Intermittent fasting during Ramadan: does it affect sleep?

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SUMMARY
Islamic intermittent fasting is distinct from regular voluntary or experimental fasting. We hypothesised that if a regimen of a fixed sleep–wake schedule and a fixed caloric intake is followed during intermittent fasting, the effects of fasting on sleep architecture and daytime sleepiness will be minimal. Therefore, we designed this study to objectively assess the effects of Islamic intermittent fasting on sleep architecture and daytime sleepiness. Eight healthy volunteers reported to the Sleep Disorders Centre on five occasions for polysomnography and multiple sleep latency tests: (1) during adaptation; (2) 3 weeks before Ramadan, after having performed Islamic fasting for 1 week (baseline fasting); (3) 1 week before Ramadan (non-fasting baseline); (4) 2 weeks into Ramadan (Ramadan); and (5) 2 weeks after Ramadan (non-fasting; Recovery). Daytime sleepiness was assessed using the Epworth Sleepiness Scale and the multiple sleep latency test. The participants had a mean age of 26.6 ± 4.9 years, a body mass index of 23.7 ± 3.5 kg m−2 and an Epworth Sleepiness Scale score of 7.3 ± 2.7. There was no change in weight or the Epworth Sleepiness Scale in the four study periods. The rapid eye movement sleep percentage was significantly lower during fasting. There was no difference in sleep latency, non-rapid eye movement sleep percentage, arousal index and sleep efficiency. The multiple sleep latency test analysis revealed no difference in the sleep latency between the ‘non-fasting baseline’, ‘baseline fasting’, ‘Ramadan’ and ‘Recovery’ time points. Under conditions of a fixed sleep–wake schedule and a fixed caloric intake, Islamic intermittent fasting results in decreased rapid eye movement sleep with no impact on other sleep stages, the arousal index or daytime sleepiness.

INTRODUCTION

Researchers have demonstrated that experimental fasting alters the sleep–wake pattern of various species (Borbely, 1977; Rashotte et al., 1998). However, the results of such experimental fasting cannot be extrapolated to Islamic intermittent fasting during Ramadan because the duration of each fasting episode of experimental fasting is usually more prolonged than the duration of fasting during Ramadan.

Ramadan fasting is unique in its intermittent nature. During each day of the month of Ramadan, Muslims abstain from food, drink and smoking between dawn and sunset, enacting a sudden shift in the circadian pattern of food intake.

The months in the Islamic (Hijri) year follow the lunar system. As the Hijri year is shorter than the Gregorian year by 11 days, Ramadan occurs during a different season every 9 years, which results in significant differences in the durations of day and night. In addition, there are changes in the day–night activity patterns during Ramadan, such as night prayer followed by rising for the pre-dawn meal (Suhur), and other associated lifestyle changes that occur during Ramadan. For example, in some Islamic countries, the opening of stores and shopping malls until pre-dawn time is a common occurrence. Moreover, eating habits change during Ramadan: specifically, people prefer fried foods and consume excessive sweets. All of these factors indicate that the physiological and behavioural changes occurring during the
month of Ramadan may be different from those that occur during experimental fasting (Azizi, 2002).

Polysomnographic (PSG) studies showed that Ramadan fasting affects sleep architecture. Two previous studies demonstrated a significant reduction in rapid eye movement (REM) sleep towards the end of Ramadan (BaHammam, 2004; Roky et al., 2001). Similar findings have been reported in animal studies (Kotrbacek et al., 1990). With regard to sleep latency and total sleep time (TST), conflicting results have been reported. While one study reported a significant increase in sleep latency and a significant reduction in TST (Roky et al., 2001), a second study reported a significant drop in sleep latency at the end of Ramadan and no change in TST (BaHammam, 2004). No significant changes were reported in non-REM sleep (NREM) sleep stages, arousal index, stage shifts and cardio-respiratory parameters during Ramadan (BaHammam, 2004). Using an experimental model of fasting, significant reductions were observed in the number of arousals and arousal index, as well as a significant reduction in periodic leg movement during fasting (Michalsen et al., 2003).

Conflicting data have been reported with regard to the effect of Ramadan fasting on daytime sleepiness (BaHammam, 2006). However, many of the previous studies did not use objective methods to assess sleep, sleepiness and the characteristics of the sleep–wake schedule. Moreover, some studies did not account for the possibility that attendant cultural and lifestyle changes that occur during Ramadan, such as delays in starting school and work, increased activity in malls until late at night, and other changes in the day–night activity patterns may affect the sleep patterns of individuals regardless of fasting (BaHammam, 2003, 2005; BaHammam et al., 2010). Additionally, previous studies did not account for the possibility of prior sleep restriction on the nights before assessing sleep in the laboratory. This limitation is important because chronic partial sleep restriction may influence daytime sleepiness (Balkin et al., 2008). Finally, the previous studies did not assess the effect of intermittent Islamic fasting performed outside the month of Ramadan on sleep architecture and daytime sleepiness.

We hypothesised that if a fixed sleep–wake schedule and a fixed caloric intake are followed during intermittent fasting during or outside Ramadan, the effects of intermittent fasting on sleep architecture and daytime sleepiness will be minimal. Therefore, we designed this study to objectively assess the effect of Islamic intermittent fasting on sleep architecture and daytime sleepiness outside of Ramadan (baseline fasting, BLF) and during Ramadan when controlling for sleep–wake schedule, caloric intake, meal composition, light exposure and circadian rhythm.

**MATERIALS AND METHODS**

**Study group**

This explorative study was conducted during the last week of Rajab (month 7, Hijri), the first and last weeks of Shaban (month 8, Hijri), the second week of Ramadan (month 9, Hijri), and the second week of Shawwal (month 10, Hijri) during the Hijri year 1432. The study period corresponded to the dates between 25 June and 30 September 2011 on the Gregorian calendar. During the BLF, dawn (the beginning of fasting) occurred at about 03:37 hours and sunset (the end of fasting) occurred at about 18:47 hours and, during the second week of Ramadan, dawn occurred at about 04:00 hours and sunset at about 18:34 hours. A non-random sample of eight non-smoking, healthy Muslim males between the ages of 20 and 35 years who were not on vacation during the study period (except for the Eid holiday: Ramadan 25–Shawwal 5), not on any medications, did not drink alcohol and who did not perform shift work were recruited. None of the participants had irregular sleep–wake schedules or sleep complaints. None of the participants travelled 2 weeks prior to or during the study. Their work hours were from 07:30 to 16:30 hours before and after Ramadan, and from 10:00 to 15:00 hours during Ramadan. The reason for the small number of subjects is due to the time constraints of the study period as the study has to be conducted during a specified period of time.

**Study protocol**

This is a descriptive study with repeated measures that was carried out at the Sleep Disorders Centre (SDC). The study was approved by the Institutional Review Board at our institute, and written informed consent was obtained from all participants.

The study group was recruited in early Rajab, and a teaching session was organised to introduce the protocol and its objectives to the participants, and to obtain informed consent. The participants were asked to report to the SDC at 18:00 hours on five occasions. During each visit, the subject spent 24 h in the SDC (Fig. 1).

1. Adaptation (last week of Rajab). The purpose of the first visit was to have a medical check-up and to adapt to the environment before the start of the study. All participants were given a wrist actigraphy monitor (Mini Mitter Company, Bend, OR, USA) for 1 week to assure a fixed sleep–wake schedule before starting the study. Thereafter, monitoring of their nocturnal sleep (nTST), nap duration, wake-up time and bedtime was performed throughout the study period on a daily basis via actigraphy, and the means were used in the analysis. Participants were instructed not to consume caffeinated products in the 24 h prior to and during monitoring in the SDC.

2. BLF. During the first week of the month of Shaban (3 weeks before Ramadan), the participants were asked to fast (abstain from food and drink from dawn to sunset) for 1 week. They reported to the SDC during the last day of the week while fasting for PSG and the multiple sleep latency test (MSLT) the next day. This

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Fasting protocol

During BLF, the participants were asked to fast during the first week of Shaban (7 days). During this period, we aimed to assess the effects of Islamic intermittent fasting in the absence of the lifestyle changes and eating habits that occur during Ramadan. During the last 3 weeks of Shaban (before Ramadan), the participants practiced their routine activities and eating habits. The participants performed fasting during the entire month of Ramadan. During Shawwal, the participants did not fast, and they returned to work during the second week of Shawwal.

Meals

While in the SDC for sleep studies, each participant received meals with a fixed caloric content and fixed proportions of carbohydrates, fats and proteins based on their ideal body weight. During BL and Recovery, three meals were served: dinner at 20:00 hours, breakfast at 07:15 hours and lunch at 12:00 hours. During BLF and Ramadan, three meals were served: Fatoor at Maghreb (sunset) prayer (between 18:30 and 18:55 hours); dinner at 21:00 hours; and Suhur between 03:00 and 03:15 hours.

Light exposure protocol

Light exposure was maintained at the same level during the participants’ stay in the SDC during the four study periods (BL, BLF, Ramadan and Recovery). The light level was measured using a Spectral Star Light Meter LX-1 (Japan). From 18:00 hours until bedtime and during Suhur, the light level was maintained at 50 lux. During the PSG and MSLT recordings, all lights were turned off and the light level was <1 lux.

PSG

The sleep studies were performed at the SDC. Alice 5 diagnostic equipment (Respironics, Murrysville, Pennsylvania, USA) was used for data acquisition. The subjects were asked to avoid napping during the study day. During BL and Recovery, the study began at 23:00 hours and was completed at 07:00 hours. During BLF and BLF, the study began at 23:00 hours. During Ramadan, the participants were awakened at 03:00 hours for Suhur, and the study was resumed at 03:45 hours until 07:45 hours. During Ramadan, the participants were awakened at 03:15 hours for Suhur (to account for the shift in dawn prayer time), and the study was resumed from 04:00 until 07:45 hours. The participants were awakened at a specified time in the study protocol regardless of the number of hours they slept.

A level I attended overnight sleep study with neuro-cardio-pulmonary monitoring was performed (Iber et al., 2007).
Analysis and scoring of the sleep studies

The analysis and scoring of the electronic raw data were performed manually by a trained PSG technologist in a blinded manner. Epoch-by-epoch analyses of the following sleep parameters were carried out: lights off; lights on; TST; sleep period time; and sleep-onset latency. Additionally, the following parameters were scored according to established criteria: stages of sleep and the percentage of TST; the sleep-onset latency; the REM onset latency and duration; the number of sleep cycles; stage shifts (total number of changes in sleep state from the lights-out to lights-on period); and arousals (American Sleep Disorders Association, 1992; Iber et al., 2007). The reports were generated using Alice-5 software.

Daytime sleepiness

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

ESS

The ESS is a validated questionnaire that assesses the likelihood that the subject will fall asleep during certain activities (Johns, 1991). The ESS was performed at the same time in the four study periods at 11:00 hours.

MSLT

A standard MSLT was performed in accordance with American Academy of Sleep Medicine (Littner et al., 2005). Four tests (naps), about 2 h apart, were performed at the same time during BL, BLF, Ramadan and Recovery at 09:15, 11:15, 13:15 and 15:15 hours. The routine hook-up was performed with the exception that the leg electromyogram and cardio-respiratory sensors were omitted. The technician performed calibrations prior to each test. The scorers of the MSLT were blinded to the sleep protocol used the night before. The sleep latencies of all naps were averaged and indicated on the report form.

Statistical analysis

The data are expressed as the mean ± SD. The comparisons between BL, BLF, Ramadan and Recovery were performed using the related-samples Friedman’s repeated-measures one-way analysis of variance (ANOVA) by ranks. Post hoc analysis was performed using the Wilcoxon signed rank test between levels of repeated measures. The results were considered statistically significant if P ≤ 0.05. A standard statistical software program (Statistical Package for the Social Sciences, version 17.0; SPSS, Chicago, IL, USA) was used for the data analyses.

RESULTS

At enrolment, the participants had a mean age of 26.6 ± 4.9 years, a mean body mass index of 23.7 ± 3.5 kg m⁻², and a mean ESS score of 7.3 ± 2.7. Table 1 reveals the weight, ESS and sleep schedules followed when the participants slept at home at BL, BLF, Ramadan and Recovery. There were no significant changes in weight or the ESS score in the four study periods. Based on the clinical data collected from actigraphy, we found no significant changes in bedtime, nTST, or nTST + nap between BL, BLF, Ramadan and Recovery. However, the bedtime and wake-up time were delayed during Ramadan.

Table 2 presents the PSG characteristics before Ramadan (BL and BLF), during Ramadan and during Recovery. There was no significant difference in the TST, sleep efficiency, sleep-onset latency and REM-onset latency between the BL, BLF, Ramadan and Recovery periods. The slow-wave sleep latency, arousal index and stage shifts did not differ significantly between the BL, BLF, Ramadan and Recovery periods. The proportion of different NREM sleep stages in relation to TST did not change significantly in the BLF and Ramadan periods compared with BL. However, the REM sleep percentage and duration were significantly lower at BLF (17.8 ± 8.1%) and Ramadan (19.8 ± 10.7%) compared with BL (27.6 ± 4.7%) and Recovery (26.6 ± 7.4%). The average number of REM cycles did not change between BL, BLF, Ramadan and Recovery.

<table>
<thead>
<tr>
<th>Table 1 The ESS scores, weight and sleep pattern obtained using actigraphy when sleeping at home</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Variable</strong></td>
</tr>
<tr>
<td>Weight (kg)</td>
</tr>
<tr>
<td>ESS</td>
</tr>
<tr>
<td>Bedtime (24 h)</td>
</tr>
<tr>
<td>Wake-up time (24 h)</td>
</tr>
<tr>
<td>nTST (h)</td>
</tr>
<tr>
<td>nTST + NAP (h)</td>
</tr>
</tbody>
</table>

BL, non-fasting baseline; BLF, baseline fasting; ESS, Epworth Sleepiness Scale; nTST, nocturnal sleep.

*The difference is statistically significant compared with BL, BLF and Recovery.
Table 2: PSG characteristics during the BL, BLF, Ramadan and Recovery phases

<table>
<thead>
<tr>
<th>Variable</th>
<th>BL</th>
<th>BLF</th>
<th>Ramadan</th>
<th>Recovery</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>TST (min)</td>
<td>375.8 ± 46.4</td>
<td>333 ± 59.8</td>
<td>353.9 ± 42.7</td>
<td>390.5 ± 34.3</td>
<td>0.165</td>
</tr>
<tr>
<td>Sleep efficiency</td>
<td>79.3 ± 9.6</td>
<td>70.7 ± 11.1</td>
<td>74.2 ± 7.3</td>
<td>81.5 ± 7</td>
<td>0.336</td>
</tr>
<tr>
<td>Sleep latency</td>
<td>29.6 ± 24.2</td>
<td>33.7 ± 33.6</td>
<td>32.8 ± 29.3</td>
<td>9.4 ± 5.5</td>
<td>0.224</td>
</tr>
<tr>
<td>REM latency</td>
<td>80.6 ± 26.9</td>
<td>108.9 ± 47.8</td>
<td>73.5 ± 40.1</td>
<td>76.8 ± 22.8</td>
<td>0.185</td>
</tr>
<tr>
<td>Stage shifts</td>
<td>66.3 ± 13.9</td>
<td>74.9 ± 20.5</td>
<td>64.1 ± 16.7</td>
<td>62.6 ± 10.6</td>
<td>0.327</td>
</tr>
<tr>
<td>Stage N1%</td>
<td>5.2 ± 2.6</td>
<td>8.2 ± 3.7</td>
<td>5.4 ± 2.4</td>
<td>4.9 ± 2.3</td>
<td>0.092</td>
</tr>
<tr>
<td>Stage N2%</td>
<td>56.6 ± 4.8</td>
<td>63.2 ± 9.3</td>
<td>64.3 ± 6.1</td>
<td>57.7 ± 9.7</td>
<td>0.070</td>
</tr>
<tr>
<td>Stage N3%</td>
<td>8.7 ± 7.3</td>
<td>10.8 ± 6.4</td>
<td>10.6 ± 7.1</td>
<td>10.8 ± 6.8</td>
<td>0.136</td>
</tr>
<tr>
<td>Stage REM%</td>
<td>27.6 ± 4.7</td>
<td>17.8 ± 8.1*</td>
<td>19.8 ± 10.7*</td>
<td>26.6 ± 7.4</td>
<td>0.024</td>
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<tr>
<td>REM cycles</td>
<td>4.1 ± 1</td>
<td>3.8 ± 0.9</td>
<td>3.8 ± 1.3</td>
<td>4.1 ± 0.4</td>
<td>0.400</td>
</tr>
<tr>
<td>REM duration (min)</td>
<td>101.3 ± 25.5</td>
<td>60.4 ± 29.3*</td>
<td>78.1 ± 46.7*</td>
<td>103.3 ± 28.8</td>
<td>0.044</td>
</tr>
<tr>
<td>REM 1 (min)</td>
<td>23.3 ± 16.1</td>
<td>17 ± 9</td>
<td>14.3 ± 6.4</td>
<td>18.5 ± 10.9</td>
<td>0.652</td>
</tr>
<tr>
<td>REM 2 (min)</td>
<td>27.4 ± 11.5</td>
<td>11.8 ± 7.8†</td>
<td>15.6 ± 10.3</td>
<td>16.8 ± 8.8</td>
<td>0.06</td>
</tr>
<tr>
<td>REM 3 (min)</td>
<td>24.7 ± 16.3</td>
<td>12.9 ± 14.5</td>
<td>21.3 ± 21.3</td>
<td>30.4 ± 18.1</td>
<td>0.158</td>
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<tr>
<td>Arousal index</td>
<td>9.1 ± 3.6</td>
<td>8.9 ± 4.6</td>
<td>7.9 ± 3.3</td>
<td>10.9 ± 5.7</td>
<td>0.369</td>
</tr>
<tr>
<td>Periodic leg movements index</td>
<td>2.7 ± 1.6</td>
<td>3.8 ± 3.4</td>
<td>4.7 ± 3.5</td>
<td>4.9 ± 3.5</td>
<td>0.217</td>
</tr>
</tbody>
</table>

BL, non-fasting baseline; BLF, baseline fasting; REM, rapid eye movement; TST, total sleep time.
*BLF and Ramadan were significantly lower than BL and Recovery.
†BLF was significantly lower than BL.

Table 3: The MSLT characteristics associated with the BL, BLF, Ramadan and Recovery phases

<table>
<thead>
<tr>
<th>Variable</th>
<th>BL</th>
<th>BLF</th>
<th>Ramadan</th>
<th>Recovery</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sleep latency (NAP1)</td>
<td>8.4 ± 6.2</td>
<td>8.7 ± 7</td>
<td>9.7 ± 7.2</td>
<td>7.1 ± 6.3</td>
<td>0.572</td>
</tr>
<tr>
<td>Sleep latency (NAP2)</td>
<td>5.2 ± 2.9</td>
<td>10.8 ± 7.5</td>
<td>11.3 ± 8.5</td>
<td>11.4 ± 7.6</td>
<td>0.141</td>
</tr>
<tr>
<td>Sleep latency (NAP3)</td>
<td>10.3 ± 6.6</td>
<td>11.6 ± 7.9</td>
<td>13 ± 8</td>
<td>8.9 ± 6</td>
<td>0.186</td>
</tr>
<tr>
<td>Sleep latency (NAP4)</td>
<td>12.3 ± 8.5</td>
<td>14.4 ± 6.7</td>
<td>13.4 ± 7.2</td>
<td>12.1 ± 6.6</td>
<td>0.824</td>
</tr>
<tr>
<td>Sleep latency (mean)</td>
<td>9 ± 4.4</td>
<td>11.4 ± 5.9</td>
<td>11.5 ± 6.2</td>
<td>9.9 ± 5.4</td>
<td>0.403</td>
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<tr>
<td>Sleep-onset REM frequency</td>
<td>0.1 ± 0.1</td>
<td>0.2 ± 0.3</td>
<td>0.2 ± 0.2</td>
<td>0.1 ± 0.2</td>
<td>0.960</td>
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<tr>
<td>Stage shift during Nap 1</td>
<td>3.8 ± 1.2</td>
<td>4.8 ± 2.5</td>
<td>3.3 ± 1.2</td>
<td>3.9 ± 2.3</td>
<td>0.492</td>
</tr>
<tr>
<td>Stage shift during Nap 2</td>
<td>3.9 ± 2.2</td>
<td>3.6 ± 1.1</td>
<td>2.6 ± 1.4</td>
<td>3 ± 1.5</td>
<td>0.604</td>
</tr>
<tr>
<td>Stage shift during Nap 3</td>
<td>4.5 ± 2.5</td>
<td>3.8 ± 2.4</td>
<td>2.8 ± 1.9</td>
<td>4.6 ± 4</td>
<td>0.514</td>
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<tr>
<td>Stage shift during Nap 4</td>
<td>2.6 ± 1.8</td>
<td>2.4 ± 1.8</td>
<td>3.8 ± 4</td>
<td>3.4 ± 2.8</td>
<td>0.874</td>
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<tr>
<td>Stage shift (mean)</td>
<td>3.7 ± 1.5</td>
<td>3.6 ± 1.1</td>
<td>3.1 ± 1.7</td>
<td>3.7 ± 1.6</td>
<td>0.539</td>
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<tr>
<td>Stage N1% (mean)</td>
<td>31.7 ± 20.7</td>
<td>23.7 ± 6.9</td>
<td>22.7 ± 16.4</td>
<td>26 ± 18.4</td>
<td>0.789</td>
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<tr>
<td>Stage N2% (mean)</td>
<td>61.3 ± 23.5</td>
<td>64.2 ± 11</td>
<td>53.5 ± 27.7</td>
<td>63.3 ± 15.5</td>
<td>0.93</td>
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<tr>
<td>WE during Nap 1</td>
<td>32.6 ± 16.8</td>
<td>43.4 ± 29.4</td>
<td>40.1 ± 29.5</td>
<td>38.1 ± 31.1</td>
<td>0.476</td>
</tr>
<tr>
<td>WE during Nap 2</td>
<td>56.8 ± 35.4</td>
<td>24.4 ± 10.8</td>
<td>53 ± 40.9</td>
<td>49.4 ± 34.6</td>
<td>0.089</td>
</tr>
<tr>
<td>WE during Nap 3</td>
<td>56 ± 34.4</td>
<td>46.1 ± 25.4</td>
<td>65 ± 38.1</td>
<td>47.1 ± 29.8</td>
<td>0.57</td>
</tr>
<tr>
<td>WE during Nap 4</td>
<td>77.7 ± 27.4</td>
<td>69 ± 42.6</td>
<td>62.5 ± 32.7</td>
<td>54.2 ± 30.2</td>
<td>0.55</td>
</tr>
</tbody>
</table>

BL, non-fasting baseline; BLF, baseline fasting; REM, rapid eye movement; WE, wake efficiency.

Table 3 summarises the MSLT findings. There were no significant differences in either the sleep latencies of individual naps or their mean between BL, BLF, Ramadan and Recovery. A further examination of the wake efficiency (WE) and the sleep-onset frequency revealed no significant differences between BL, BLF, Ramadan and Recovery in either the individual naps or their mean. An analysis of the sleep stages during the MSLT revealed no significant differences in the mean of all naps between BL, BLF, Ramadan and Recovery. None of the participants progressed into N3 during the naps. The frequency of sleep-onset REM showed no differences between BL, BL Fasting, Ramadan and Recovery. Fig. 2 demonstrates the distribution of sleep latencies of naps in BL, BLF, Ramadan and Recovery. The time of day of the nap had no significant effect on sleep-onset latency during fasting.

**DISCUSSION**

To our knowledge, no study has assessed the effects of Islamic intermittent fasting outside the Ramadan season. In this study, under conditions of a fixed sleep–wake schedule and caloric intake, we assessed the effects of intermittent fasting on sleep architecture and daytime sleepiness. Then,
we assessed the same parameters after the completion of the fasting month (Recovery). The study demonstrates that Islamic intermittent fasting results in decreased REM sleep with no impact on other sleep stages, arousal index or daytime sleepiness.

The study revealed no difference in sleep latency at night between the four study periods (BL, BLF, Ramadan and Recovery). Previous studies have reported conflicting findings with regard to the effects of fasting on sleep latency. In a well-designed study that assessed sleep architecture among performers of Ramadan fasting, Roky et al. (2001, 2003) reported an increase in sleep latency during Ramadan. However, Michalsen et al. (2003), in a home-based 1-week modified fasting experiment, reported no change in sleep latency. A third study reported no change in sleep latency in the first and third weeks of Ramadan (BaHammam, 2004). The difference in sleep latency between the Roky et al. study and the current study can be explained by the different protocols used. For example, in the Roky et al. study, the time difference between dinnertime and bedtime was 1 h (dinner was served at 22:30 hours, and PSG recording started at 23:30 hours), while the difference was 2 h in the current study (dinner was served at 21:00 hours, and PSG recording started at 23:00 hours). It is quite possible that late dinners affect nTST. Therefore, the relationship between dinnertime during Ramadan and nTST should be assessed in future research.

In the present study, REM sleep was reduced during BLF and Ramadan compared with BL and Recovery. The level of REM sleep returned to normal after the completion of fasting (Recovery). However, there were no significant differences between the two fasting periods (BLF and Ramadan) and BL with regard to NREM sleep stages, arousal index and stage shifts. Two previous studies assessed sleep architecture during Ramadan using a level I attended sleep study (BaHammam, 2004) and a level II comprehensive unattended sleep study at home (Roky et al., 2001). Both studies demonstrated a significant reduction in REM sleep toward the end of Ramadan. Another experimental study conducted on piglets demonstrated that REM sleep did not occur after 18 h of fasting but recurred after feeding (Kotrbacek et al., 1990).

Several theories have been proposed to explain the reduction in REM sleep during fasting. A shift in cortisol and insulin rhythms has been reported during Ramadan, with an increased level at night (Al-Hadramy et al., 1988; Iriki et al., 1997). The reduction in REM sleep during fasting may be due to a nocturnal rise in cortisol and insulin (Born et al., 1989; Sangiah and Caldwell, 1988). The eating of meals exclusively at night during Ramadan has been proposed to increase the nocturnal body temperature (Roky et al., 2000, 2001). Because REM sleep is inversely proportional to core temperature (Krueger and Takahashi, 1997), a nocturnal increase in temperature would be expected to decrease REM sleep (Libert et al., 1988). In addition, animal studies have proved that imposed meal times and temporally restricted feeding are potent synchronisers for secondary clocks in peripheral organs and in certain brain regions (Challet and Mendoza, 2010). Even when animals were exposed to a light–dark cycle, timed calorie restriction was found to be a powerful synchroniser of the suprachiasmatic clock (Challet and Mendoza, 2010). In addition, a predictable daily mealtime triggers the expression of neural and circadian clock gene perturbations in many mammalian species, which is considered to be guided by a food-entrainable clock (Challet and Mendoza, 2010; Mistlberger, 2009). As REM sleep follows an endogenous circadian rhythm (Czeisler et al., 1980; Johnson, 1980), the interaction between changes in meal time and the biological clock may influence the rhythmicity of REM sleep and hence its duration. Future studies should assess the effect of meal time and composition during Ramadan on REM sleep. Another plausible mechanism is the relationship between orexin, fasting and REM sleep. Orexin, also called hypocretin, is a hypothalamic neurotransmitter that regulates arousal, wakefulness and appetite. Orexin gene expression has been shown to be upregulated during fasting in animals (Sakurai et al., 1998). Reduced leptin levels and hypoglycaemia may activate orexin-secreting cells (Griffond et al., 1999). Studies have shown that Ramadan fasting influences the level and the time of the acrophase of serum leptin concentration (Bogdan et al., 2005; Kassab et al., 2003). However, orexin has been proposed to suppress REM sleep (Hagan et al., 1999). Infusion of orexin into the cerebroventricular space has been shown to decrease REM sleep duration (Hagan et al., 1999). Theoretically, intermittent fasting may increase orexin levels through changes in serum leptin levels, which in turn may suppress REM sleep (Komaki et al., 2001). However, previous data on the effect of orexin on REM sleep were obtained from studies on animal models that utilised prolonged underfeeding. Future studies should explore the changes in the leptin–orexin system in intermittent fasting. Another possible explanation for the reduction in REM sleep during Ramadan is the interruption of sleep for the predawn meal during the early morning hours, the time period in which a

![Figure 2. The distribution of sleep latencies of naps during the baseline (BL), baseline fasting (BLF), Ramadan and Recovery stages. Data are expressed as mean ± SE.](image-url)
larger amount of REM sleep usually occurs. We tried to compensate for the lost sleep time during Suhur by delaying the awakening time by 30 min (TST was not different between BL, BLF and Ramadan). Apart from the above results, we found that the sleep architecture was within normal parameters, and revealed no difference between BL and BLF. During experimental fasting consisting of 7 days of underfeeding, Michalsen et al. (2003) reported no changes in TST or sleep stages, and a significant reduction in the arousal index. Moreover, the participants reported improvement in the quality of sleep during the fasting period (Michalsen et al., 2003).

Using subjective and objective assessment tools, the current study revealed no difference in daytime sleepiness between BL and BLF. Previous studies have reported conflicting data on the effect of Ramadan fasting on daytime sleepiness. Although some studies using the ESS have reported a significant increase in daytime sleepiness during the entire month of Ramadan (Bahammam, 2006), others found no significant change (BaHammam, 2004, 2005; Margolis and Reed, 2004). This difference may be attributed to the different groups studied. Previous studies recruited different groups of volunteers, including medical and university students, who may have had irregular sleep habits or a shortening of mean sleep length due to life constraints. Concern has been raised about the effects of lifestyle changes during Ramadan on nTST and thus daytime sleepiness (Bahammam, 2006; BaHammam et al., 2010). We tried to control for these effects by studying the effects of fasting outside the Ramadan period, and by controlling for TST and light–dark exposure during the laboratory monitoring. Our data demonstrated no subjective or objective evidence of increased daytime sleepiness during Ramadan fasting when the participants were kept under controlled conditions of fixed TST, caloric intake and light exposure.

Researchers have found that food deprivation increases wakefulness in different species (Rashotte et al., 1998). This effect could be related to the fasting effect on orexin. It has been shown that monoaminergic neurons express orexin receptors and are heavily innervated by orexin neurons (Ohno and Sakurai, 2008). In addition, orexin has been shown to activate these wake-promoting neurons (Ohno and Sakurai, 2008). Direct injection of orexin A into the laterodorsal tegmental nucleus (a pontine site involved in the regulation of the behavioural states) of cats resulted in an increase in wake time and a decrease in REM sleep time (Xi et al., 2001). However, fasting in such experiments is usually more prolonged than fasting during Ramadan, so we do not know if this evidence can be applied to Islamic intermittent fasting. Moreover, recent data have showed that intermittent fasting induced brain-derived neurotrophic factors (BDNFs) in different regions of the brain (Mattson, 2005). BDNF can improve learning and memory, protect neurons against oxidative and metabolic insults, and stimulate neurogenesis (Mattson, 2005; Mattson et al., 2002).

Two previous objective studies have assessed daytime sleepiness in Ramadan using the MSLT to evaluate sleepiness (BaHammam, 2004; Roky et al., 2003). One study using a portable, at-home PSG recording device demonstrated increased daytime sleepiness at 10:00 hours and 12:00 hours toward the end of Ramadan (Roky et al., 2003). In the other study (BaHammam, 2004), a standard MSLT was performed in the sleep laboratory, circumventing the limitation of the previous study. No differences in sleep latency, sleep-onset frequency and WE were observed between the first and third weeks of Ramadan and BL (BaHammam, 2004). However, previous studies measured TST for only 1 night prior to performing the MSLT. Therefore, the possibility of prior sleep restriction on the nights before the PSG and MSLT tests was not taken into account. This limitation is important because chronic partial sleep restriction may influence daytime sleepiness (Balkin et al., 2008). In the current study, we monitored TST at home prior to each monitoring in the sleep centre using actigraphy to ensure that the participants maintained the TST at home. In the free living environment, the bedtime and awakening time were delayed during Ramadan only, which may reflect the delay in starting work during Ramadan (Bahammam, 2006). Delays in awakening time have been reported in some Islamic countries that delay the starting time of work (Bahammam, 2006).

Recent clinical observations demonstrated an early (within few days) favourable effect of medically supervised fasting (for 7–20 days) on depressive symptoms, and an improvement in mood, alertness, pain and a sense of tranquility (Fond et al., 2013; Michalsen, 2010). The effect of Ramadan intermittent fasting on mood and depressive symptoms remains to be determined in well-designed studies.

The study has a few limitations that need to be addressed. First, the non-random small sample of subjects recruited in this study. 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 (BaHammam, 2004; Roky et al., 2001). Second, the lack of a control group; nonetheless, the recruited subjects acted as a control group for themselves in this case-crossover study as the same subjects were tested in the four study periods.

In summary, this study showed that under conditions of a fixed sleep–wake schedule, a fixed light–dark exposure and a fixed caloric intake, Islamic intermittent fasting results in decreased REM sleep with no impact on other sleep stages, the arousal index or daytime sleepiness. We anticipate that future critical research will be performed to help understand the effect of decreased REM sleep during fasting on cognitive function.

ACKNOWLEDGEMENTS

This study was supported by a grant from the National Plan for Science and Technology, Saudi Arabia. The authors A. S. B, K. A, S. R. P and M. M. S were equally contributed.

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DISCLOSURE AND CONFLICT OF INTEREST
SRP-P is a stockholder, and the President and Chief Executive Officer of Somnogen Canada Inc., a Canadian corporation. He declares that he has no competing interests that might be perceived to influence the content of this article. All remaining authors declare that they have no proprietary, financial, professional or other personal interest of any nature in any product, service and/or company that could be construed or considered to be a potential conflict of interest that might have influenced the views expressed in this manuscript.

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