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Original Article

Original Article

Characterizing sleep–wake patterns in mothers and children in an agrarian community: results from the Ghana Randomized Air Pollution and Health Study

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Abstract

Study Objectives: Several studies have examined sleep patterns in rural/indigenous communities, however little is known about sleep characteristics in women of reproductive age, and children within these populations. We investigate sleep–wake patterns in mothers and children (ages 3–5 years) leveraging data from the Ghana Randomized Air Pollution and Health Study (GRAPHS).

Methods: The GRAPHS cohort comprises of rural/agrarian communities in Ghana and collected multiday actigraphy in a subset of women and children to assess objective sleep–wake patterns. Data were scored using the Cole–Kripke and Sadeh algorithms for mothers/children. We report descriptive, baseline characteristics and objective sleep measures, compared by access to electricity/poverty status.

Results: We analyzed data for 58 mothers (mean age 33 ± 6.6) and 64 children (mean age 4 ± 0.4). For mothers, mean bedtime was 9:40 pm ± 56 min, risetime 5:46 am ± 40 min, and total sleep time (TST) was 6.3 h ± 46 min. For children, median bedtime was 8:07 pm (interquartile range [IQR]: 7:50,8:43), risetime 6:09 am (IQR: 5:50,6:37), and mean 24-h TST 10.44 h ± 78 min. Children with access to electricity had a reduced TST compared to those without electricity ($p = 0.02$). Mean bedtime was later for both mothers ($p = 0.05$) and children ($p = 0.08$) classified as poor.

Conclusions: Mothers in our cohort demonstrated a shorter TST, and earlier bed/risetimes compared to adults in postindustrialized nations. In contrast, children had a higher TST compared to children in postindustrialized nations, also with earlier sleep-onset and offset times. Investigating objective sleep–wake patterns in rural/indigenous communities can highlight important differences in sleep health related to sex, race/ethnicity, and socioeconomic status, and help estimate the impact of industrialization on sleep in developed countries.

Statement of Significance

Our study is the first to measure objective sleep–wake patterns in mothers and children from a rural agrarian community in Ghana. Consistent with prior studies, mothers in our cohort demonstrate a shorter sleep time, and earlier bedtime/risetime compared to adults in postindustrialized nations. In contrast, sleep time in children met AASM recommendations, and was higher compared to children of this age group in postindustrialized nations, with earlier sleep-onset/offset times. However, children with access to electricity demonstrated a reduced sleep time compared to those without electricity. Investigating objective sleep–wake patterns in mothers and children within rural communities can highlight important differences in sleep health related to sex, race/ethnicity, and socioeconomic status, and help estimate the potential impact of industrialization on sleep in developed countries.

Key words: actigraphy; sleep; children; women; indigenous; rural; agrarian; Ghana; Africa

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Introduction

The American Academy of Sleep Medicine (AASM) and Sleep Research Society (SRS) recommend an average of 7–8 h of sleep per night to promote optimal health for adults [1, 2], and anywhere from 9 to 14 h of sleep in children between the ages of 1–12 (depending on the age group) [3]. Despite this, the Center for Disease Control (CDC) reports that 35% of the general population—an estimated 86.3 million U.S. adults—sleep less than 7 h in a 24-h period [4]. Moreover, it is estimated that 25%–50% of children do not meet the recommended guidelines for pediatric sleep by age group [5]. Particularly for ages 3–5 years, AASM recommends 10–13 h of sleep per (including naps), however a recent meta-analysis reported a significantly lower mean sleep time (8.64 h) for this group [6]. The widespread use of electricity in industrialized countries enables work, recreation, and wakefulness around the clock, leading to sleep disruption [7], and potential adverse health outcomes in both children and adults [3, 8].

One way to estimate the impact of industrialization on sleep is to study sleep in indigenous agrarian communities with limited access to electricity. Several studies have used wrist-worn actigraphs or accelerometers to examine sleep patterns in indigenous hunter–gatherer and agricultural communities, demonstrating that individuals with access to electricity had later bedtimes, delayed sleep onset as compared to participants relying exclusively on natural light [7, 9]. However, despite delays in sleep timing, a recent study showed no difference in sleep duration between neighboring urban and rural communities [10]. Moreover, in comparison to objective sleep data gathered from postindustrialized countries [11, 12], habitual sleep duration among several rural/indigenous populations has been observed to be unexpectedly shorter [13–16].

While several studies have examined sleep patterns in rural/indigenous communities, little is known about sleep characteristics in women of reproductive age, and children within these populations. This is important because in addition to environmental and cultural differences, biological and physiological age and sex are also key factors influencing alterations in sleep–wake patterns within a population. Moreover, sleep patterns of children residing in the household can also influence sleep characteristics in females who are often their primary caretakers. In 2014, the Society for Women's Health Research convened a group of interdisciplinary experts to acknowledge gaps related to sex/gender differences in sleep health, and recognize areas for future research to better understand sleep in women [17]. This includes examining sex and gender differences to better understand hormonal effects on sleep, and analyze sleep patterns of various ethnic, racial, and socioeconomic groups. Therefore, studying objective sleep characteristics in women and children within specific age groups among indigenous communities can allow us to estimate the impact of industrialization on sleep in both women and children in postindustrialized, developed countries.

To further investigate the impact of lifestyle—defined as an aggregate of factors including occupation, household characteristics/living quarters, and socioeconomic status (as previously described) [18]—on sleep in women and children within indigenous communities, we utilized data available from a rural, agrarian community in Ghana, via the Ghana Randomized Air Pollution and Health Study (GRAPHS) cohort. The GRAPHS study collected multiday actigraphy data in a subset of mothers and children within the cohort. We describe objective sleep–wake patterns in the GRAPHS cohort, which provides a unique opportunity to make these assessments specifically in children (ages 3–5 years), and women in the reproductive age group. The study population also provides notable advantages, including homogeneity of ethnicity, sex, lifestyle, as well as age of the study participants, permitting objective sleep assessments in a truly unique population subset.

Methods

GRAPHS cohort

The GRAPHS cohort is cluster-randomized trial evaluating the efficacy of clean fuels in the forest-savannah transition zone in Central Ghana [19]. It builds on an established collaboration between Columbia University and Mount Sinai in New York City, and the Kintampo Health Research Center (KHRC) in Ghana. The study initially enrolled 1414 pregnant women between August 2013 and March 2016, from communities in the Kintampo North Municipality and Kintampo South District of Ghana prior to 24 weeks gestation, to investigate the effect of clean biomass cook stoves on birth weight and pneumonia incidence in the mother–infant dyads followed through the first year of life [20]. In July 2017, additional funding was obtained for further phenotyping of mothers and children, beginning at child ages 3–4 years. Multiday actigraphy data were collected in mothers and children along with an air pollution assessment in a subset of participants. This assessment was then followed up by a health visit, with anthropometric measurements including body weight, and height collected for both mothers and children, lung function testing, biospecimen collection, and questionnaires on the health status of the participants. The analyses presented herein represent a convenience sample of 58 mothers and 64 children, including 36 mother–child pairs, with actigraphy data collected between October 2018 and July 2019. Informed written consent was obtained from all mothers, and all procedures were approved by the Institutional Review Board of Icahn School of Medicine Mount Sinai (17-01265), Columbia University (AAAR4373), and the Ghana Internal Review Board (0004854).

Living quarters, sleep environment, and occupation

Living quarters

The study area comprised of rural communities in the forest-savannah transition zone in Central Ghana. Participants resided in single unit or communal homes (Figure 1, A–C), with multiple adults and children residing per household. Traditional homes were either constructed with cement floors/walls and metal roofs, or mud/clay. Nearly all households also had enclosed or covered kitchen areas for wet season cooking, though outdoor cooking was prevalent during the dry season [19]. Electricity connections were available to many of the households, although access to electricity depended largely on the ability of the family units to pay for power on a monthly basis.

Sleep environment

Sleeping spaces were shared by immediate family (i.e. parents and children), and sometimes with extended family as well. Sleeping arrangements were variable, some consisting of beds with a mattress (Figure 1D), while others consisting of blankets

Figure 1. Living quarters. Picture A shows a communal home. Pictures B and C show free standing homes and an outdoor cooking area. Picture D shows a mattress.

and woven floor mats. Co-sleeping was common, where participants shared sleeping quarters with multiple children or adults. Sleeping arrangements were also flexible (and could change readily)—though typically parents would sleep on the mattress with younger children while older children and other members of the family may sleep on a floor mat.

Occupation

Farming was the main occupation of the residents, and farming was the primary daily activity for majority of the women in the study. GRAPHS women were also the primary cooks for their households [21]. Women often carried their children to farm. At home children typically played in the neighborhood or within their households. Older siblings helped their parents take care of younger children.

Data collection

At the time of GRAPHS enrollment and following the woman's first prenatal visit to the study clinic, questionnaires were administered by trained local interviewers conducted in the indigenous language to assess respiratory symptoms along with living quarters/household characteristics, socioeconomic status, education level, and kitchen/cooking characteristics [22]. A household asset index was constructed as a proxy for socioeconomic status to calculate the wealth index (a categorical measure), using household characteristics enumerated as counts (e.g. materials of walls and floor, ownership of household durables such as tables, mattresses, radios, phones and TV, household's primary source of drinking water and toilet facility, etc.) [23]. A higher score indicated a higher relative household socioeconomic status.

Actigraphy data collection and analysis

Participating mothers and children were provided with a wrist actigraphy/accelerometer (MicroMotionlogger; Ambulatory Monitoring Inc [AMI], Ardsley, NY) and were instructed to wear the actigraph for 5–7 days collected between October 2018 to July 2019. Participants were instructed to wear their actigraphs on the nondominant hand during all waking hours which overlapped with sleep monitoring. Data were downloaded from the device using *Watchware Version 1.99.5.1*, and analyzed using *Action4 software, Version 1.1*. The software uses movement to score behavioral state as wake vs. sleep. Subjects were anonymized and each actogram was visually inspected and manually scored for sleep during analysis (Figure 2). Data were generated in 60-s epochs for adults and scored using the Cole–Kripke algorithm [24–26]. For children, data were also generated in 60-s epochs, and scored using the Sadeh algorithm [27, 28]. We define nighttime awakenings as activity above threshold (50 crossings above the zero-crossing mode [ZCM]) for at least 1 min. A nap constituted a minimum of a 15-min period of inactivity. Occasional periods of inactivity with invariant or no light level where the watch was off were evident in some records. If >4 h were excluded, then activity and light counts for that entire 24 h recorded day were excluded. In such cases, sleep onset and wake events were analyzed for those days that were available.

Variables and measurements

Demographic data including age, sex, height, weight, body mass index, ethnicity, education, and socioeconomic status, as well as data on home characteristics, living quarters, and sleep environment were collected. Actigraphic sleep measures included bedtime, sleep-onset time, wake-onset time, risetime, total time-in-bed (TIB; from bedtime to risetime), total sleep time (TST; from sleep-onset time to wake-onset time excluding all periods of wakefulness), sleep efficiency (percent of actual sleep time from total sleep duration excluding wake time after sleep onset), sleep-onset latency, wake after sleep-onset, and number of nighttime awakenings. TIB, TST, and sleep efficiency were also calculated for naps. TST was further divided into active and quiet sleep for the children based on the Sadeh algorithm.

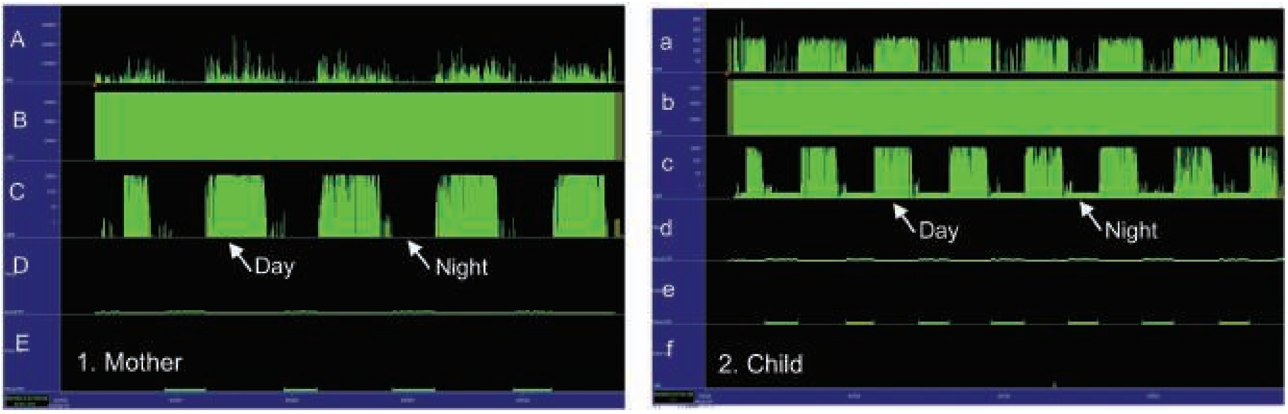

Figure 2. 1. Mother (4 nights and 4 days): A: proportional integration mode (PIM), B: life channel, C: light channel, D: AutoPIM, E: manual TIB (time-in-bed). 2. Child (7 nights and 7 days): a: Actigraph channels and examples of manual scoring of actigraphy in mothers and children: Zero-crossing mode (ZCM), b: life channel, c: light channel, d: AutoZCM, e: manual TIB, f: naps.

Statistical analysis

SAS version 9.4 was used for data analysis. Statistical significance was defined by $p < 0.05$ for all tests. Baseline characteristics and outcome measures (sleep characteristics) were reported using descriptive statistics. Outcomes of interest were compared based on electricity connection, poverty status, and education status using *t*-tests or Wilcoxon ranked sum tests as appropriate. Linear regression was used to evaluate the association between age, number of children per household, and sleep outcomes. Night-to-night variability (between night 1 and night 2) for (continuous) sleep measures was analyzed using intraclass correlation coefficients (ICCs) and Bland–Altman plots, as well as Pearson correlation.

Results

Baseline characteristics

We analyzed data from 58 mothers and 64 children, for a total sample size of 122 participants. Of this sample, 36 were mother–child pairs. Baseline characteristics are shown in Table 1. Mean age of mothers was 33 years (range 22–48), and mean age of children was 4 years (range 3–4). Of the mothers, 34 (59%) were married, and approximately half classified as poor (31, 53%) based on the poverty index. An electric connection was available for 35%–40% of the households. Majority of the subjects lived in freestanding homes (~70%). A median of 10 people (5 adults and 5 children) occupied a household, with approximately 4 rooms and 1 mattress per house.

Table 1. Baseline characteristics

	Mother (58)	Child (64)
Anthropometrics (mean, *SD*)		
Age	32.6 (6.6)	4 (0.4)
Age range	22–48	3–5
Female (%)	58 (100%)	38 (59%)
Height (m)	1.60 (0.05)	0.98 (0.05)
Weight (kg)	62.0 (10.6)	14.4 (2.03)
BMI (kg/m^2)	24.3 (4.4)	15.1 (1.5)
Demographics (*n*, %)		
Married	34 (59%)	N/a
Education—primary school or higher	33 (57%)	N/a
Smoking	9 (16%)	N/a
Poverty*	31 (53%)	41 (64%)
Living environment (median, IQR)		
People in household	10.0 (6, 12)	10.1 (6, 13.5)
Adults in household	5.0 (3, 6)	4.0 (2, 6.5)
Children in household	5.0 (4, 7)	5.0 (3, 7.5)
Rooms in household	4.0 (3, 6)	4.0 (2, 6)
Mattresses in household	1.0 (1, 2)	1.0 (1,2)
Home characteristics (*n*, %)		
Electricity connection	23 (40%)	22 (34%)
Freestanding house	39 (67%)	46 (72%)
Cement floor	57 (98%)	61 (95%)
Mud/clay floor	1 (2%)	3 (5%)
Metal roof	47 (81%)	49 (77%)
Mud/clay roof	11 (19%)	15 (23%)
Cement walls	47 (81%)	46 (72%)
Mud/clay walls	11 (19%)	18 (28%)

BMI, body mass index; *SD*, standard deviation.
*Poverty is defined based on a calculated wealth/household asset index, constructed as a proxy for socioeconomic status, using housing characteristics (materials of walls and floor), ownership of household durables (e.g. tables, mattresses, radios, phones, and TV), and household's primary source type of drinking water and toilet facility.

Objective sleep characteristics and actigraphy data

Table 2 reports outcome measures for both mothers and children. An example of mother/child actigraphy data is shown in Figure 3. Majority of the outcome variables were approximately normally distributed. A median of 3.5 and 3 nights (interquartile range [IQR] 2.6; 2.5) nights were recorded for mothers and children. For mothers, average bedtime was 9:40 pm (±56 min), and risetime was 5:46 am (±40 min). Mean TIB was 7.9 h (±60 min), TST was 6.3 h (±46 min), and sleep efficiency was 80.4%. For children, median bedtime was 8:07 pm (IQR 7:50, 8:43), and risetime was 6:09 am (IQR 5:50, 6:37). Mean TIB was 9.8 h (±62 min), TST was 9.4 h (±62 min), and median sleep efficiency was 97.5%. Majority of the children took daytime naps, with a mean nap TST of 56 ± 30 min. Mean 24-h TST for children was 10.44 h (±78 min).

Table 3 reports the associations between age, number of children per household, and various sleep outcome measures (in minutes) in mothers. There was an inverse and statistically significant association between age, TIB (Beta ± *SD* = −2.86 ± 1.14 min [confidence interval, CI −5.2, −0.58], $p = 0.02$), and risetime (Beta ± *SD* = −1.8 ± 0.84 min [CI −3.6, −0.3],

Table 2. Objective sleep measures/characteristics

Actigraphy	Mother (n = 58)	Child (n = 64)
Number of nights	*3.5 (2.6)	*3 (2.5)
Bedtime	9:40 pm (0:56 min)	*8:07 pm (7:50, 8:43)
Sleep onset	9:48 pm (0:56 min)	*8:08 pm (7:52, 8:43)
Wake time	5:43 am (0:40 min)	*6:09 am (5:49, 6:37)
Risetime	5:46 am (0:40 min)	*6:09 am (5:50, 6:37)
TIB (h)	7.9 (1.0)	9.8 (1.04)
TST (h)	6.3 (0.77)	9.4 (1.03)
Active sleep (h)	N/a	3.3 (1.0)
Quiet sleep (h)	N/a	6.1 (1.03)
WASO (h)	1.6 (0.7)	0.1 (0.1)
Nocturnal sleep efficiency % (SD)	80.4% (7.7)	*97.5 (95.5, 98.9)
† Number of awakenings	21.6 (7.2)	*2.6 (1.6, 4.5)
24-h TIB (h)	7.9 (1.0)	10.84 (1.15)
24-h TST (h)	6.3 (0.8)	10.44 (1.3)
Naps (n = 60)		
TIB (min)	N/a	58 (31)
TST (min)	N/a	56 (30)
Nap sleep efficiency %	N/a	*99.6%, (96.7, 100)

h, hours; min, minutes; TIB, time-in-bed; TST, total sleep time; WASO, wake after sleep onset.
*Median, IQR; all other findings reported as mean (standard deviation).
†Nighttime awakenings defined as activity above threshold (50 crossings above the ZCM for at least 1 min).

p = 0.02). Additionally, there was an inverse and statistically significant association between number of children per household and TIB (Beta ± SD = −4.97 ± 2.32 min [CI −9.6, −0.32], p = 0.04), and a positive association between number of children per household and (later) bedtime (Beta ± SD = 4.8 ± 2.2 min [CI 0.18, 9], p = 0.04) in mothers.

Table 4 reports outcome measures by electricity and poverty status. When categorized by electricity status, there was no significant difference in the sleep-related outcome measures in mothers. However, among children, the electricity group had a significantly reduced mean TST (9.0 ± 0.92 vs. 9.63 ± 0.93 h, p = 0.02) and TIB (9.4 ± 0.93 vs. 10.01 ± 1.03 h, p = 0.02) as compared to those without electricity. When categorized by poverty status, there was no significant difference in TST and TIB between the two groups in both mothers and children. However, mean bedtime was later for both mothers (p = 0.05) and children (p = 0.08) classified as poor, with a trend toward significance. There were no significant differences in the outcome measures based on education status (primary school or higher) in mothers (Supplementary Table S1).

We calculated ICC for sleep outcomes (TIB, TST, bedtime, sleep time, wake time, risetime) to understand within-person reliability of night 1 and night 2 measures for both mothers and children (Supplementary Tabled S2 and S3). In mothers, ICC values for sleep outcome measures (night 1 vs. night 2) ranged from 0.4 to 0.6, suggesting moderate reliability, with the highest ICCs observed for risetime and wake time (0.62). All outcomes for night 1 vs. night 2 were significantly correlated (p < 0.05). In children, ICC values for sleep outcome measures (night 1 vs. night 2) ranged from 0.3 to 0.4, suggesting low-to-moderate reliability, with the highest ICCs observed for TIB (0.40) and TST (0.36). Risetime, wake time, TST, and TIB for night 1 vs. night 2 were significantly correlated (p < 0.05).

Discussion

This is the first study to describe objective sleep–wake patterns in a subset of indigenous women *and* children (in early childhood, ages 3–5 years), leveraging the GRAPHS cohort—a rural, agrarian community in Ghana. We found that habitual sleep duration and TST among mothers of this cohort were short on average (6.3 h ± 46 min), similar to other indigenous/rural populations in Africa, including a small scale agricultural community in Madagascar [15], a hunter–gatherer community in Tanzania (the Hadza) [14] and Namibia (the San) [16], as well as an agropastoral society in Namibia (the Himba) [13]. Notably, time to sleep onset and offset were also similar among these communities, and differ from that of postindustrialized countries where sleep duration was typically longer with a later time of sleep onset and offset [11, 12]. In mothers, increasing age was associated with shorter TIB and earlier risetime, while increasing number of children in the household was associated with a shorter TIB and later bedtime.

Additionally, to our knowledge, this study was one of the first to describe objective sleep–wake patterns among children ages 3–4 in a rural, agrarian community. Among children, those with access to electricity demonstrated a significantly reduced TST and TIB compared to those without electricity. We also illustrate that in contrast to the adults, 24-h TST among children in this cohort was consistent with the AASM recommendations of 10–13 h of sleep for children age 3–5 [3, 29], more specifically among children *without* access to electricity. This is higher compared to the normative values for TST among children ages 3–5 in postindustrialized nations, who also demonstrate later sleep-onset and offset times compared to children in our cohort [6, 30].

The postindustrial sleep degradation hypothesis [15] suggests that lack of access to electricity and other artificial light sources (electronics) will result in increased sleep duration as compared to Western societies. However, while prior studies have established that adults with access to electricity in rural or hunter–gatherer communities demonstrated later bedtimes, and delayed sleep onset as compared to participants relying exclusively on natural light, data on sleep duration is conflicting. Some studies reported a reduced sleep duration (in adults) with access to electricity (in comparison to those relying on natural light) [7, 9] while others did not [10]. Moreover, many studies have demonstrated that sleep duration was unexpectedly shorter in preindustrialized/rural hunter–gatherer and agricultural communities in Africa [13–16] when compared to objective sleep duration in postindustrialized countries [11, 12]. Our results are consistent with these findings among the mothers in our cohort.

These findings may be partially explained by the sleep intensity hypothesis, which postulates that early humans evolved to have characteristic sleep architecture that fulfilled homeostatic need in the shortest time possible [31]. Thus, a shift to less TST and greater sleep intensity (i.e., deeper, more efficient sleep with a higher rapid-eye movement to nonrapid-eye movement ratio) could have had important implications for early human evolution. This suggests that human sleep is flexible and efficient in meeting the requirements of cognitive demands and day-to-day activity in as short a time as possible, and lifestyle factors (a

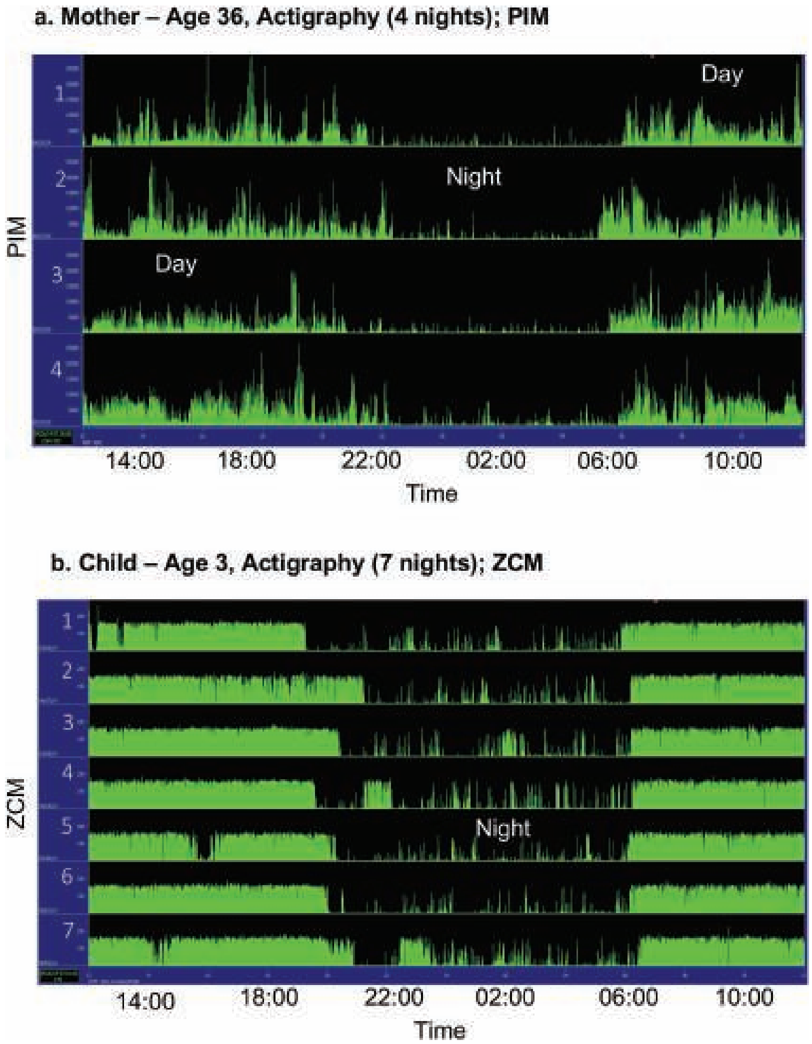

Figure 3. Example of mother/child actigraphy data (scored). (A) Mother (four nights of actigraphy): mean sleep onset: 9:51 pm, mean sleep offset: 5:36 am, mean TIB: 7 h, 45 min, mean TST: 4 h, 55 min, mean WASO: 2 h, 51 min. (B) Child (seven nights of actigraphy): mean sleep onset: 8:15 pm, mean sleep offset: 6:08 am, mean TIB: 9 h, 55 min, mean TST: 9 h, 06 min, mean WASO: 50 min, naps: 1, TST 26 min. PIM, proportional integration mode; TIB, time-in-bed; TST, total sleep time; WASO, wake after sleep onset; ZCM, zero-crossing mode.

Table 3. Linear regression—sleep outcomes vs. (1) age and (2) children per household (in mothers)

Outcomes	Beta estimate (*SD*)	CIs	*p*
Continuous (minutes per 1 year increase in age)			
TST	−1.72 (0.91)	−3.5, 0.09	0.06
TIB	−2.86 (1.14)	−5.2, −0.58	**0.02**
Bedtime	0.9 (1.2)	−1.8, 3.6	0.46
Risetime	−1.8 (0.84)	−3.6, −0.3	**0.02**
Continuous (minutes per 1 child increase in household)			
TST	−1.80 (1.86)	−5.5, 1.9	0.34
TIB	−4.97 (2.32)	−9.6, −0.32	**0.04**
Bedtime	4.8 (2.2)	0.18, 9	**0.04**
Risetime	−0.7 (1.8)	−4.2, 2.4	0.70

SD, standard deviation; TIB, time-in-bed; TST, total sleep time.
p-values in bold denote statistical significance (alpha ≤.05).

reflection of socioeconomic status among other things) may be an important determinant of habitual sleep duration [14]. This theory may explain why overall sleep duration appears to be shorter in rural/indigenous adult populations, while sleep may be potentially more consolidated, with lower nightly variability as compared to postindustrialized nations [14, 15].

Our study was unique in several domains. First, the cohort provides homogeneity of sex, age, and lifestyle factors (occupation/living arrangements/socioeconomic status), permitting objective sleep assessments in a truly unique subset of a population. Sleep was characterized specifically in women of reproductive age, where a majority of the women were in their 30 s. Investigating objective sleep patterns in this age group is important, because normal sleep is impacted by hormonal changes during key timepoints in a woman's life (menses during reproductive ages, pregnancy/lactation, and postpartum) [17, 32]. This can lead to age-specific sleep health disturbances, as well as changes in sleep quality and duration in unique ways [32]. In our cohort of mothers, increasing age was associated with shorter TIB and earlier risetime, while increasing number of children in the household was associated with a shorter TIB and later bedtime.

For mothers, average bedtime was 9:40 pm and risetime was 5:46 am, with a mean TST of 6.3 h. When comparing these results to studies from postindustrialized nations, it is important

Table 4. Sleep outcomes by electricity access and poverty status

Electricity access						
	Mother			Child		
Mean (*SD*)	Yes (*n* = 23)	No (*n* = 35)	*p*	Yes (22)	No (41)	*p*
TST	6.37h (0.74)	6.27h (0.80)	0.64	9.0h (0.92)	9.63h (1.02)	**0.02**
TIB	7.78h (1.0)	7.98h (0.99)	0.46	9.4h (0.93)	10.01h (1.03)	**0.02**
Bedtime	9:46 pm (62 min)	9:37 (54 min)	0.55	8:26 pm (57 min)	8:14 pm (54 min)	0.42
Risetime	5:43 am (40 min)	5.50 (41 min)	0.53	6:10 am (73 min)	6:19 am (40 min)	0.60
* Poverty status						
	Mother			Child		
Mean (*SD*)	Yes (*n* = 31)	No (*n* = 27)	*p*	Yes (41)	No (22)	p
TST	6.16h (0.74)	6.48h (0.78)	0.11	9.43h (1.09)	9.38h (0.93)	0.87
TIB	7.70h (0.93)	8.12h (1.03)	0.11	9.82h (1.13)	9.73h (0.87)	0.74
Bedtime	9:54 pm (62 min)	9:25 pm (48 min)	**0.05**	8:26 pm (64 min)	8:05 pm (29 min)	0.08
Risetime	5:50 am (40 min)	5:43 am (42 min)	0.48	6:26 am (56 min)	6:11 am (50 min)	0.55

SD, standard deviation; TIB, time-in-bed; TST, total sleep time.

p-values in bold denote statistical significance (alpha ≤ .05).

*Poverty is defined based on a calculated wealth/household asset index, constructed as a proxy for socioeconomic status, using housing characteristics (materials of walls and floor), ownership of household durables (e.g. tables, mattresses, radios, phones, and TV), and household's primary source type of drinking water and toilet facility.

to note that while there are several studies describing objective sleep–wake patterns in middle-aged, postmenopausal women in industrialized countries (ages >50), to our knowledge, there is limited data measuring *objective* sleep characteristics in women in their reproductive years [33]. Two studies—one measuring objective sleep (using actigraphy) in 18 pairs of preschool children and their mothers in Japan [34], and another measuring both subjective and objective sleep in a community sample of mothers and young children (ages 3–4 years) in the United States [35] demonstrated a higher mean TST (6.5 and 6.75 h), and later bedtimes (11:14 pm) [35] compared to mothers in our cohort. When comparing to *subjective* sleep duration from a 2007 *Sleep in America* Poll, urban women between the ages of 25–34 approximated an average of 7.5 h in bed on workdays, and 8.7 h on nonworkdays [36], with an average sleep-onset/offset time of 11 pm/6:41 am on workdays and 11:44 pm/8:21 am on nonworkdays. In the same study, urban women between the ages of 35–44 approximated an average of 7.2 h in bed on workdays, and 8.2 h on nonworkdays [36], with an average sleep-onset/offset time of 10:52/6:13 am on workdays and 11:24 pm/7:37 am on nonworkdays. These data suggest a longer overall sleep duration compared to the women in rural Ghana in GRAPHS, with a later sleep-onset and offset time. Studies among industrialized populations have demonstrated that short SD is associated with obesity [37], diabetes [38], subclinical atherosclerosis [39–42], and cardiovascular disease (CVD) [43, 44]. Future analysis in the GRAPHS cohort can investigate surrogate CVD outcomes in relation to sleep duration.

Second, our study is one of the first to characterize *objective* sleep–wake patterns among children ages 3–5 in an indigenous population. Interestingly, sleep duration in children was consistent with the AASM recommendations of 10–13 h of sleep for children in this age group [3, 29]. In contrast, a recent meta-analysis of normative values for nighttime sleep measured using actigraphy among pediatric studies (in industrialized nations) showed that in children between ages 3–5 years, mean TST was 8.6 h, with an average sleep-onset time of 9:31 pm, and an average sleep-offset time of 7:07 am [30]. While this meta-analysis did not account for daytime napping, total sleep duration was lower, with a later time to sleep onset and offset in comparison to children in our cohort (particularly those *without* access to electricity). Delayed sleep timing and shorter sleep duration in postindustrialized countries may be in-part due to the consequences of increased use of electronic devices and screen time exposure resulting in adverse sleep outcomes [45]. Corroborating with this, we found that children with access to electricity within our cohort did in fact demonstrate a significantly reduced TST and TIB compared to those without electricity (potentially due to later bedtimes and earlier wake times—Table 4). The AASM consensus reports that inadequate sleep for children between ages 3 and 5 is found to be associated with several adverse outcomes, including an increased risk of obesity (<12 h) [46], increased emotional and behavioral problems (<10 h) [47], and increased irritability. Inadequate sleep can also affect the development of children's cognition, language, memory, and emotional reactivity [3].

Lastly, for both mothers and children, we found that those classified as "poor" based on the wealth/household asset index tended to have a reduced TST and TIB, and a later bedtime with a trend toward significance—a potential consequence of longer workdays and increased at home and child-care responsibilities. This is consistent with literature that suggests poverty and lower socioeconomic status as social determinants of poor sleep health in both adults and children [48, 49].

Limitations

Our study has several limitations. First, we did not have subjective sleep logs for the study participants to validate measure of objective sleep. However, given that several participants had limited access to electricity in this subset, actigraphic measures for sleep onset and offset appeared to coincide with sunset and sunrise, potentially given the lack of modern-day interferences (i.e. electronics). Therefore, despite lack of subjective sleep measures, the results are likely to be reliable. Second, some of the participants only had 2–3 nights of data measured. However, given the daily consistency in sleep-onset/offset timing, these measures are likely to represent habitual sleep duration over a longer period. Third, we defined nighttime awakenings as activity above threshold (50 crossings above ZCM) for at least 1 min (as opposed to 5 min as previously reported in some studies) [50]. This may have resulted in overestimation of nighttime awakenings among our cohort participants. However, a higher-than-normal number of awakenings may be somewhat reasonable for this population given mother–child co-sleeping, and multiple family members sleeping in one room within each housing unit. Moreover, bed-sharing (especially among children) may potentially result in more movement-related artifacts, and impact the validity of actigraphy assessment [51]. However, since we analyzed sleep using an actigraph wristwatch, securely fastened to each participant's wrist—we feel such artifacts may be less likely.

Fourth, our sample size from the cohort was small, and a larger sample size would have allowed for further analysis into the associations between objective sleep, air pollution measures, and various health outcomes. Moreover, sleep in both adults and children is often influenced by several factors, including individual (genetics, age, health, behavior, etc.), social (race/ethnicity, socioeconomics, occupation), and societal (technology, environment, public policy) level factors, embedded within each other [52, 53]. As such, multidimensional modeling incorporating socioeconomical factors is necessary to comprehensively assess the impact of socioeconomic status on health outcomes and objective sleep measures, and should be evaluated in future, larger studies evaluating objective sleep outcomes in low-income countries/indigenous populations. Additionally, lifestyle and diverse occupations within a population may have varying impacts on sleep, yielding different results when evaluating objective sleep outcomes. However, the GRAPHS cohort is primarily agrarian, and therefore variations between occupational classes cannot be assessed using available data, but should certainly be investigated in future research. Despite these limitations, our sample size was larger than most studies conducted in indigenous rural populations, including an agricultural community in Madagascar (n = 21) [15], the Hadza in Tanzania (n = 33) [14, 54], the Vanuatu on Tanna Island (an indigenous Melanesian Population n = 91) [18], and the Himba in Namibia (n = 75). One study (n = 110) evaluated patterns of daily activity and TIB among adult women and adolescent girls from a rural community in Senegal, however they utilized hip accelerometry for measurement of activity and estimation of TIB [55].

Fifth, the cohort is homogeneous in regard to age, sex, and occupation—however differences in these variables often drive changes in objective sleep measures such as sleep duration. Therefore, this study population is uniquely positioned in allowing us to investigate sleep among a specific sex and age group, allowing for meaningful comparisons with women and children of this age group in postindustrialized nations. We also did not have data on whether the women participating in the study were breastfeeding or pregnant, which would likely effect the results of the data collected, given that sleep is impacted by hormonal changes during key timepoints (i.e., pregnancy, lactation, postpartum) in a women's life [17, 32]. Lastly, while some of the participants of the GRAPHS cohort reported having access to electricity, whether electricity was used in the household largely depended on the ability of the family units to pay for power on a monthly basis. Therefore, it was difficult to categorize those that truly used electricity in their homes and ascertain its effects on sleep–wake patterns.

Despite these limitations, the current study is one of the first to assess objective sleep–wake patterns using actigraphy in a well-characterized cohort of mothers and children in a developing country in West Africa. While several studies have evaluated objective sleep patterns in various indigenous populations across the globe, none (to our knowledge) have focused on investigating these measures in a population of females of child-bearing age, and children between the ages of 3 and 5 years. There are limited studies evaluating sleep in women between the ages of 30–60 [33]—even in postindustrialized nations [34, 35, 56, 57]. Therefore, this unique cohort provides important, hypothesis-generating data highlighting important gaps related to sex, race/ethnicity, and socioeconomic differences in sleep health for future research—an area prioritized for research by the Society for Women's Health Research [17]. Moreover, it may allow us to estimate the impact of industrialization on sleep in both women and children in postindustrialized, developed countries.

Conclusion

In conclusion, our study is the first of its kind to measure objective sleep–wake patterns in mothers and children leveraging the GRAPHS cohort, a rural agrarian community in Ghana. Our results suggest a habitually shorter sleep duration, and earlier bedtime and risetime among the mothers in the cohort as compared to adults in postindustrialized nations, consistent with prior studies conducted in rural/indigenous populations. Moreover, we share novel findings of objective sleep–wake patterns among children in this cohort. In contrast to adults, sleep duration among children was consistent with the AASM recommendations for this age group, and higher compared to the normative values for TST among children in postindustrialized nations, with earlier sleep-onset and offset times. However, children with access to electricity demonstrated a significantly reduced TST and TIB compared to those without electricity. Future analysis using a larger sample size of women and children within the GRAPHS cohort should investigate the effect of various exposures (i.e., indoor air pollution) on objective sleep wake patterns and circadian alignment to natural light collected using actigraphy.

Supplementary Material

Supplementary material is available at *SLEEP* online.

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