the T32 HL07901 training grant, allowing her to complete her postdoctoral fellowship in sleep and circadian rhythms and start investigating sleep and health in Africa.

Public health relevance

We are documenting here for the first time the lower sleep duration and poorer sleep quality in urban compared to rural-dwelling adolescents in Nigeria. Those findings may help devise public policies to improve adolescent sleep, not only in Africa but also in the rest of the world, as we draw lessons from the sleep-enabling culture in the rural areas of Africa.

Author contributions

OEO, KS, AOF, and FXGO designed the study. OEO received funding from CARTA to help run the study. OEO supervised data collection and performed statistical analyses. All authors contributed to the write-up of the manuscript and have approved the final version of this manuscript.

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Declaration of conflicts of interest

There is no conflict of interest to report in this project.

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APPENDIX 9: PARTICIPANT INFORMATION AND INFORMED CONSENT FORMS

Hello,

I am Oluwatosin Olorunmoteni, from the Obafemi Awolowo University, Ile-Ife, Nigeria. I am a Neurodevelopmental Paediatrician (a doctor who takes care of conditions affecting brain function and development) at the Obafemi Awolowo University Teaching Hospital, Ile-Ife. I am undergoing a PhD in Sleep Physiology at the University of Witwatersrand, South Africa. We are investigating the sleep patterns and problems among Nigerian adolescents. Sleep is very important for everyone, including adolescents. In previous studies, it has been observed that many adolescents in Nigeria have problems with their sleep. We want to understand why adolescents may have sleeping problems and the factors that can lead to this. We also want to know how the sleep problem of adolescents can affect their health. Finally, we want to know how your sleep as a parent and other aspects of your personal and family life affect how your child sleeps.

For all these reasons we would like to invite you and your child to participate in this study. Therefore, before deciding about your participation in the study, we would like you to read the details below carefully. Moreover, we will also give your child a verbal explanation of the study before taking the final decision. Please do not hesitate to ask any questions.

Purpose of the study

It has been shown from recent research that adolescents are getting less sleep all over the world. Sleep problems are common among adolescents who go to school. Many of them go to sleep late, may not sleep long enough at night and sleep a lot during the day. However, no research has evaluated in detail, the reasons why students may not be sleeping well. The possible factors may involve the child, the family, the school, and the community where they live.

Therefore, the purpose of our study is to evaluate the sleep patterns and problems in secondary school students, and the causes and the effect of sleep on specific aspects of their health. Also, we want to know what parents and adolescents think about the causes and effects of sleep problems in the students.

Details of the study

We will be recruiting adolescents (secondary school students), from the rural areas and the urban areas. The students to be recruited will be students of age 13-19 years. We will ask your child a few question about his/her habits and health to determine if he/she can be included in this study.

The study will involve:

Main study (all participants):

a) an initial data collection, at the beginning of the new school term. We will ask the child to answer questions to fill the following sleep questionnaires to assess the various aspects of sleep: the adolescent self-report questionnaires to be used include the Adolescent sleep habit questionnaire, Epworth Sleepiness Scale(ESS) to assess daytime sleepiness and Pittsburgh Sleep Quality

Index(PSQI) to assess sleep quality. The Munich Chronotype Questionnaire will be used to assess their sleep chronotype (Your child's best waketimes and bedtimes over 24 hours) while the modified STOP-Bang questionnaire will be used to assess the risk factors for sleep apnea (cessation of breathing during sleep) in the adolescents. It will take between 30 and 45 minutes to answer to fill in these questionnaires. The questionnaires will be filled in at their school with the assistance of research assistants.

b) In addition to the questionnaires mentioned in a), we will also take measurements of your child's weight, height, blood pressure, and waist circumference to assess aspects of their health status and to be able to relate their sleep and their health status. In addition, to understand if sleep can affect blood sugar, we will prick your child's finger on their non-dominant hand to collect a drop of blood to measure their glucose (blood sugar).

In-depth Sub-study:

c) Actigraphy: we will ask your child to wear a wrist-worn device, which looks like a wristwatch, for one week to assess his/her sleep patterns. This device will also measure the physical activity and light exposure of each participant. A subset of adolescents will be involved in the use of actigraphy. By signing this consent form, you are allowing your child to be part of this aspect of the study.

d) Sleep diary: Each participant using actigraphy will also be required to use the sleep diary to record their sleep patterns over one week. By signing this consent form, you are allowing your child to be part of this aspect of the study.

e) We may also ask you to participate in an interview with the researcher. During this interview, we will ask questions to you and your child on factors that can cause difficult or problematic sleep.

<u>What will be required from you and your child</u>

We will ask your child to fill out sleep questionnaires, wear the actigraphy on their wrist for one week, fill out a sleep diary for one week, and to allow us to measure their weight, height and blood pressure. Blood sugar checks will be done with a glucometer via finger-prick. We will also ask both you and your child questions about your own opinion on the causes of sleep problems in secondary school students.

The results will be analyzed and published in scientific papers and presented at scientific conferences. However, your identity and your child's identity will remain anonymous. Yours and your child's results will be made available to you if you wish. Anonymized and aggregated results of the study may also be made available to the school and to the government departments that have approved the study.

Benefits and risks

Importantly, should any of these procedures cause distress to either you or your child, I and other members of our team will be available to offer the required help. It may be slightly uncomfortable when we measure the sugar from your child's finger. Apart from potential distress, there are no other risks involved in taking part in the study.

Your child may benefit from this study by obtaining the results of his/her weight, height, body mass index, blood pressure and blood sugar checks. Participants with abnormal levels will be referred to the appropriate clinics in the hospital.

Right to refuse to participate

You and your child may withdraw from participating at any time should you choose to, for whatever reason and without consequences. If after reading this information sheet you decide against participating in the study, please be assured that this will not impact you negatively in any way.

Confidentiality

The information you provide is private and strictly confidential and will not be disclosed to anyone. We will conduct this interview in a private area to ensure that others will not overhear what you say during the interview. The information that you give us will only be used for research purposes. Your name, address, and other personal information will be removed from the questionnaire and a code will be used to connect your name and your answers without identifying you. The study team may contact you again only if it is necessary to complete the information on the survey or to collect additional information at a later point in time.

Ethical approval

We have obtained ethical approval for this study from the Human Research Ethics Committee (HREC) of the Obafemi Awolowo University whose contact details are listed below and the Human Research Ethics Committee (HREC) of the University of Witwatersrand.

If you have further questions, please don't hesitate to ask.

We are inviting you and your child to participate in the study. In case you decide to participate we would like you to sign the consent form overleaf.

If you decide to discontinue your child's participation in the study, kindly inform me

Oluwatosin Olorunmoteni (+234 8039413535 or by email: tosinolorunmoteni@gmail.com)

Call or contact the Obafemi Awolowo University Institute of Public Health HREC Office if you have questions about your rights as a study participant. Contact the HREC if you feel you have not been treated fairly or if you have other concerns. The HREC contact information is:

Address: The Secretary,

Health Research Ethics Committee

Institute of Public Health

Obafemi Awolowo University

PMB 045, OAU Post Office

Postal Code 220005

Ile Ife

Telephone: +234 808 842 8726

E-mail: iph@oauife.edu.ng

iphoauife@gmail.com

Sincerely,

Oluwatosin Olorunmoteni

CONSENT FOR CHILD/WARD TO ACT AS A PARTICIPANT IN A RESEARCH PROJECT

I ………………………………………………………………….. being 18 years or older, give consent for my child/ward………………………………………………………………………… to participate in a research project entitled: **Sleep characteristics among In-school Adolescents in South-Western Nigeria: Patterns, Determinants and Association with Cardio-metabolic risk factors.**

1. The procedures have been explained to me and my child/ward. I understand and appreciate the purpose, any risks involved, and the extent of my child/ward's involvement. I have read and understand the attached information leaflet.
2. I understand that the procedures form part of a research project, and may not provide any direct benefit to me or my child/ward.
3. I understand that all experimental procedures have been sanctioned by the Committee for Research on Human Subjects, University of the Witwatersrand, Johannesburg.
4. I understand my child/ward participation is voluntary, and that my child/ward, as a participant, is free to withdraw from the project at any time without prejudice.

______________________________ ______________________

Parent/Guardian name and signature Date__________________

____

Participant name and signature Date

______________________________ ________________________

Name and signature of a Witness Date

______________________________ ________________________

Investigator name and signature Date

APPENDIX 10: SCREENING QUESTIONNAIRE

This questionnaire is aimed at assessing your general health and sleep health. Please respond to all questions. The information you provide is VERY important and will assist in determining your eligibility for the main study. We may use this information for future research.

DEMOGRAPHICS

LAST NAME		FIRST NAME		DATE	
		DOB		SEX	☐ M ☐ F
PERSONAL NAME OF SCHOOL ________ CLASS(GRADE)____________					

HEALTH (Check YES or NO and all that apply)			
1. From which of the following medical conditions do you suffer?	**YES**	**NO**	
• Diabetes (high blood sugar, high sugar in urine)	☐	☐	
• Asthma (recurrent cough, chest tightness and noisy breathing, often worse at night and triggered by exposure to dust, smoke etc)	☐	☐	
☐ Nocturnal			
☐ Allergic			
• Tuberculosis (chronic cough, that is, cough of several weeks or months, usually associated with night sweats and weight loss)	☐	☐	
• Hypertension {High blood pressure} (provide blood pressure)	☐	☐	_____ / _____ mmHg
• Mental health	☐	☐	
☐ Depression (feelings of severe sadness, sorrow and misery)			

☐ Anxiety (Intense, excessive and persistent worry and fear about everyday situations. Fast heart rate, rapid breathing, sweating and feeling tired may occur)			
☐ Panic Disorder (an anxiety disorder where some regularly have sudden attacks of panic or fear)			
☐ Schizophrenia {mental illness that is characterized by disturbances in thought (such as delusions), perception (such as hallucinations} ☐ Bipolar Disorder {**Bipolar disorder** causes extreme mood swings that include emotional highs (mania or hypomania) and lows (depression)}			
☐ Other			
• Heart disease	☐	☐	
☐ Congenital Heart Disease (heart condition that someone was born with such as hole in the heart0			
☐ Irregular heart beat (often called Arrhythmia, diagnosed in the hospital with tests like ECG)			
☐ Other			
• Neurodevelopmental disorder	☐	☐	
☐ Cerebral palsy (characterized by abnormal posture and movement difficulties. May be associated with a small head, crossed eyes, difficulty in speaking, hearing, swallowing etc)			
☐ Epilepsy (recurrent convulsion without fever or other provocative factors)			
☐ Migraine headaches (recurrent headaches often associated with triggers such as flashes of light or noise)			
☐ Autistic spectrum disorder (disorder of social communication and interactions diagnosed in the hospital by a specialist) ☐ Attention Deficit Hyperactivity Disorder (characterized by difficulty in maintaining attention and excessive activity usually diagnosed after assessments in the hospital by a specialist)			
• Kidney disease	☐	☐	

☐ Chronic Kidney Disease (reduction in urine quantity occurring over a long time, facial swelling, body swelling etc that has been diagnosed in the hospital).			
☐ Kidney stones (stones in the kidneys causing recurrent abdominal pain, usually diagnosed with Xrays and other tests in the hospital),			
☐ Other Haematological Disease			
☐ Sickle cell anaemia (people with SS genotype who usually have recurrent bone pains, recurrent yellowness of the eyes, recurrent blood transfusion etc)			
☐ Glucose 6 Phosphate Dehydrogenase deficiency (G6PD deficiency): {Characterised by recurrent passage of dark coloured {coke-like} urine and yellowness of the eyes, often occurring during a febrile illness.			
• Have you ever been diagnosed or treated for a sleep disorder? (difficulty in sleeping or excessive sleeping diagnosed in an hospital)	☐	☐	
Type:	☐	☐	
When:			
By whom:			
List all medications you use regularly:			

APPENDIX 11: STUDY QUESTIONNAIRE

A. Demographics		
Q1	Gender	☐ Female ☐ Male
Q2	Date of Birth	DD/MM/YYYY: ☐☐ ☐☐ ☐☐☐☐
Q3	Age as at last birthday	
Q4	Name of School	
Q5	Class in school	
Q6	Residential address	
Q7	Category of residence	☐ Rural ☐ Urban
Q8	Ethnicity	☐ Yoruba ☐ Hausa ☐ Igbo ☐ Others (Specify)_____

B. Risk and Protective Factors affecting Sleep		
Q9	Do you share your bed with someone else?	☐ Yes ☐ No
Q10	Do your parents set your bedtime (tell you when you go to bed)?	☐ Yes ☐ No ☐ If Yes, specify who: Dad___Mum___Other adults_ ☐ If No, are you the one who decides when to go to bed?
Q11	Does any of your parents have any of the following physical health problems?	Father Mother None I don't know a. Hypertention b. Diabetes mellitus c. Snoring. d. Asthma e. Cancer f. Mental illness
Q12	Parental socioeconomic status	a. Father **(i)**Highest education completed. Nil ____ primary______ secondary________________ tertiary________Others (specify)_________ (ii) Occupation____ (iii) Average Income/ month in Naira < 5,000 ☐ 5,000 -10, 000 ☐ 10,000-50,000 ☐ >50,000 ☐ b. Mother: (i) Highest education completed: Nil_____ primary______secondary____ tertiary____ (ii) Occupation____ (iii) Average Income/ month in Naira< 5,000 ☐ 5,000 -10, 000 ☐ 10,000-50,000 ☐ >50,000 ☐
Q13	Family set up	Monogamous ☐ Polygamous ☐ Single parenthood ☐

		Separated parents ☐

Q14	What is the nature of the school you attend?	☐ Public ☐ Private
Q15	What Class or Grade are you?	
Q16	When is your School start time?	Hours Minutes
Q17	When is your home departure time?	Hours Minutes
Q18	What is the estimated distance from your home to school?	
Q19	What is your approximate Home-to-School commuting time?	Hours: Minutes
Q20	What is your mode of transportation to and from school?	
Q21	What is the usual time when you close from School?	Hours Minutes

C. CARDIOMETABOLIC RISK FACTORS		
Q22	Anthropometry	☐ a. Weight_____________ ☐ **b.** Height_________
Q23	BMI_[calculated by RedCap]	☐
Q24	Waist circumference_ (cm)	☐ __________
Q25	Neck circumference_ (cm)	☐ __________
Q26	Blood pressure (mmHg)	☐ __________
Q27	Random blood sugar (mmol/L)	☐ __________

Q28 PHYSICAL ACTIVITY QUESTIONNAIRE FOR ADOLESCENTS

We are trying to find out about your level of physical activity from ***the last 7 days*** (in the last week). This includes sports or dance that make you sweat or make your legs feel tired, or games that make you breathe hard, like tag, skipping, running, climbing, and others.

		No	**1-2**	**3-4**	**5-6**	**7 or more**
	Physical activity in your spare time: Have you done any of the following activities in the past7 days (last week)? If yes, how many times? (Mark only one circle per					

	row.)					
Q29	Skipping	☐	☐	☐	☐	☐
Q30	Rowing/canoeing	☐	☐	☐	☐	☐
Q31	In-line skating	☐	☐	☐	☐	☐
Q32	Tag	☐	☐	☐	☐	☐
Q33	Walking for exercise	☐	☐	☐	☐	☐
Q34	Bicycling	☐	☐	☐	☐	☐
Q35	Jogging or running	☐	☐	☐	☐	☐
Q36	Aerobics	☐	☐	☐	☐	☐
Q37	Swimming	☐	☐	☐	☐	☐
Q38	Baseball, softball	☐	☐	☐	☐	☐
Q39	Dance	☐	☐	☐	☐	☐
Q40	Football	☐	☐	☐	☐	☐
Q41	Badminton	☐	☐	☐	☐	☐
Q42	Skateboarding	☐	☐	☐	☐	☐
Q43	Soccer	☐	☐	☐	☐	☐
Q44	Street hockey	☐	☐	☐	☐	☐
Q45	Volleyball	☐	☐	☐	☐	☐
Q46	Floor hockey	☐	☐	☐	☐	☐
Q47	Basketball	☐	☐	☐	☐	☐
Q48	Ice skating	☐	☐	☐	☐	☐
Q49	Cross-country skiing	☐	☐	☐	☐	☐
Q50	Ice hockey/ringette	☐	☐	☐	☐	☐
Q51	Other, Specify: ___________________	☐	☐	☐	☐	☐

D. SLEEP QUESTIONNAIRES

Q52. PITTSBURGH SLEEP OUALITY INDEX (PSQI)

INSTRUCTIONS: The following questions relate to your usual sleep habits during the past month only. Your answers should indicate the most accurate reply for the majority of days and nights in the past month. Please answer all questions.

1. During the past month, when have you usually gone to bed at night?

   USUAL BED TIME ____

2. During the past month, how long (in minutes) has it usually take you to fall asleep each night?

   NUMBER OF MINUTES ____

3. During the past month, when have you usually gotten up in the morning?

   USUAL GETTING UP TIME ____

4. During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spend in bed.)

HOURS OF SLEEP PER NIGHT ____

INSTRUCTIONS: For each of the remaining questions, check the one best response. Please answer all questions.

---

5. During the past month, how often have you had trouble sleeping because you...

	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
(a) cannot get to sleep within 30 minutes				
(b) ..wake up in the middle of the night or early morning				
c) .have to get up to use the bathroom				
(d ..cannot breathe comfortably				
(e) ..cough or snore loudly				
(f) ..feel too cold				
(g) ..feel too hot				
(h) .had bad dreams				
(i) .have pain				
(j) Other reason(s), please describe				

	Very good	Fairly good	Fairly bad	very bad
6. During the past month, how would you rate your sleep quality overall?	___	___		___

	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
7. During the past month, how often have you taken medicine (prescribed or "over the counter") to help you sleep?	___	___	___	___
8. During the past month, how often have you had trouble staying awake while driving, eating meals, or engaging in social activity?		___	___	

	No problem at all	Only a very slight problem	Somewhat of a problem	A very big problem
9. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?	___	___	___	___

	No bed partner or roommate	Partner/ roommate in other room	Partner in same room, but not same bed	Partner in same bed
10. During the past month, how much of a problem has it been for you to keep up enough enthusiasm to get things done?	___	___		

scores

If you have a roommate or bed partner, ask him/her how often in the past month you have had...

	Not during the past month	Less than once a week	Once or twice a week	Three or more times a week
(a) Loud snoring'				
(b) Long pauses between breaths while asleep				
(c) Legs twitching or jerking while you sleep				
(d) Episodes of disorientation or confusion during sleep				
(e) Other restlessness while you sleep; please describe				

Q53. SLEEP APNEA

MODIFIED (TEEN) STOP BANG QUESTIONNAIRE FOR SLEEP APNEA

	QUESTIONS	YES	NO
S	SNORING (Do you SNORE loudly (louder than talking or loud enough to be heard through closed doors).		
T	TIRED (Do you often feel TIRED during the daytime?)		
O	OBSERVED APNEA (Has anyone ever OBSERVED you stop breathing while sleeping?)		
P	BLOOD PRESSURE		
B	BMI (Is the BMI > 95th percentile?)		
A	Academic problems (Do you have learning problems?)		
N	NECK circumference		
G	Male GENDER?		

Q54. DAYTIME SLEEPINESS

EPWORTH SLEEPINESS SCALE FOR CHILDREN & ADOLESCENTS

Over the past month, how likely have you been to fall asleep while doing the things that are described below(activities)? Even if you haven't done some of these things in the past month, try to imagine how they wouldhave affected you.

Use the following scale to circle the number that best describes what has been happening to you duringeach activity over the past month.

0. Would ***never*** fall asleep
1. ***Slight*** chance of falling asleep
2. ***Moderate*** chanceof falling asleep
3. ***High*** chance offalling asleep

Activity	Chance of Falling Asleep			
Sitting and reading	0	1	2	3
Sitting and watching TV or a video	0	1	2	3
Sitting in a classroom at school during the morning	0	1	2	3
Sitting and riding in a car or a bus for about half an hour	0	1	2	3
Lying down to rest or nap in the afternoon	0	1	2	3
Sitting and talking to someone	0	1	2	3
Sitting quietly by yourself after lunch	0	1	2	3
Sitting and eating a meal	0	1	2	3
Total Score:				

Q. 55 WEEKEDAY- WEEKEND VARIABILITY IN BEDTIME AND SLEEP HABITS	**WEEKDAYS**	**WEEKENDS**
1. What time do you turn off the lights to go to sleep?	_____ AM / PM	_____ AM / PM
2. What time do you get out of bed to start the day?	_____ AM / PM	_____ AM / PM
3. How many hours do you think you actually sleep?	_____ HOURS	_____ HOURS
4. How many hours do you spend awake between bedtime and getting up?	_____ HOURS	_____ HOURS
5. Do you often wake up in the middle of the night?	☐ **YES**	☐ **NO**

a) If yes, how often? ☐ Every night ☐ 1 – 2 times per week ☐ 3 or more times per week

b) What awakens you? ____________________

c) What do you do when you are awake? ____________________

APPENDIX 12: SCORING TEMPLATE FOR THE PITTSBURGH SLEEP QUALITY INDEX

The Pittsburgh Sleep Quality Index (PSQI) contains 19 self-rated questions and 5 questions rated by the bed partner or roommate (if one is available). Only self-rated questions are included in the scoring. The 19 self-rated items are combined to form seven "component" scores, each of which has a range of 0-3 points. In all cases, a score of 'O[t] indicates no difficulty, while a score of "3 [11] indicates severe difficulty. The seven component scores are then added to yield one "global" score, with a range of 0-21 points, "0" indicating no difficulty and "21 " indicating severe difficulties in all areas. Scoring proceeds as follows:

Component 1: Subjective sleep quality

Examine question #6, and assign scores as follows:

Response	Component 1 score
"Very good"	0
"Fairly good"	1
'Fairly bad"	2
"Very bad"	3

Component 1 score:________

Component 2: Sleep latency

1. Examine question #2, and assign scores as follows:

Respo\nse	Score
<_ 15 minutes	0
16-30 minutes	1
31-60 minutes	2
> 60 minutes	3

Question #2 score.' ________

2. Examine question #5a, and assign scores as follows:

Response	Score
Not during the past month	0
Less than once a week	1
Once or twice a week	2
Three or more times a week	3

Question score.' ________

3. Add #2 score and #5a score

Sum of and #5a: ________

4. Assign component 2 score as follows:

Sum of #2 and #5a	Component 2 score
0	
1-2	1
3-4	2
5-6	3

Component 2 score:______

Component 3: Sleep duration

Examine question #4, and assign as follows:

Component 3

Response	score
> 7 hours	0
6-7 hours	1
5-6 hours	2
< 5 hours	3

Component 3 score:________

Component 4: Habitual sleep efficiency

1. Write the number of hours slept (question #4) here:________

2. Calculate the number of hours spent in bed:

    Getting up time (question #3): ________Bedtime (question #1): ________

    ____

    Number of hours spent in bed:________

3. Calculate habitual sleep efficiency as follows:

    (Number of hours slept/Number of hours spent in bed) X 100 = Habitual sleep efficiency (^{0}/0)

    (________/________) x 100 = ^{0}/0

4. Assign component 4 score as follows:

Habitual sleep efficiency %	Component 4 score
> 85%	
75-84%	1
65-74%	2
< 65%	3

Component 4 score:________

Component 5: Step disturbances

1 . Examine questions #5b-5j, and assign for each question as follows:

Response	Score
Not during the past month	0
Less than once a week	1
Once or twice a week	2
Three or more times a week	3

5b score: ____________

5c score_____________

5d score._____________

5e score._____________

5f score._____________

5g score:_____________

5h score: ____________

5i score: ____________

5j score: ____________

2. Add the scores for questions #5b-5j: Sum of +5b-5j: ________

3. Assign component 5 score as follows:

Sum of #5b-5j	Component 5 score
	0
1-9	1
10-18-4	2
19-27	3

Component 5 score:________

Component 6: Use of sleeping medication

Examine question #7 and assign scores as follows:

Response	Component 6 score
Not during the past month	0
Less than once a week	1
Once or twice a week	2
Three or more times a week	3

Component 6 score:________

Component 7: Daytime dysfunction

Examine question #8, and assign as follows:

Response	Score
Never	0
Once or twice	1
Once or twice each week	2
Three or more times each week	3

Question #8 score: ________

1. Examine question #9, and assign scores as follows:

Response	Score
No problem at all	
Only a very slight problem	1
Somewhat of a problem	2
A very big problem	3

Question #9 score. ________

2. Add the scores for question #8 and #9:

Sum of #8 and #9: ________

3. Assign component 7 score as follows:

Sum of #8 and #9	Component 7 score
1-2	1
3-4	2
5-6	3

Component 7 score:________

Global PSQI Score

Add the seven component scores together:

Global PSOI Score:

APPENDIX 13: SLEEP DIARY

DATE	BED TIME	TIME TO FALL ASLEEP(MINUTES)	TIME OF NIGHT AWAKENINGS		NUMBER OF AWAKENINGS	FINAL AWAKENING	NAPS (Afternoon Sleep)		Number of hours of electronic device (screen) use on that day	Time of last screen use	Type of screen use (phone/smartphone/TV/Computer/Play-station etc)
			TIME	LENGTH			TIME	LENGTH			
(eg:01/20/2010)	10:00pm	10 mins	3:45 am	15 mins		6:00 am	4:00 pm	1 hour			

APPENDIX 14: STANDARD OPERATING PROCEDURE FOR ACTIGRAPHY DATA COLLECTION AND SCORING

Importing Sleep Diaries

- Enter sleep diary as a text file (The correct text file format can be obtained by exporting a sample text file from the ActStudio software to do this, go to the Data section, then Sleep Diary, then select 'Export' to get the sample text file). Use the sample text file obtained to enter sleep diary data for each study participant.
- NB: Always check your text file to ensure that the sleep diary entries are in the right format. Bedtimes after midnight on the sleep diary should be entered as the next day in the text file, e.g. 00:30:00 instead of 24:30:00. Always check again to ensure that the dates are correct on the text file.
- To import the sleep diary to your data, go to the Data section, then Sleep Diary, then select 'Import'. Select the corresponding sleep diary text file for each respondent. Once, sleep diary import is successful, the sleep diary marker (grey dotted lines) is seen on the Actigraphy plots

Marking sleep periods

- See Figure 1 below for the algorithm for determining rest intervals (bedtime and get up time) using the actigraphy modified from the criteria/algorithm by Chow et al (2016). In the absence of event marker, use the light vs activity as shown on the Figure below.
- Go to 'Analysis' and select 'Sleep scoring'. Use your mouse to hover over the actogram at the position you decide to indicate as bedtime. Click the right mouse button and a dialogue box with a menu will appear. On this menu select Insert, and another menu will appear with two options; Event and Sleep Diary Mark. Select the sleep diary mark and a line should appear at the position you have clicked.
- Repeat the above process with wake-up time.
- To remove the sleep diary marks individually or all at the same time place your mouse pointer on the particular sleep diary mark and click the right mouse button and the dialogue

box with a menu will appear. Select Remove, another menu will appear with three options; Event, Sleep Diary Mark, and All Sleep Diary Marks. Select the appropriate option.

- Once you have inserted all the desired sleep dairy marks click the Generate button at the top of the screen. (Make sure that under Settings, Parameters Selection – you have indicated that you wish to generate Bedtime / Get-up time parameters using Sleep Diary.
- You can save this NEW LOG by going to the Data tab on the main menu.

NB: If you should reinsert the new log into the software, you will have to re-import the sleep diary. However, if you click generate afterwards, it says: "The sleep scoring was loaded with the log file. Do you wish to recalculate the sleep scoring? Select "Yes" or "No" as appropriate.

- Sleep periods: In the sleep periods section, you can select the study dates you want to include by clicking 'use Sleep Diary to delimit Bed Time and Get Up Time, and unselect days you do not want to include.

Statistics

- Next to the sleep scoring tab is the statistics tab which has two tables.
- The first table shows the summary statistics for the entire period recorded, maximum,
- The second table shows sleep variables for each day over the recorded period for the same individual.
- To refresh the information in this page just click the **Calculate Statistics** button in the main Menu.
- To export the data to a CSV file place the mouse pointer in the top left corner of either of the statistics tables and click the right mouse button. For the Summary statistics table, right click on any cell and it gives the option to export. Then export and save the table as a CSV file. For the Statistics (Daily Summary), once you right click on any cell, two options will appear: to either export as text file or image. Select the option to export as a text file and it gives you the table as a CSV file
- Thereafter, change the time variables (bedtime, get up time, time in bed, sleep onset latency and WASO to decimal time on excel and save with participant ID.

Circadian Data Scoring

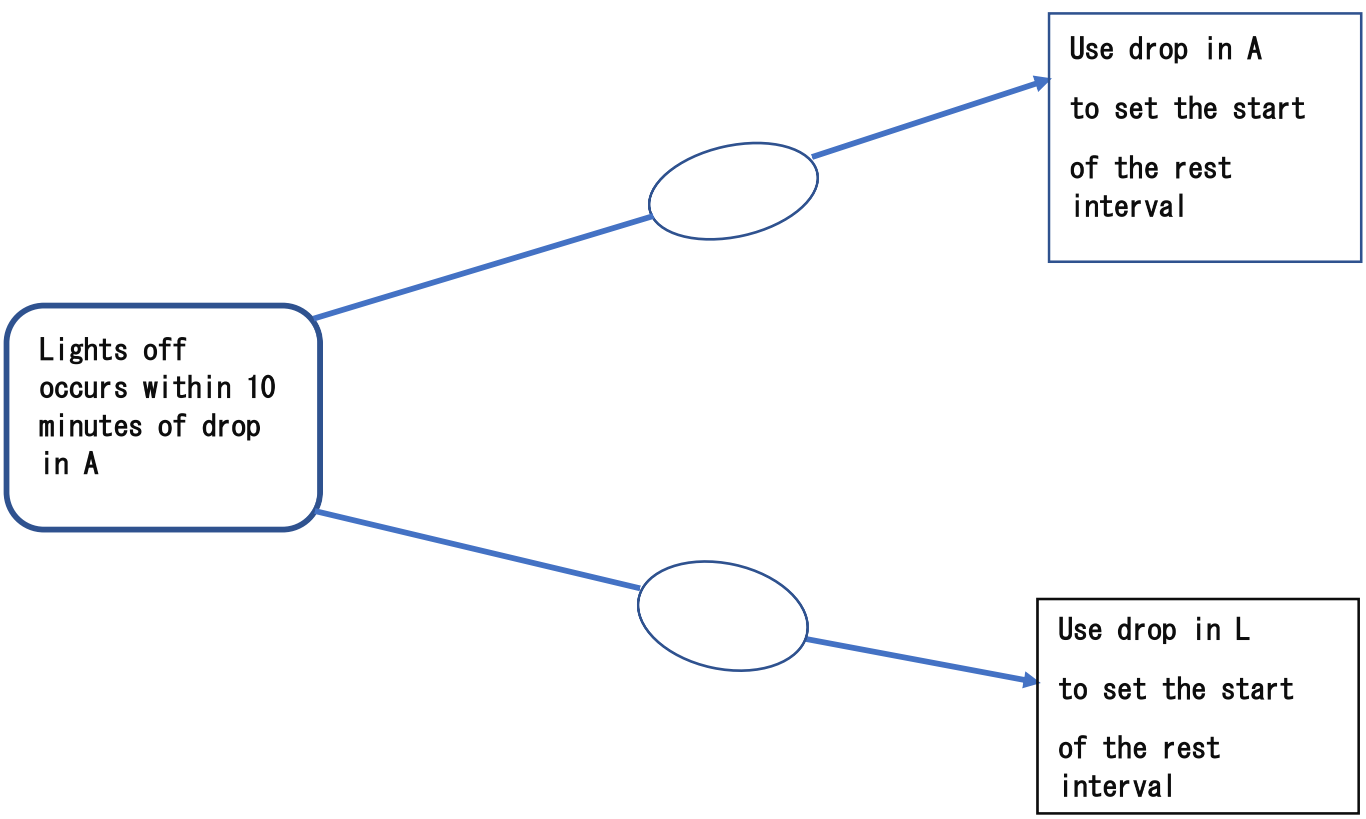
- To score and generate report for other circadian phase related data, select each of the options under analysis and select if you will be using the entire study period or selected days.
- Thereafter, generate and save report.
- You can also save again this NEW LOG by going to the Data tab on the main menu.
- You can also export, and save on your computer, the new sleep diary so that you can insert the corrected sleep diary to generate the same result if the need arises.

Sleep Data Scoring:

a. Bedtime criteria

• A pronounced decrease in activity based on visual inspection of the actogram; no specific threshold used

• Drop in light level (L) to 0 µW/cm2



b. Rise time criteria

• Rise in activity level (A)

• Rise in the light level (L) .1.0 µW/cm2