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Infant co-sleeping patterns and maternal sleep quality among Hadza hunter-gatherers[☆]

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ABSTRACT

Objective: Despite widespread interest in maternal–infant co-sleeping, few quantified data on sleep patterns outside of the cultural west exist. Here, we provide the first report on co-sleeping behavior and maternal sleep quality among habitually co-sleeping hunter-gatherers.

Design: Data were collected among the Hadza of Tanzania who live in domiciles constructed of grass huts with no access to synthetic lighting or climate controlled sleeping environments. Using interview data, we recorded baseline ethnographic data on co-sleeping. Using actigraph data, we tested whether sleep quality, sleep–wake activity, and/or sleep duration differs among breastfeeding women, non-breastfeeding women, and men.

Measurements: CamNtech Motionwatch 8 actigraphs were used to collect 1 minute, epoch-by-epoch data on a sample of 33 adults. Functional linear modeling (FLM) was used to characterize sleep–wake patterns and a linear mixed-effects model was used to assess factors that drive sleep duration and quality.

Results: The FLM suggests that breastfeeding mothers were early risers and had reduced day-time activity. Additionally, total number of co-sleepers, not breastfeeding, was associated with less sleep duration and quality, suggesting that greater number of co-sleepers may be a primary driver of poorer sleep.

Conclusion: The current study makes important contributions to the cross-cultural literature on sleep and augments our understanding of maternal–infant co-sleeping. The majority of Hadza participants co-sleep with at least one other individual and the majority of married couples sleep with their spouse and their children on the same sleeping surface. Our preliminary sleep quality data suggest that breastfeeding does not negatively impact maternal sleep quality.

Introduction

Mother-infant bed sharing practices, also generally known as "co-sleeping", describe sleeping behaviors where both individuals share a bed, share a room, or are within close physical proximity to one another[1,2] Here, we use the terms "co-sleeping" and "bed sharing" interchangeably to refer to infants and adult caregivers sleeping in close proximity to one another on the same sleeping surface. Research on the topic of co-sleeping, which is one of the most controversial topics in parenting research[3] has gained momentum over the past 30 years in scientific inquiry, medical policy, and in the popular media. Despite the interest in maternal–infant sleep behavior in regard to the physical and psychological wellbeing of the co-sleeping infant, strikingly little attention has been paid to maternal sleep quality (see[4] for review). This is a significant omission, as maternal–infant co-sleeping not only has deep evolutionary roots, but is the most widely used sleeping arrangement cross-culturally.[5] Studying sleep patterns among co-sleeping breastfeeding mothers from populations outside of the cultural west will shift some of the focus from the infant to the mother.[6] It will also provide the opportunity to correct culture-bound views of infant–maternal sleep behavior and physiology by allowing us to better understand sleep quality

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among populations where maternal–infant co-sleeping is the standard cultural practice.

The majority of the world practices simultaneous co-sleeping and breastfeeding, more recently referred to as “breastsleeping”.[7] yet the current canon of research is dominated by studies conducted among western, educated, industrialized, rich, and democratic populations, the so called “WEIRD” societies.[8] Indeed, while the concept of breastsleeping may be new to some WEIRD breastfeeding communities (including physicians, support groups, doulas, and midwives), most human beings worldwide would simply consider this practice a mutually reinforcing sleeping and feeding arrangement with no better alternative. The dominant models in the cultural west regarding what is considered “normal, healthy” infant sleep, and how to study it, have been derived exclusively from research on solitary sleeping bottle fed infants, which produce different sleep and arousal patterns when compared to breastsleeping infants studied using polysomnographic methodologies.[9,10] Moreover, the assuredness by which the western infant sleep research paradigm, and its associated underlying assumptions, has been adopted has contributed to a lacuna of research data on mother-infant sleeping practices cross-culturally and to a dearth of data collected among small-scale non-industrialized populations.

By exploring and expanding our comparative ethnographic data, bolstered by data collected among populations who may live in ecological conditions more closely resembling those in which our ancestors evolved, we have the opportunity to gain a broader range of useful clinical insights, even where exact cultural translations may not always be possible. At the present, the small number of studies that have explicitly measured maternal sleep quality among co-sleeping maternal–infant dyads have yielded inconsistent results.[4] Differences in methodology, sample size, and presence/absence of control participants has led to an opaque understanding of how maternal sleep quality is impacted by co-sleeping and/or breastfeeding.

Here, we provide, to our knowledge, the first examination of maternal sleep quality among habitually co-sleeping breastsleeping hunter-gatherers. We report baseline ethnographic data on co-sleeping behaviors and, using a small sample size of breastfeeding women, provide preliminary data testing whether or not sleep quality, sleep–wake activity, and/or sleep duration differs between breastfeeding women, their non-breastfeeding female counterparts, and men. These data not only provide the first systematic study of infant co-sleeping among the Hadza and one of the first studies of co-sleeping conducted among foragers (see [11] for data on Aka foragers), but also provide critical data on maternal sleep quality.

Methods

Participants and study location

The Hadza are a population of semi-nomadic, equatorial hunter-gatherers residing in a 4000km[2] area around the shores of Lake Eyasi in Northern Tanzania, East Africa.[12] Of the total population of approximately 1000 individuals, only around 150 individuals currently practice a predominantly hunting and gathering way of life where the majority of their diet is derived from wild plant foods and game animals. They collect plant foods (eg, baobab fruit, figs, berries, and several species of tubers), target the honey and larvae of both stingless and stinging bees, and hunt the familiar fauna that comprises East African ecosystems.[13] Hadza mothers practice on-demand, long-term breastfeeding, and infants are most often held by their mothers very early in life but are then readily cared for by other community members.[14] Young children are typically weaned around 2 years of age and historically consumed a transitional weaning diet composed of baobab and berry juice, liquid honey, pre-masticated meat, and broth. The weaning diet is changing, as is the adult diet, with the influx of domesticated cultigens into the area.[15] Currently, the Hadza are undergoing massive sociopolitical and environmental shifts as they begin transitioning into the market economy and struggle to secure land rights to maintain their hunting and gathering way of life. Despite these changes, Hadza family arrangements and sleeping patterns have remained largely unchanged.[16,17]

It is standard for married men and women to sleep in the same home with their offspring, predominantly in huts during the rainy season, and often with a light covering during the dry season. Domiciles, or huts, and often outside with a light covering during the dry season. Historically, homes (which are built exclusively by women) were covered with grasses and leaves. Currently, as climate change continues and grasses are less available, homes are also often covered with tarps, blankets, and various types of plastic. Regardless of the season, sleep is often supported with a sleeping surface composed of dried animal skins (eg, impala hide) and/or textiles such as blankets, sheets, linen sacks, woven grass matts, and/or mosquito nets. Pillows, when used, are composed of rolled up textiles or a formed mound of soft earth. Adults of both sexes sleep on these surfaces with their offspring, infants included. During some seasons, it is normal for sleep to be accompanied by the use of fire, although presence of fire does not appear to influence sleep quality.[17]

Hadza participants were recruited from a bush camp (latitude: 03–04 °S and longitude 34–36 °E) and participated in the study between January 21 and February 11, 2016. Participants included healthy adults above 18 years of age who engaged in daily foraging. Thirty-three subjects completed the study: 21 women (18 non-breastfeeding; 3 breastfeeding) with a mean age of 34.9 $\pm$ 14.3 years; 12 men with a mean age of 35.6 $\pm$ 14.7 years. All women residing in camp who were expressing breast milk for any infant or child at the time of data collection were coded as breastfeeding. Exclusion criteria included self-reported insomnia or physical disability due to injury or infirmed status that prevented an individual from engaging in active foraging. Based on these criteria, three individuals residing in the study camp were excluded from the current study. All research was approved by the Tanzanian Commission for Science and Technology (COSTECH) and the Tanzanian National Institute for Medical Research (NIMR). All eligible subjects gave their verbal informed consent and all research consent procedures and research methodologies were approved by the Institutional Review Boards for human subjects research at the University of Nevada, Las Vegas and Duke University.

Protocol

Interviews were conducted for all 33 participants where the following information was collected: (1) basic demographic questions (sex, age, breastfeeding status); (2) self-reported average number of hours slept per night; (3) whether or not reported number of hours slept was considered sufficient by the participant; (4) whether or not the participants slept in the same hut (co-roomed) with anyone; (5) whether or not the participants slept on the same sleeping surface (co-slept) with anyone; (6) the total number of individuals (including participant) who co-slept on the same surface, (7) and who the co-sleepers consisted of. The three participants who were breastfeeding participated in an additional interview where the following information was collected: (1) approximate age of breastfeeding infant, (2) self-reported estimated number of infant feedings during the night, (3) whether or not they found co-sleeping with an infant disruptive to sleep, (4) whether or not they considered co-sleeping with an infant to be dangerous, (5) whether or not they considered co-sleeping with an infant to place the infant in mortal danger, and finally, (6) why they chose to co-sleep.

In order to measure sleep quality, we used the Motionwatch 8 actigraph (CamNtech), with all watches configured to generate data in 1-min epochs. Building upon refined methods from previous sleep research conducted among the Hadza,[18] subjects were asked to press the event marker preceding any sleep event throughout the study, including sleep after nighttime wake-bouts and before initiating daytime naps. Although polysomnography (PSG) is currently considered the gold standard for quantifying sleep, it remains cumbersome, expensive, and difficult to apply with ambulatory participants, particularly among small-scale non-industrial populations. Actigraphy, on the other hand, is a noninvasive, wrist worn device that has been increasingly adopted to investigate sleep in varying ecological settings – urban, peri-urban, and rural.[19,20] Actigraph data were scored using the CamNtech MotionWare 1.1.15 program. The parameters were set as follows: a *nap* constituted a minimum of a 15-minute period of inactivity with an activity count of less than or equal to 50 counts; sleep segmentation *wake-bout* as a period of 20 consecutive epochs categorized as 'awake' from the beginning time of sleep onset until sleep end. These settings were validated by comparing reported, participant marked events to actigraphy scored events using the Bland–Altman technique to determine concordance with previous field studies conducted among the same study population.[21] As the algorithmic high-sensitivity settings are most reliable for determining sleep,[22] we used the high-sensitivity setting throughout data collection.

Day length during this time of year ranged between 12.23–12.28 hours. Sunrise occurred between 06:43–6:46 and sunset occurred between 18:59–19:00. Lunar phase ranged from full moon to complete cover of lunar light (0–1). Day length and lunar phase were recorded from the Astronomical Applications Department of the United States Navy.[23] Meteorological variables (temperature, relative humidity (RH), and wind speed) were recorded with Kestral 4000 pocket weather trackers. The weather trackers were set to record data at five-minute intervals.

Statistical analyses

We used *R* version 3.3.0[24] (2016) to conduct all statistical analyses. We generated descriptive statistics for sleep measures among three groups: (1) men, (2) non-breastfeeding women, and (3) breastfeeding women; the groups were then compared using the *BayesFactor* package with default priors.[25] We adopted a Bayesian approach (eg, anovabf (sleep parameter ~ group + ID)) that controlled for repeated measures for subjects and showed the likelihood of the alternative hypothesis, compared to the null.[26] In addition, we used Functional linear modeling (FLM) to characterize and illustrate similarities and differences in 24 sleep–wake patterns between these three groups.

The FLM approach, specifically designed for actigraphy time-series data analysis, measures raw, activity counts within and between samples, which is ideal, as summary statistics can mask differences across groups.[27] We applied a non-parametric permutation test method in the R package "actigraphy"[28] to assess differences between these three categories. This method does not rely on distributional assumptions; the *P* value is calculated by counting the proportion of permutation *F* values that are larger than the *F* statistics for the observed data. Here, we used the point-wise test (bspline method, with 500 permutations) that provides a curve which is the proportion of all permutation *F* values at each point in the time series. Due to the fact that sleeping with infants and children may be disruptive to adult sleep, we included an interaction term between subadult (infants and children) and adult co-sleepers. These predictors were scaled to ensure comparability between coefficients. To control for repeated measures, we included "subject" as a random effect and we obtained coefficients based on optimization of the log-likelihood using *shrinkage*. Shrinkage incorporates measurement error (i.e. standard error) into the regression model, which improves less certain estimates by pooling information from more certain estimates.[29] We used the *MuMIn* package[30] to average models with ΔAIC <10 and interpreted models.

In order to assess the influence of co-sleeping and breastfeeding on sleep, we ran linear mixed effects models for each of our different response variables – sleep duration (*nighttime total sleep time in hours*) and sleep quality (*sleep efficiency* and *sleep fragmentation*) using the *lme4* package.[31] In this model, we included variables known to influence Hadza sleep,[21] including: age, mean daylight activity, day length, nighttime noise (dB), cosleep (total number of individuals sleeping in/on the same bed/surface), children (total number of children sleeping in/on the same bed/surface), daily mean light exposure (lux), moon phase, temperature, humidity, wind, and breastfeeding status. Finally, we ran a simpler model comparing sleep fragmentation and female reproductive status among four categories: (1) not pregnant/not breastfeeding/not menopausal, (2) breastfeeding, (3) pregnant, and (4) post-menopausal. The model was run with the following additional factors: age, moonlight, temperature, humidity, co-sleep, children, including "subject" as a random effect.

Results

Co-sleeping interviews

Of the total sample of 33 participants, 30 reported that they co-room[i] (same hut) and co-sleep (same sleeping surface) with at least one other person (see Table 1). The three participants who reported no co-sleeping consisted of one single man in his mid-30s, one single woman in her early 40s, and one married man in his early 40s who slept outside while his wife and four children slept together inside of the hut. His reported reason for sleeping outside was temperature discomfort inside the hut. A total of 11 participants, none of whom had young children residing in camp, responded that they slept only with their spouse or one other adult. The remaining 20 participants reported sleeping with several other individuals. For young unmarried adults (n = 2), this consisted of same-sex age mates with 3 co-sleepers sharing the same hut. For married adults with children (n = 12), the total number of co-sleepers sharing the same hut ranged from 3–7 individuals, with an average of 4.2 co-sleepers on a single sleeping surface. Of the remaining co-sleeping participants (n = 5), one reported sleeping with another adult and children and the remaining four individuals reported sleeping with more than one child and no other adults.

When asked how many hours (on average) they sleep per night, 2 individuals reported less than six hours, 5 individuals reported greater than six hours, 21 individuals reported between 6–8 hours, one individual reported 9 hours, and four reported that they did not know how many hours they slept per night (Table 1). When asked if they felt that they slept enough or too little, only two individuals reported that they did not sleep enough. Interestingly, both of these individuals were in their early twenties, married, without children, and only co-slept with their spouse. The male participant reported that his lack of sleep was associated with smoking a combination of tobacco and marijuana, which he reported negatively impacted his ability to fall asleep and stay asleep; he reported that smoking marijuana alone, however, aided him in sleeping soundly all night.

Of the total 21 female participants, 10 were not pregnant, breastfeeding, or menopausal, 2 were pregnant, 3 were breastfeeding, and 6 were post-menopausal (Table 1). The breastfeeding women

[i] We use the term "co-room" to indicate room sharing; as the Hadza live in one room huts, this denotes individuals who sleep in the same hut, but not on the same sleeping surface.

Table 1
Sleep interview, including demographics of age and sex

Age	Sex	Female reproductive status (1=not pregnant; not breastfeeding; 2=pregnant; 3=breastfeeding; 4=post-menopausal)	Self-reported avg. # hours of sleep/night	Sleep amount (0=not enough, 1=enough)	Co-room (0=no; 1=yes)	Co-sleep (0=no; 1=yes)	Co-sleep # (total # of individuals on platform)	Co-sleepers
18	1		9	1	1	1	3	other males his age
23	1		6-8	1	1	1	2	spouse
26	1		<6	1	1	1	2	spouse
28	1		I don't know	1	1	1	6	spouse and children
28	1		6-8	1	1	1	2	another adult
29	1		6-8	1	1	1	3	spouse and child
29	1		>6	0	1	1	2	spouse
35	1		6-8	1	0	0	1	none
40	1		>6	1	1	1	6	spouse and children
46	1		6-8	1	0	0	1	spouse and children
50	1		6-8	1	1	1	2	spouse
58	1		>6	1	1	1	4	spouse and children
18	2	1	6-8	1	1	1	3	spouse and children
20	2	1	I don't know	1	1	1	3	other females her age
20	2	1	6-8	1	1	1	2	spouse
20	2	1	6-8	1	1	1	2	spouse
21	2	1	6-8	0	1	1	2	another adult
22	2	1	6-8	1	1	1	2	another adult
24	2	1	6-8	1	1	1	3	another adult and child
30	2	1	I don't know	1	1	1	2	spouse
32	2	1	6-8	1	1	1	3	children
40	2	1	>6	1	0	0	1	none
26	2	2	6-8	1	1	1	4	spouse and children
38	2	2	6-8	1	1	1	7	spouse and children
30	2	3	6-8	1	1	1	3	spouse and breastfeeding infant
32	2	3	>6	1	1	1	6	children
34	2	3	6-8	1	1	1	4	spouse and children
45	2	4	6-8	1	1	1	2	spouse
50	2	4	I don't know	1	1	1	4	spouse and children
50	2	4	<6	1	1	1	3	children
55	2	4	6-8	1	1	1	4	spouse and children
60	2	4	6-8	1	1	1	3	children
65	2	4	6-8	1	1	1	6	spouse and children

participated in an additional interview (Table 2). Participant 1, aged 35 years, reported co-sleeping with her breastfeeding infant (aged 6 months), three children under the age of six years, and her spouse. While she reported that her infant fed "all night long", she reported no sleeping disturbances associated with co-sleeping and reported sleeping less than six hours per night. When asked why she co-slept with her infant, she responded "This is my child, so I can protect [them]". Participant 2, aged 25 years, reported co-sleeping with her breastfeeding infant (aged 8 months) and her spouse. She reported that her infant fed once during the night, she slept over six hours per night, and reported no sleeping disturbances for herself; she did, however, report that her husband's sleep was negatively impacted. When asked why she co-slept, she responded, "To be together – the physical contact." Participant 3, aged 20 years, reported co-sleeping with her breastfeeding infant (aged 18 months), one child under age five, and her spouse. She reported that her infant fed once during the night, that she slept over six hours per night and had no sleeping disturbances. When asked why she co-slept with her infant, she responded "Because [they] are my child." All three women reported no dangers associated with co-sleeping and no fear of infant mortality arising from the practice. Breastfeeding women's average age was 32 (SD = 1.9) whereas the average age of non-nursing/non-pregnant/non-menopausal women was 25.8 (SD = 7.4). Additionally, we ran a correlation analysis that showed older women have more co-sleepers ($t = 2.1272$, $df = 89$, p-value $= 0.036$).

Using the entire sample of 33 individuals, the average number of individuals sleeping in the same hut was calculated to be 3.4 (S.E. = 0.33), while the average number of co-sleepers (i.e. individuals

Table 2
Co-sleeping interview of breastfeeding women. Includes ages of mother and infant

ID #	Age of mother	Age of infant (in months)	Self-reported #of infant feedings/night	Disruption of sleep from co-sleeping? (0 = no; 1 = yes)	Danger associated with co-sleeping (0 = no; 1 = yes)	Mortality associated with co-sleeping (0 = no; 1 = yes)	Why co-sleep?
1	35	6	Several[a]	0	0	0	"This is my child, so I can protect [them]."
2	25	8	Once	0[b]	0	0	"To be together; physical contact."
3	20	18–24	Once	0	0	0	"Because [they] are my child."

[a] Participant reported that her infant "nursed the whole night".
[b] Participant reported that her spouse's sleep was negatively impacted by co-sleeping with an infant.

Table 3
Sleep measures in Hadza foragers (mean and standard deviation). BF = Bayes factor for comparison of breast feeding women, non-breastfeeding women, and men

Sleep parameters	Men	Non-breastfeeding women	Breastfeeding women	BF
Sleep latency (h)	0.37 (0.71)	0.38 (0.48)	0.27 (0.32)	0.14 (null, positive)
Time in bed (h)	6.89 (0.70)	6.96 (0.78)	6.78 (0.56)	0.22 (null, positive)
Sleep duration (h)	6.14 (1.41)	6.39 (1.25)	6.28 (1.06)	0.22 (null, positive)
Wake after sleep onset (h)	1.99 (0.90)	1.86 (0.81)	2.42 (0.69)	0.46 (weak)
Sleep efficiency (%)	68.73 (13.5)	70.81 (10.5)	65.17 (8.3)	0.35 (weak)
Sleep fragmentation	46.14 (17.9)	43.33 (15.8)	52.96 (12.1)	0.4 (weak)
Cumulative night-time activity	15,981 (11736)	14,917 (8917)	23,397 (12524)	0.98 (weak)
Segmented sleep ratio (Wake bouts >20 min)	0.73 (0.41)	0.51 (0.76)	0.62 (0.95)	0.23 (null, positive)

sleeping on the same bed) was calculated to be 2.4 (S.E. = 0.31). The average sleeping surface was characterized by the following dimensions: length = 181.2 ± 17.5, width = 126.9 ± 24.1, thickness = 0.75 ± 1.1, surface area = 2.30 (sq m) ± 0.6 (Samson, Crittenden, Mabulla, Mabulla, & Nunn, 2017). Average sleep parameters for: (1) men, (2) non-breastfeeding women, and (3) breastfeeding women, are shown in the Table 3. In general, the Bayes factor analysis showed that there are only a few parameters for which there is support for difference among groups.

Breastfeeding status did not reduce sleep quality when comparing general measures among breastfeeding women, non-breastfeeding women, and men (Table 3). Measures included sleep latency, time in bed, sleep duration, wake after sleep onset, sleep efficiency, sleep fragmentation, cumulative night-time activity, and segmented sleep ratio.

Despite no differences found using the Bayes factor for comparison (Table 3), the FLM (Fig. 1) suggests that breastfeeding mothers awoke the earliest (during the 05:00–07:00) and had reduced day-time activity (as illustrated by the point-wise significant differences between groups during that time period) relative to non-breastfeeding women. Importantly, the linear mixed effects model showed, when controlling for confounding variables,[ii] sleep duration was negatively influenced by the number of co-sleepers but not breastfeeding status itself. (Table 4). Moreover, a similar pattern was shown with sleep quality: greater number of co-sleepers on the same surface increased *sleep fragmentation* ($\beta \pm$ SE = −0.27 ± 0.10, $P < .009$, C.I. = 0.07 to 0.48) and decreased *sleep efficiency* ($\beta \pm$ SE = −0.28 ± 0.10, $P =$ .018, C.I. = −0.42 to −0.04). Breastfeeding status did not influence sleep quality (Fig. 2). Finally, among the four female categories (not pregnant/not breastfeeding/not menopausal, breastfeeding, pregnant, and post-menopausal), sleep fragmentation increases with the number of co-sleepers (consistent with the original model). When compared to breastfeeding women, the only category to experience less sleep fragmentation was non-pregnant/non-breastfeeding/non-menopausal women ($\beta \pm$ SE = −0.45 ± 0.15, $P < .004$, C.I. = −0.767 to −0.138).

Discussion and conclusions

Our interview data suggest that the vast majority (91% of participants) co-room and co-sleep, independent of marital status or whether or not children are residing in camp. Unmarried participants either slept alone (in the case of two participants), with same-sex age mates, with another adult (not their spouse) and children, or with children and no adults. Nearly all married adults with children co-roomed and co-slept with their children, ranging from one infant to five children. The majority of participants reported an average of over 6 hours sleep per night and reported that this was an adequate amount of sleep. The study sample included three breastfeeding women who participated in an additional interview. The results from this interview indicate that the younger infant in the study (approximate age of 6 months) fed throughout the night while the older infants (greater than 6 months) fed only once. It is important to note, despite the fact that these are self-reported night feedings and a small sample size, that the participating mothers felt quite confident in their estimated reporting of feeding frequency. All three mothers reported no sleeping disturbances arising from co-sleeping and all three considered co-sleeping to be a safe sleeping practice that did not impose any mortal danger on the infant. The responses of all mothers when asked, "Why do you co-sleep?" were similar in nature – they all responded that they do so because these are their infants. The question was met with some dismay, as all Hadza women co-sleep with their breastfeeding infants and no alternative sleeping arrangement is practiced.

The actigraph data yielded results suggesting that while breastfeeding status was not characterized by differences in sleep duration or quality, the FLM showed subtle circadian differences in sleep–wake pattern where breastfeeding participants tended to wake early, and exhibited reduced daytime physical activity relative to other non-breastfeeding women (Fig. 1). These results may be linked with reduced foraging postpartum in general, which has been previously reported among the Hadza,[32] but more data are needed to test this hypothesis. Importantly, the linear mixed-effects model showed that breastfeeding status did not influence sleep duration. Rather, an increase in total number of co-sleepers on the same sleeping surface was associated with a reduction in nighttime total sleep time (Fig. 2), reduced sleep efficiency, and more sleep fragmentation (Fig. 3). When reproductive status of female participants was stratified in the model (categories: not pregnant/not breastfeeding/not menopausal, breastfeeding, pregnant, or post-menopausal) the results held and sleep fragmentation increased with the number of co-sleepers. When all categories were compared to breastfeeding women, the singular reproductive category to experience less sleep fragmentation was the category non-pregnant/non-breastfeeding/non-menopausal. Taken together, these data suggest that a greater number of co-sleepers, but not breastfeeding, is associated with a reduction in sleep quality.

These data offer an important insight to the growing canon of literature on maternal sleep quality by directly measuring the quality of sleep among co-sleeping mothers, with and without breastfeeding infants. Many studies conducted in the post-industrialized west show that co-sleeping mothers exhibit a reduction in total sleep time and sleep efficiency.[33] Interestingly, breastfeeding co-sleeping mothers in the current study did not increase the number or duration of

[ii] All confounding variables, listed above in the statistical analyses summary, include: age, mean daylight activity, day length, nighttime noise (dB), cosleep (total number of individuals sleeping in/on the same bed/surface), children (total number of children sleeping in/on the same bed/surface), daily mean light exposure (lux), moon phase, temperature, humidity, wind, and breastfeeding status.

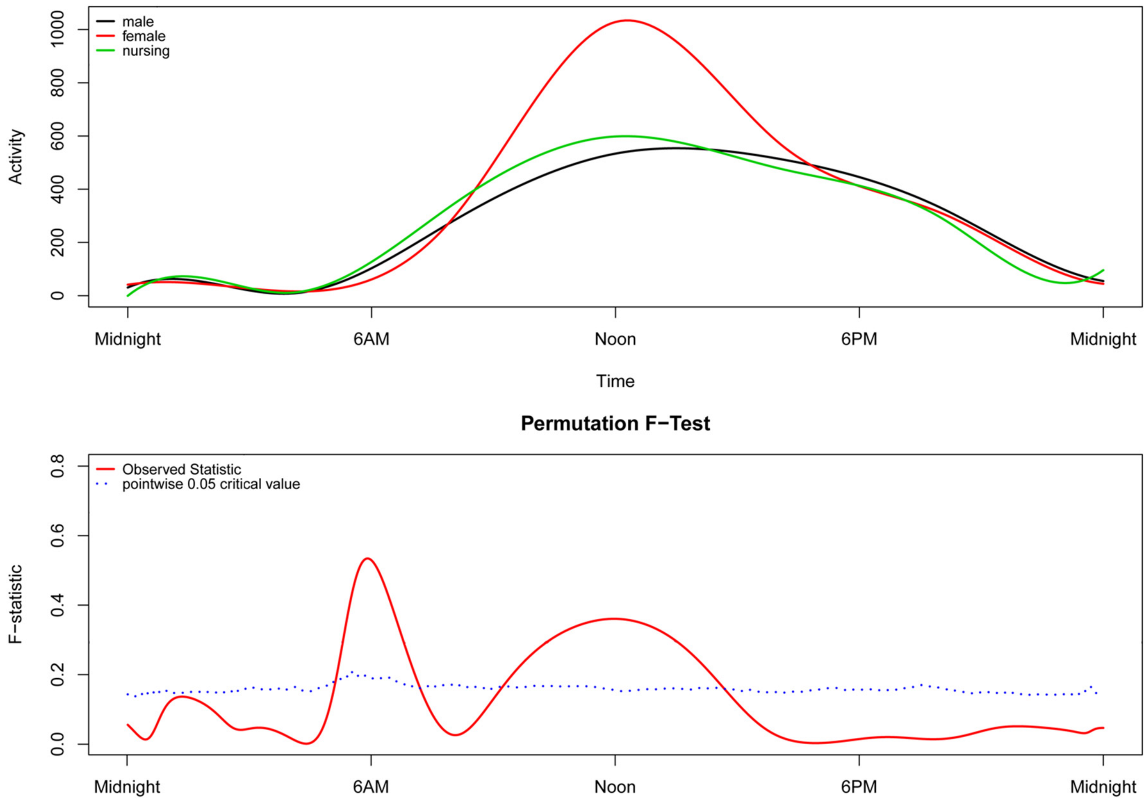

Fig. 1. Functional linear modeling (FLM) with three groups of Hadza: men, non-breastfeeding women, and breastfeeding women.

daytime naps to compensate for nocturnal sleep deprivation, as has been reported in other studies of maternal sleep quality,[34–36] as Hadza breastfeeding and co-sleeping mothers did not exhibit a reduction in total sleep time compared to their non-breastfeeding counterparts. Despite our small sample size, our finding is consistent with results from a study of 33 first time mothers and their four-week old infants in the United States that found that breastfeeding mothers recorded more sleep when compared to bottle feeding mothers if their newborns co-slept for any part of the night.[37] Consistent with these data, and the only study in which both the mother and infant were simultaneously monitored over three consecutive nights using polysomnography, routinely bedsharing-breastfeeding (breastsleeping) mothers were found, on average, to sleep for 33 minutes more per night compared with routinely solitary sleeping breastfeeding mothers who slept separately (in different rooms) from their infants.[10] While not exhibiting any reduction in total sleep time, breastfeeding co-sleeping mothers in our sample did, however, exhibit more nighttime awakenings and exhibited more sleep fragmentation, which is consistent with other studies of mothers in the US.[10,35,38] Using the linear mixed effects model, our results also indicate that after controlling for confounding variables that might influence sleep, the greater numbers of co-sleepers on a sleeping surface was associated with a reduction in total sleep time. These preliminary data indicate that overall sleep quality was not reduced in co-sleeping breastfeeding women and that any reductions in overall sleep time were associated with greater number of co-sleepers, not breastfeeding status.

Our study has several noteworthy limitations. First, we had a small sample size, which is often characteristic of studies conducted among small-scale non-industrial foraging populations. Second, all female participants in our sample habitually co-slept with their children, therefore no control participants in this ecological setting exist. Third, we did not have a large enough sample size to stratify by age of infant, effectively limiting our ability to compare sleep quality in the first 3 months postpartum, where circadian rhythms may be the most impacted.[39] Finally, we did not concomitantly administer general sleep surveys (such as the Pittsburgh Sleep Quality Index) or the Edinburgh Postnatal Depression Scale to our breastfeeding participants – which is often done in studies on maternal sleep quality. Thus, our approach was to measure the underlying sleep physiology of our participants, which may not capture the subjective 'sleep quality' a mother experiences emerging from sleep.

Future work aims to not only increase the sample size of breastfeeding women in our sample, but to also collect additional measures of sleep quality using alternative standardized tools. Notwithstanding

Table 4
The effect of co-sleeping predictor variables on nighttime sleep duration (hours)[a]

Predictor	β	SE	Confidence interval
Co-sleep	−0.16	0.08	(−0.347, −0.002)
Day length	0.49	0.27	(−0.038, 1.014)
Mean nighttime noise	−0.53	0.10	(0.731, −0.325)
Moon phase	−0.46	0.27	(−0.998, 0.077)
Temperature	0.45	0.10	(0.262, 0.637)
Light exposure	0.10	0.07	(−0.034, 0.226)
Wind	−0.11	0.09	(−0.284, 0.053)
Breastfeeding	0.04	0.12	(−0.195, 0.288)
Activity	−0.03	0.07	(−0.172, 0.115)
Age	−0.04	0.11	(−0.246, 0.170)
Humidity	−0.02	0.06	(−0.150, 0.093)
Children	−0.06	0.12	(−0.303, 0.174)
Children × co-sleep	<0.00	0.10	(−0.194, 0.195)

[a] Positive coefficients indicate greater sleep duration, while negative coefficients shorter sleep duration. *Active nursing* is the reference category for breastfeeding.

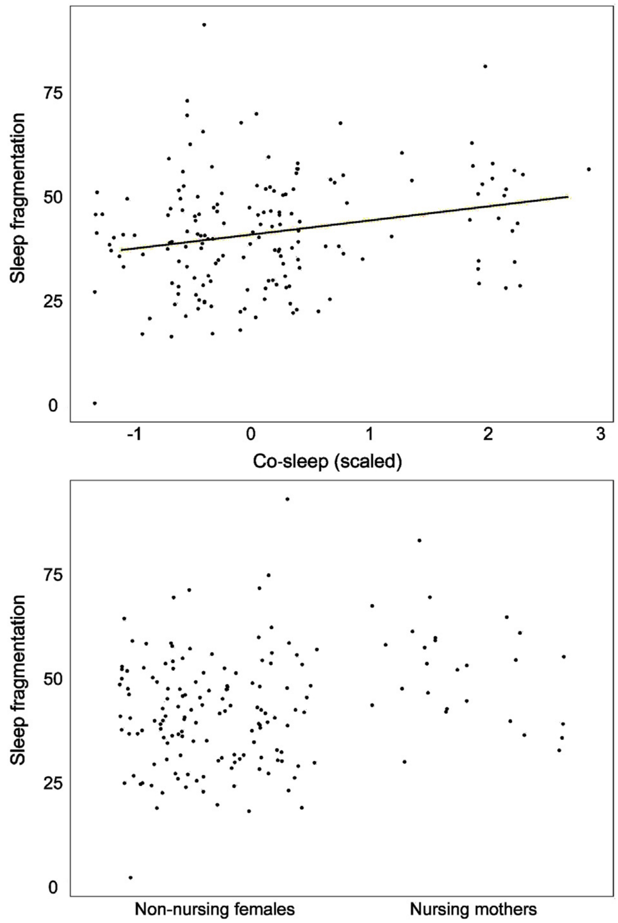

Fig. 2. The greater number of co-sleepers, not breastfeeding status (with jitter effect), negatively influences sleep fragmentation.

the above-mentioned limitations, our data make an important contribution to studies in maternal sleep health. Here, we provide the first baseline ethnographic data on infant co-sleeping among the Hadza foragers and, using actigraph data, report on sleep quality among habitually co-sleeping mothers, suggesting that breastfeeding does not negatively impact sleep quality.

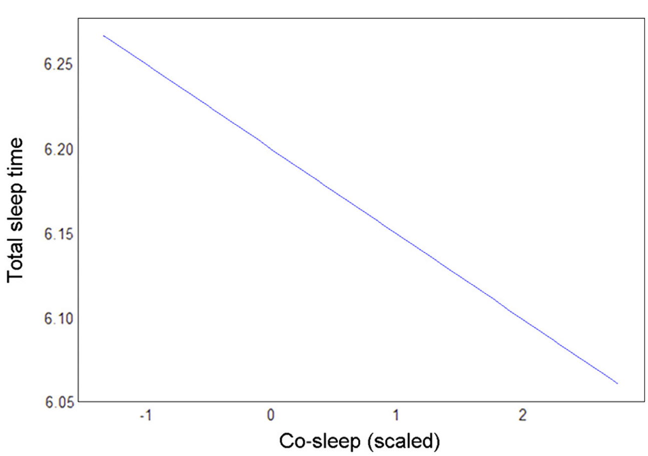

Fig. 3. Greater number of co-sleepers negatively influences total sleep duration.

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