ORIGINAL ARTICLE

The effects of Ramadan fasting on sleep patterns and daytime sleepiness: An objective assessment

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Background: Ramadan fasting and its associated lifestyle changes have been linked to changes in sleep and daytime sleepiness. This study was designed to assess the effects of Ramadan fasting on patterns of sleep and daytime sleepiness. **Methods:** The SenseWear Pro Armband™ was used to assess the duration and distribution of sleep in eight Muslim and eight non-Muslim volunteers during the last week of Shaaban [baseline (BL) and the first (R1) and second (R2) weeks of Ramadan (1430 H)]. OPTALERT™ was used to assess daytime drowsiness objectively using the John Drowsiness Scale (JDS) to assess sleepiness, and a visual reaction time test was used to assess mean reaction time (MRT). **Results:** The mean ages of Muslims and non-Muslims were 36.25 ± 4.46 and 34.75 ± 3.33 years, respectively. Although the start of work was delayed for Muslims from 0730 to 1000 hours, there was no change in working hours for non-Muslims. During Ramadan, bedtime and wake-up time were delayed, and there was a significant reduction in total sleep time for Muslims (5.91 ± 1.36 hours, 4.95 ± 1.46 hours, and 4.78 ± 1.36 hours during BL, R1, and R2, respectively, $P < 0.001$), but not for non-Muslims. JDS values in both Muslims and non-Muslims were normal at BL (1.70 ± 1.16 and 1.68 ± 1.07, respectively), and no changes occurred during Ramadan (R1 or R2), indicating no increase in daytime sleepiness. There were no significant changes in MRT during R1 and R2 from BL in either group. **Conclusion:** Although the sleep cycle of the studied sample shifted during Ramadan among fast observers, there was no objective evidence for increased sleepiness during fasting.

Key words: Ramadan, fasting, sleep, sleepiness, vigilance

INTRODUCTION

Researchers have long recognized that experimental fasting alters the sleep-wakefulness pattern in various species. For example, food deprivation has been shown to increase wakefulness and markedly reduce rapid eye movement (REM) sleep.[1-3] Fasting during the holy month of Ramadan is the fourth pillar of Islam, and more than 1.5 billion Muslims worldwide fast during Ramadan every year.[4-6] However, the effects of experimental fasting cannot be generalized to Islamic fasting during Ramadan due to its distinctive characteristics.[5] First, because the daily duration of Islamic fasting is determined by sunrise and sunset, the duration of fasting is influenced by the season in which Ramadan occurs.[5] Ramadan is one of the twelve Hijra months in the Islamic lunar calendar year. The Hijra year is 11 days shorter than the Gregorian year; therefore, Ramadan occurs in a different season every nine years.[5] The season during which Ramadan occurs influences the length of fasting, because daytime is longer in summer than in winter. Furthermore, the geographical locations influence the fasting. As we move away from the equator, days are longer in the summer and shorter in the winter. Therefore, when studying patterns of sleep during Ramadan, it is essential to report the time of year and the times of dawn and sunset.[5] Second, Ramadan fasting is distinguished by an abrupt change in eating habits; caloric intake increases at night, and the long duration of this practice (one month) may allow adaptation to the new regimen.

The fasting protocol during Ramadan may influence sleep. For example, Muslims rise for the predawn meal (*Suhur*) and dawn (*Fajr*) prayer during Ramadan.[7] Moreover, several changes in habits and lifestyle occur during Ramadan in some Islamic countries, such as delaying the start of work, shortening the working hours, and keeping the stores and shopping malls open until late at night.[8,9] All of these factors indicate that the physiological and behavioral changes occurring during the month of Ramadan may be different from those during experimental fasting.[10]

Studies using sleep diaries have shown a delay in bedtime and the time of rising during Ramadan.[7-9] However, no study has objectively assessed sleep patterns continuously during Ramadan in a natural environment (i.e., not in the laboratory under controlled conditions).

Previous studies hypothesized that bedtime and the time of rising would be delayed in Muslims during Ramadan and that these changes may affect the duration of sleep

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and daytime sleepiness. However, the pattern of sleep was not assessed objectively in the natural environment. Therefore, we designed this study to assess the effect of Ramadan fasting on circadian changes in sleep, daytime sleepiness, and vigilance in a natural environment.

MATERIALS AND METHODS

Study group

This is a descriptive study with repeated measures in a nonrandom sample of healthy volunteers. The study group comprised nonsmoking males who were employees of the King Khalid University Hospital. Eight Muslims and eight non-Muslims were included. None of the participants were on any medication or worked the night shift during or immediately prior to the study.

The study was conducted during the last week of Shaaban (i.e., the month before Ramadan), which was used as a baseline period (BL), and during the first (R1) and second (R2) weeks of Ramadan 14:30 Hijra (corresponding to the period from August 15, 2009 to September 4, 2009).To ensure that the participants had regular sleep patterns, they were asked to maintain sleep diaries for two weeks prior to the study. Working hours for the participants were from 07:30 hours to 16:30 hours during Shaaban. During Ramadan, Muslims worked from 10:00 hours until 15:00 hours, whereas the working hours for non-Muslims did not change. During the study period, dawn (beginning of fasting) was between 04:05 and 04:16 hours, and sunset (end of fasting) was between 18:10 and 18:28 hours.

Before starting the study, all participants reported to the sleep disorders center (SDC) for a medical examination, training, and orientation. Each participant was asked to wear a SenseWearPro Armband™ on the triceps area of the right arm at the midpoint between the acromion and olecranon processes.

The study was approved by the institutional review board of the college of medicine (09/2365/E), and informed consent was obtained from all participants.

The SenseWearPro Armband™

The SenseWear Pro Armband™ (Body Media, Pittsburgh, PA) is a small validated device measuring 8.8 × 5.6 × 2.1 cm in size and 82 g in weight. The sensors in the armband measure acceleration (movement) of the body, and these measurements provide information regarding total sleep time (TST) and circadian rhythms. The collected data are processed by an advanced algorithm to calculate the duration of sleep in the natural environment of the participants.[11] The SenseWearPro Armband™ has been validated for sleep studies, as its body media algorithm can identify sleep and wakefulness with moderate to high sensitivity, specificity, and accuracy.[12-14] For technical details of the armband, the reader may refer to our previous publications.[13,14] Furthermore, The American Academy of Sleep Medicine (AASM) has indicated that actigraphy, the use of devices that monitor body movements, can be a useful adjunct for diagnosing circadian rhythm disorders.[15] Indeed, some studies have shown that wrist-mounted actigraphy was highly correlated with polysomnography (PSG), the traditional tool used for differentiating sleep from wakefulness.[16,17]

TST was defined as the main consolidated sleep period, and Nap time as any other brief period of sleep.[14] Values for TST, Naps, and TST plus Nap are detailed in the results.

Mean reaction time test

Participants took a 15-minute visual reaction time test. In this mean reaction time test (MRT), three 20 mm circles were displayed on a computer screen. Their shape frequently changed into squares or diamonds of similar size for 400 ms before reverting back to circles, which occurred at random intervals of 5 to 15 seconds. The participants were instructed to push a button on a response pad held in the dominant hand as quickly as possible after a shape change.[18] The test was performed during BL, R1, and R2 at the same time between 11:00 and 12:00 hours.

All participants had normal vision without correction and practiced with the equipment and procedures before starting the test.

Assessment of daytime sleepiness

Daytime sleepiness was assessed subjectively using the Epworth Sleepiness Scale (ESS) and objectively using the Johns Drowsiness Scale (JDS).

Epworth sleepiness scale

ESS is a validated questionnaire that assesses the likelihood that the subject will fall asleep during certain activities.[19]

Johns drowsiness scale

The JDS continuously measures different features of drowsiness. It is based on a combination of oculometric variables, including the relative velocities of eye and eyelid movements, measured by a new method of infrared reflectance (IR) oculography (OPTALERT™, Optalert Pty Ltd, Melbourne, Australia).[20,21] OPTALERT™ measures eyelid velocity and blink duration.[21] An IR transmitter and receiver bar, attached to the frame of a pair of glasses, is positioned below and in front of the eye. Pulses of IR light (pulse-width: 69 μs; wavelength: 935 nm; frequency: 500 Hz) are directed toward the lower edge of the upper eyelid. The IR exposure delivered by the system is safe for use.[[21]] The characteristics of each reflected pulse are related to the reflectance and proximity of each part of

the reflecting surface (cornea, iris, sclera, conjunctiva, and eyelid).[18] "JDS is a 10-point scale in which alert subjects are rated from 0 to 4 and a critically drowsy person scores above 5".[18,21] The JDS score was derived from the means and standard deviations (SD) of several variables computed each minute, including the duration and relative velocity of eyelid movements during blinks. Using proprietary software, these numbers were automatically multiplied by previously determined weights and added to calculate JDS scores for each minute of the recording.[[18]] The test has been used in previous studies as a measure of drowsiness.[18,21]

Statistical analysis

InnerView® Professional 5.1 software (Body Media®, Inc., Pittsburgh, PA, USA) was used to download data from the monitoring devices of the participants. Data from each subject were analyzed individually, and the overall weekly averages, hourly averages for each day, and hourly averages for each week were calculated. Data are expressed as mean ± SD. Comparisons among BL, R1, and R2 were performed using one-way repeated measures analysis of variance (ANOVA) for all variables. The results were considered statistically significant if $P \leq 0.05$. Standard statistical software (SPSS version 17.0, Chicago, IL, USA) was used for the analyses.

RESULTS

The mean age of Muslims was 36.25 ± 4.46 years and the mean body mass index (BMI) was 26.27 ± 2.38 kg/m^2. For non-Muslims, the mean age was 34.75 ± 3.33 years and BMI was 25.67 ± 3.41 kg/m^2. Although the start of the work day was delayed for Muslims (from 0730 to 10:00 hours), there was no change for non-Muslims. Table 1 presents the demographics of the study participants. There were no significant differences in age or BMI. Table 2 presents data collected during BL, R1, and R2 in the Muslim group. When BL, R1, and R2 were compared within Muslims, there were significant changes in bedtime and time of rising and a significant reduction in TST. Conversely, there were no changes in the sleep patterns within non-Muslims [Table 3].

No changes in ESS values were found for either group. In addition, JDS values for both Muslims and non-Muslims were normal at BL (1.70 ± 1.16 vs. 1.68 ± 1.07, respectively), and there were no significant increases in JDS values for either group during R1 or R2. MRT for Muslims was 684.50 ± 127.75 ms and for non-Muslims, 513.5 ± 196.88 ms at BL. There was no significant increase in MRT during R1 and R2 [Table 4].

DISCUSSION

This is the first study to assess sleep patterns objectively over a continuous period during Ramadan. Importantly, the participants slept in their natural environment, and both Muslims and non-Muslims were included. The study demonstrated that bedtime and the time of rising were delayed in Muslims during Ramadan. However, we found no objective evidence for increased sleepiness during fasting.

Previous studies utilizing surveys have demonstrated several modifications in patterns of sleep during Ramadan, including sudden and significant delays in bedtime and the

Table 1: Demographics of study participants

Variable	Muslim (*n*=8)	Non-Muslim (*n*=8)	*P* value
Age	36.25±4.46	34.75±3.33	0.459
Height	170.38±7.73	166.88±5.57	0.316
Weight (BL)	76.58±11.03	71.59±10.74	0.375
Weight (R1)	75.86±11.54	69.91±10.5	0.299
Weight (R2)	75.58±11.65	69.84±10.79	0.324
BMI (BL)	26.27±2.38	25.67±3.41	0.687
BMI (R1)	26.01±2.57	25.07±3.36	0.538
BMI (R2)	25.91±2.61	25.04±3.41	0.573

BMI=Body mass index; BL=Last week of shabaan (baseline); R1=First week of ramadan; R2=Second week of ramadan

Table 2: Comparison among baseline (BL), first (R1), and second (R2) weeks of Ramadan in the Muslim group

Variable	BL	R1	R2	*P* value
ESS	2.88±1.46	2.13±1.55	2.38±1.19	0.590
Bedtime (24 h)*	23.57±1.17	0.89±1.87□	1.13±1.79□	0.004
Wake-up time (24 h)*	5.48±0.92	7.02±2.53□	7.08±2.4□	0.070
TST (h)*	5.91±1.36	4.95±1.46□	4.78±1.36□	<0.001
NAP bedtime (24 h)	16.55±1.09	15.6±0.96	15.82±0.72	0.110
NAP wake-up time (24 h)	17.79±1.7	16.71±1.08	16.81±0.67	0.168
NAP (h)	1.18±0.63	1.12±0.6	0.99±0.24	0.692
TST+NAP*	7.67±1.55	6.62±1.32□	6.38±1.21□	0.014

*P <0.05 based on repeated measures ANOVA (overall group difference); □The difference was statistically different compared to baseline (P <0.05) when pair-wise comparisons were made through paired sample *t*-test; ESS=Epworth Sleepiness Scale; TST=Total sleep time

Table 3: Comparison among baseline (BL), first (R1), and second (R2) weeks of Ramadan in the non-Muslim group

Variables	BL	R1	R2	*P* value
ESS	3.38±1.06	3.38±1.06	2.88±1.25	0.060
Bedtime (24 h)	23.39±0.58	23.58±0.69	23.88±0.89	0.126
Wake-up time (24 h)	4.38±0.37	4.42±0.42	4.52±0.4	0.290
TST (h)	4.98±0.53	4.84±0.85	4.64±0.74	0.240
NAP bedtime (24 h)*	15.03±0.98	13.68±1.23□	14.97±1.21	0.028
NAP wake-up time (24 h)	15.78±1.1	14.37±1.62	15.7±0.96	0.060
NAP duration (h)	0.75±0.3	0.69±0.49	0.73±0.25	0.974
TST+NAP (h)	5.73±0.62	5.62±1.09	5.31±0.8	0.678

*P<0.05 based on repeated measures ANOVA (overall group difference); □The difference was statistically different compared to baseline (P<0.05) when pair-wise comparisons were made through paired sample *t* -test; ESS=Epworth Sleepiness Scale; TST=Total sleep time

Table 4: JDS and MRT test scores for all participants during baseline (BL) and the first (R1) and second (R2) weeks of Ramadan

Variables	BL	R1	R2	*P* value
Both groups				
JDS	1.69±1.06	2.12±1.22	2.55±1.54	0.100
MRT (ms)	599.00±183.04	608.63±177.81	614.44±199.52	0.683
Non-Muslims				
JDS	1.68±1.07	2.74±1.29	2.88±1.91	0.207
MRT (ms)	513.5±196.88	540±201.33	548.50±223.13	0.18
Muslims				
JDS	1.70±1.16	1.60±0.97	2.28±1.29	0.249
MRT (ms)	684.50±127.75	676.75±128.87	680.38±159.94	0.968

JDS=John Drowsiness Scale; MRT=Mean reaction time test; ms=Milliseconds

time of rising.[8,9,22,23] However, conflicting results have been reported regarding TST. Although some studies reported a reduction in TST,[22,23] others reported no changes.[8,9] Nevertheless, previous studies had the major limitation of using subjective measures. The current study utilized objective methods to demonstrate that both bedtime and wake-up time were significantly delayed among working Muslims during Ramadan. The shift in bedtime was more pronounced than the shift in the time of rising, but the end result was a significant reduction in both TST and TST plus Nap duration during Ramadan. These findings contrast with a recent study that objectively reported increased TST plus NAP duration during Ramadan in a group of young, healthy students[14] The discrepancy between the two studies may be explained by an important difference between the study groups; the volunteers with increased TST plus NAP were off from school,[14] whereas the participants in the current study were working during Ramadan.

An objective assessment of patterns and duration of sleep during Ramadan fasting has not been performed previously in the natural environment. However, two previous studies did investigate architecture of sleep objectively (using PSG) in the laboratory setting.[7,24] In these studies, a reduction in the proportion of REM sleep was reported during Ramadan, although these studies have reported conflicting results with regard to sleep latency and TST. One of the studies reported a significant decrease in sleep latency at the end of Ramadan and no change in TST,[7] whereas the other study reported a significant increase in sleep latency and a significant reduction in TST.[24] The disagreement between these studies may be due to the time period between dinner and bedtime (one hour[24] *vs.* three hours[7]). Nevertheless, the results of both studies may not reflect normal patterns as they were performed under controlled conditions.

The current study demonstrated no evidence of subjective or objective increase in daytime sleepiness during Ramadan. Several studies have assessed daytime sleepiness subjectively[8,9,22,23] using the ESS and objectively under controlled laboratory conditions using the Multiple Sleep Latency Test (MSLT),[7,25] which uses mean sleep latency during standardized daytime naps as an objective measure of daytime sleepiness. Subjective studies have reported conflicting results. Specifically, although some studies using the ESS have reported a significant increase in daytime sleepiness during the entire month of Ramadan,[8,23] others found no significant change.[9,22] In addition, the above studies recruited different groups of volunteers, including medical and university students, who may have had irregular sleep habits or a shortened mean length of sleep due to life constraints. The two objective studies used the MSLT to evaluate sleepiness under controlled conditions.[7,25] In one study using MSLT, increased daytime sleepiness at 10:00 and 12:00 hours was reported toward the end of Ramadan.[25] In the other, no differences in sleep latency, sleep onset frequency, or wake efficiency were observed between the first and third weeks of Ramadan and BL.[7] However, both studies measured TST for only one night prior to performing MSLT. Therefore, the possibility of prior sleep restriction on the nights before the PSG and MSLT tests was not taken into account. This caveat is important because chronic partial sleep restriction may influence daytime sleepiness.[26]

Daytime functioning during Ramadan has yet to be properly studied under controlled conditions. Previous studies assessing daytime function during fasting have reported conflicting results.[27-29] However, deprivation or disruption of sleep could not be ruled out as possible confounders in some of the previous studies because the duration and quality of sleep of the participants were not assessed objectively before and during Ramadan. The current study found no changes in MRT during fasting. This finding concurs with an experimental study of individuals subjected to one week of controlled experimental underfeeding whose sleep was monitored by PSG; that study reported increased energy, concentration, and emotional balance in the daytime during fasting.[29]

The notion that Ramadan fasting affects daytime sleepiness and functioning is not supported by the data collected in our study. Further research is needed to clarify this issue, and control of potential confounders, such as sleep deprivation, should be an important consideration in future studies.

A limitation of this study is the small number of participants. Nevertheless, small participant numbers are typical in studies that use objective assessment methods and must be conducted within a limited time (the month of Ramadan), as both of these factors limit the number of recruited volunteers.[7,14,24,25] Another limitation is the fact that the sleep parameters were monitored only during the first two weeks of Ramadan and not for the whole month.

In summary, the results of this objective study confirm the findings of previous studies utilizing subjective assessment methods, demonstrating a delay in bedtime and wake-up time during Ramadan. However, we found no objective evidence for increased sleepiness during fasting.

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