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Daytime Alertness, Mood, Psychomotor Performances, and Oral Temperature during Ramadan Intermittent Fasting

Rachida Roky[a] Leila Iraki[a] Rachida HajKhlifa[a] Nouria Lakhdar Ghazal[b] Farid Hakkou[a]

[a]Department of Pharmacology, Faculty of Medicine and Pharmacy, Casablanca, and
[b]Groupe de Recherche sur les Rythmes Biologiques, Laboratoire de Physiologie Animale, Faculté des Sciences, Rabat, Morocco

Key Words
Human · Islamic fasting · Movement reaction time · Meal time · Feeding · Visual analogue scale · Alertness · Vigilance · Sleep

Abstract
During the month of Ramadan, Moslems abstain from drinking and eating daily between sunrise and sunset. This change of meals schedule is accompanied with changes in sleep habit, which may affect diurnal alertness. This study examined the effect of Ramadan intermittent fasting on the diurnal alertness and oral temperature in 10 healthy young subjects. The cognitive task battery including movement reaction time (MRT), critical flicker fusion (CFF) and visual analogue scale, was administered at 6 different times of the day: 09.00, 11.00, 13.00, 16.00, 20.00 and 23.00 h on the 6th, 15th, and 28th days of Ramadan. The baseline day was scheduled one week before Ramadan, and the recovery day 18 days after this month. Oral temperature was measured prior to each test session and at 00.00 h. During Ramadan oral temperature decreased at 09.00, 11.00, 13.00, 16.00 and 20.00 h and increased at 23.00 and 00.00 h. Subjective alertness decreased at 09.00 and 16.00 h and increased at 23.00 h. Mood decreased at 16.00 h. MRT was increased at the beginning of Ramadan (R6) and CFF was not changed. These results showed that daytime oral temperature, subjective alertness and mood were decreased during Ramadan intermittent fasting.

Introduction

Ramadan fasting is an Islamic practice observed by over one billion people worldwide. During this lunar month, Muslims abstain from drinking, eating and having sexual activity between sunrise and sunset. Thus, all meals are nocturnal, which results very often in sleep shortening.

Several studies have reported that Ramadan intermittent fasting affects plasma level of lipids [1, 2], proteins [3], glucose [1, 4, 5], and metabolic rate [1, 6]. Only a few studies have examined the effects of Ramadan on performance. It has been shown that muscular force decreased during Ramadan [7]. Psychomotor performances, such as critical flicker fusion [8], subjective alertness [9] and memory [10, 11] were impaired by Ramadan fasting, which could be important for traffic accident and work performance. Effectively, it was reported that traffic accident increased [12] and study performance decreased dur-

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Rachida Roky, PhD
Department of Pharmacology, Faculty of Medicine and Pharmacy
19, rue Tarik Bnou Ziad, Casablanca (Morocco)
Tel. +212 2 20 11 56/+212 2 47 12 89, Fax +212 2 47 12 90
E-Mail r.roky@fmp-uh2c.ac.ma

ing Ramadan [13]. In these studies, the diurnal variations of these parameters were not considered.

In normal conditions, there is a diurnal variation in alertness as measured by subjective rating scale [14], by immediate memory [15], by logical reasoning test [16], and by manual dexterity test [17]. Further, alertness is impaired by caloric restriction [18] or by sleep length limitation [19, 20]. In rat, the sleep/wake cycle is altered when food and water are given only during the rest period [21]. However, little information is available on the effects of changing meals schedule on cognitive functions in human. The aim of the present work is to determine the daily distribution of body temperature and alertness during Ramadan fasting.

Materials and Methods

Subjects

Ten healthy male volunteers aged between 20 and 28 years were recruited through advertisement within the University. They were informed about the procedure of the study and they gave their consent to participate to it. The protocol was approved by the religious committee of Hassan II Foundation for Scientific and Medical Research on Ramadan, and by the ethical committee of Casablanca faculty of medicine.

Subjects underwent a careful interview about their sleep and eating habits. During regular days, all subjects met the following criteria: (1) Time in bed from 23.00 to 07.00 h ± 1 h. (2) Breakfast at 07.30 h ± 1 h, lunch at 12.00 ± 1 h and dinner at 20.00 h ± 1 h. (3) Infrequent napping. (4) No smoking, no more than 2 cups of coffee daily and no alcohol. (5) Good physical and mental health. Subjects were intermediate type as determined by the Morningness-Eveningness self assessment questionnaire of Horne and Östberg [22].

During Ramadan, subjects had the following sleep and eating habits: (1) Time in bed from 01.00 to 08.00 h ± 1 h. (2) The first meals at sunset (between 18.00 and 18.30 h) and the second at 00.00 h ± 30 min.

Alertness, Mood and Psychomotor Performance Measures

Visual Analogue Scale. Eight unipolar visual analogue scale (VAS) ratings were used. Four concerned subjective alertness and vigor (alertness, tiredness, sleepiness and awkwardness), four concerned subjective mood and affect (happiness, sadness, calmness and tension). Global subjective alertness and mood were calculated as shown by Monk [23]:

Global alertness = [(alert) + 300 – (sleepy) – (tired) – (awkward)]/4
Global mood = [(happy) + (calm) + 200 – (sad) – (tense)]/4

Critical Flicker Fusion (CFF) [24]: Subjects were required to discriminate flicker from fusion in a set of four red light emitting diodes (LED) held at 1 m from the subject. The light flickered at a constantly increasing or decreasing rate. The average from three descending and three ascending frequencies was calculated. Lighting intensity in the room was maintained constant throughout the experiment.

Choice Reaction Time (CRT) [25]: Subjects were required to extinguish, as quickly as possible, one of the six LED lights, illuminated at random, by pressing the appropriate response button. The buttons were equidistant from the resting position of the finger. The mean from 30 stimuli presentations, split into five trials of 10 stimuli each, was calculated. Out of the three components of reaction time obtained [total reaction time, from the stimulus onset to completion of response; motor reaction time, movement reaction time (MRT), and the recognition time], only the MRT values are reported.

Temperature Measures

Oral temperature was measured using a medical thermometer (precision of 0.01 °C) prior to each test battery and just before bed time.

Procedure

Days of the Study. The experiment consisted of 6 days, scheduled as follows:

(1) Adaptation day: 2 weeks before the beginning of Ramadan fasting before which they were entrained on the test battery at least 5 times. Data from the day were not included in the statistical analysis. (2) Baseline day (B-R) 1 week before Ramadan. (3) The 6th fasting day (R6). (4) The 15th fasting day (R15). (5) The 28th fasting day (R28). (6) Recovery day: (A-R) on the 18th day after the end of Ramadan. Prior to each session day, the subjects slept at the laboratory.

Time of the Tests. Subjects were tested at 09.00, 11.00, 13.00, 16.00, 20.00 and 23.00 h. To prevent any practice effect, the tests were administered to the subjects in different timing orders as recommended by Monk [23]. The tests were always administered in this order: VAS, CFF, CRT.

Meals and Sleep Schedules. During the experimental days, daily meal composition and duration (20 min) were maintained constant on both fasting and nonfasting days. During nonfasting days, meals were scheduled as follows: Breakfast was at 08.30, lunch at 12.30, snack at 16.00 and dinner at 21.00 h. During Ramadan fasting, the first meal was at sunset (18.00 h at the beginning and 18.30 h at the end of Ramadan) and the second at 00.30 h, a snack was given at 20.30 h. Sleep, as observed by the investigator, was from 00.00 to 08.00 h during nonfasting days and between 01.30 and 08.30 h during fasting days. To maintain a constant physical activity for the 6 experimental days, the subjects were not allowed to leave the laboratory. They watched television, played cards or read between the tests sessions. During the other days of the month, subjects were instructed to have the same food and sleep schedule.

Statistical Analysis

Statistical analysis of the data were carried out using ANOVA for repeated measure with two factors (fasting effect and time of day effect). Posthoc testing was accomplished using Dunn's multiple comparison test.

Results

The effects of Ramadan fasting, time of day, and the interaction between these two effects on all variables are shown in table 1. Figures 1–3 show the daily distribution of the parameters during Ramadan (R6, R15 and R28) and recovery (AR), as compared to the baseline day (BR).

Table 1. Summary of ANOVA and Dunn's multiple comparison tests results

	Time effect	Fasting effect (compared to B-R)	Time and fasting interaction effect
Oral temperature	(F = 13.5, p < 0.0001)	(F = 17.1, p < 0.0001)	(F = 4.2, p < 0.0001)
Posthoc Dunn's multiple comparison test			
B-R	p < 0.0001		
R6	p < 0.001	p < 0.0001	p < 0.002
R15	p < 0.001	p < 0.0001	p < 0.001
R28	p < 0.0001	p < 0.0001	p < 0.0001
R-R	p < 0.001	n.s.	n.s.
Global alertness	(F = 3.6, p < 0.007)	(F = 4.6, p < 0.002)	(F = 2.6, p < 0.0003)
Posthoc Dunn's multiple comparison test			
B-R	p < 0.0001		
R6	n.s.	p < 0.01	p < 0.002
R15	n.s.	p < 0.02	p < 0.001
R28	n.s.	p < 0.0002	n.s.
R-R	p < 0.0002	p < 0.02	n.s.
Global mood	n.s.	(F = 8.5, p < 0.0001)	n.s.
Posthoc Dunn's multiple comparison test			
B-R	n.s.		
R6	n.s.	p < 0.01	n.s.
R15	n.s.	p < 0.003	n.s.
R28	n.s.	p < 0.0001	n.s.
R-R	n.s.	n.s.	n.s.
MRT	n.s.	(F = 4.7, p < 0.001)	n.s.
Posthoc Dunn's multiple comparison test			
B-R	n.s.		
R6	n.s.	p < 0.02	n.s.
R15	n.s.	n.s.	n.s.
R28	n.s.	n.s.	n.s.
R-R	n.s.	n.s.	n.s.
CFF	n.s.	n.s.	n.s.

For the posthoc analysis, each fasting period was compared to baseline period before Ramadan.

Oral Temperature (table 1; fig. 1)

ANOVA revealed a significant fasting effect for oral temperature ($p < 0.0001$). The posthoc analysis (table 1) showed that oral temperature changed from BR on R6 ($p < 0.0001$), R15 ($p < 0.0001$) and R28 ($p < 0.0001$).

The time effect was significant for BR ($p < 0.0001$), the fasting days (R6 $p < 0.001$, R15 $p < 0.0001$, R28 $p < 0.0001$ and AR $p < 0.001$). The two-way ANOVA revealed a significant interaction between day and time effects ($p < 0.0001$).

During fasting days, oral temperature significantly decreased at 09.00, 11.00, 13.00, and 16.00 h and significantly increased at 23.00 and 00.00 h. The maximal value was at 16.00 h BR and at 23.00 h during Ramadan. Oral temperature resumed baseline values after Ramadan (AR) (fig. 1).

Global Alertness (table 1; fig. 2)

Global alertness varied with fasting ($p < 0.002$). The posthoc analysis showed that as compared to the baseline

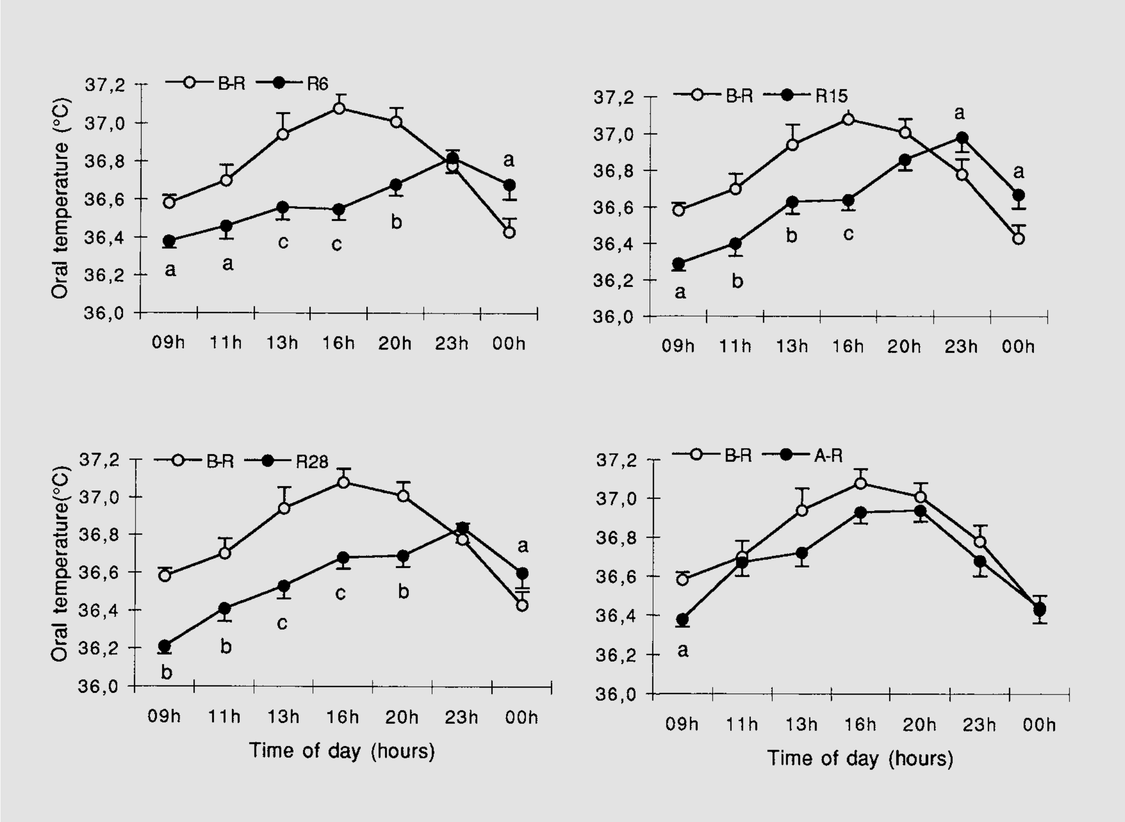


Fig. 1. Mean and SEM of the daytime values of oral temperature during the 6th, (R6) the 15th (R15) and the 28th (R28) days of Ramadan and during the recovery day (AR) 18 days after Ramadan. Each experimental day (solid symbols) was compared to the baseline day: BR (open symbols). [a] $p < 0.05$; [b] $p < 0.01$; [c] $p < 0.001$.

day, global alertness changed significantly during R6 ($p < 0.01$), R15 ($p < 0.02$) and R28 ($p < 0.0002$). The two-way ANOVA revealed an interaction between day and time effects during R6 ($p < 0.0003$) and R15 ($p < 0.001$) (table 1). Global alertness decreased at 09.00 ($p < 0.05$) and 16.00 h ($p < 0.01$) during R6, R15 and R28 and increased at 23.00 h ($p < 0.05$) during R15 (fig. 2).

The time effect was significant only for the BR ($p < 0.0001$). The highest global alertness rating were observed at 09.00 and at 16.00 h and the lowest at 13.00 and 23.00 h.

Global Mood (table 1; fig. 3)

Global mood decreased with fasting ($p < 0.0001$). The time of day effect and the interaction between day and time effects were not significant. Figure 3 shows that as compared to the baseline day, global mood significantly decreased at 09.00 h during R6, R15 and R28 and at 16.00 h during R6 and R28, and did not return to baseline value at 09.00 and 23.00 h during recovery.

Movement Reaction Time (table 1)

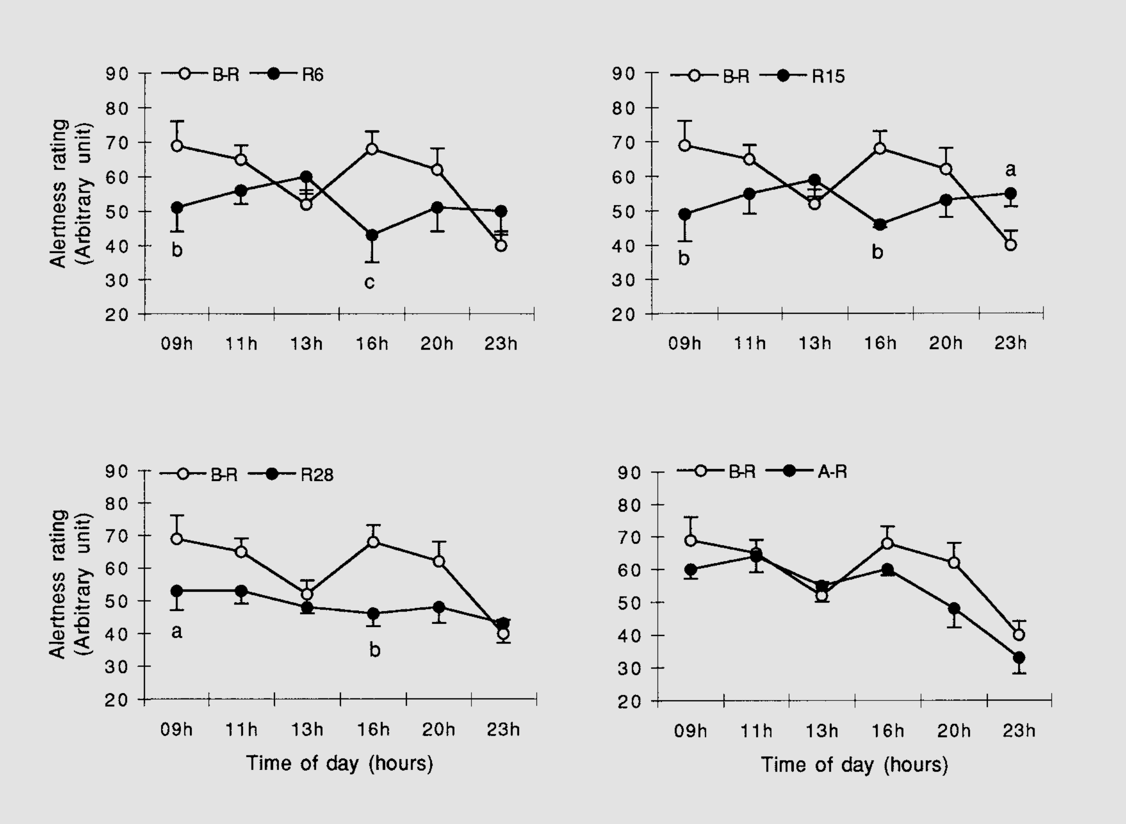
MRT increased significantly ($p < 0.02$) during the first fasting period. Time of day effect was not significant for MRT.

Critical Flicker Fusion

Fasting effect, time of day effect and interactions were not significant for CFF.

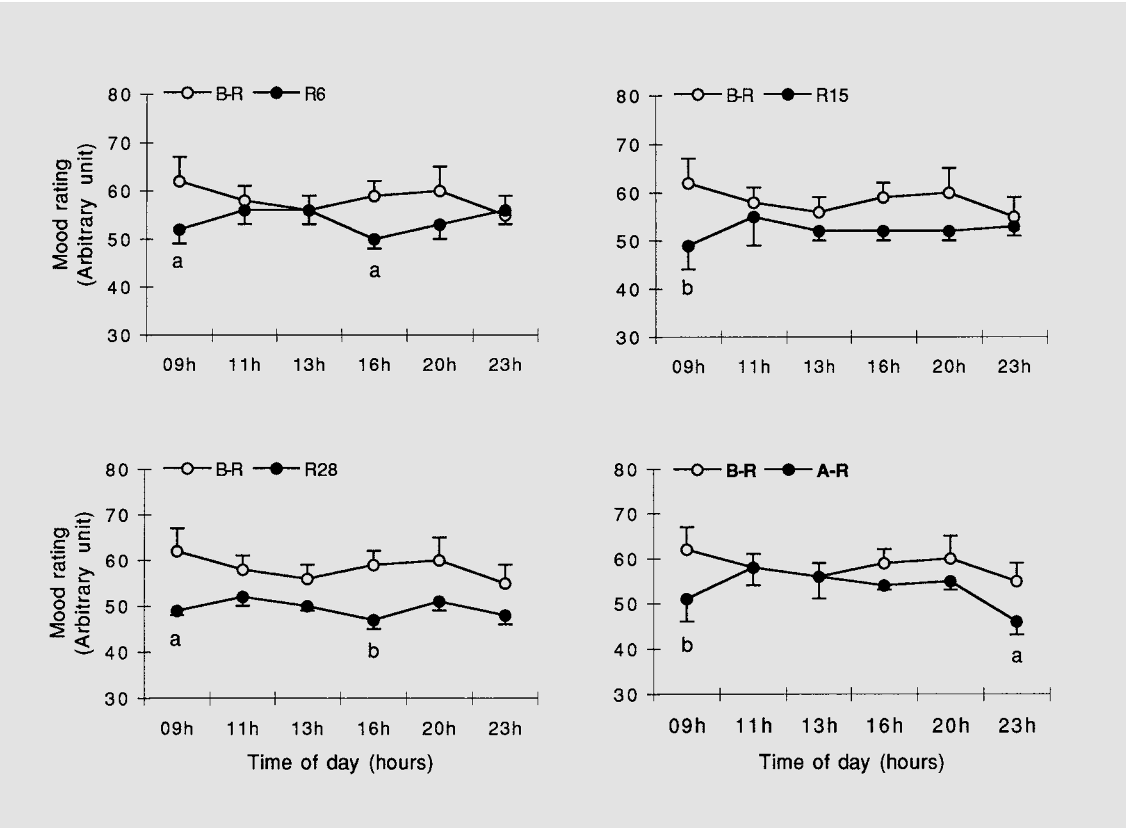
Fig. 2. Mean and SEM of the daytime values of global alertness on the visual analogue scale (VAS) during the 6th, the 15th and the 28th days of Ramadan and during the recovery day (AR) 18 days after Ramadan. Each experimental day (solid symbols) was compared to the baseline day: BR (open symbols). [a] $p < 0.05$; [b] $p < 0.01$; [c] $p < 0.001$.

Fig. 3. Mean and SEM of the daytime values of global mood on the visual analogue scale (VAS) during the 6th, the 15th and the 28th days of Ramadan and during the recovery day (AR) 18 days after Ramadan. Each experimental day (solid symbols) was compared to the baseline day: BR (open symbols). [a] $p < 0.05$; [b] $p < 0.01$.



Alertness rating (Arbitrary unit)
B-R
R6
R15
R28
A-R
a
b
c
Time of day (hours)
09h
11h
13h
16h
20h
23h

2



Mood rating (Arbitrary unit)
B-R
R6
R15
R28
A-R
a
b
Time of day (hours)
09h
11h
13h
16h
20h
23h

3

Discussion

The main finding of this study was that the daily distribution of oral temperature and alertness were affected by Ramadan fasting. Mood was impaired by Ramadan, but did not show a time of day effect. Oral temperature decreased during the daytime and increased during the nighttime. The decrease was more important at 16.00 (–0.5 °C) than at 09.00 h and 11.00 (–0.2 °C) but the daily mean was slightly changed (–0.17 °C).

In normal conditions, body temperature presents a circadian rhythm which is controlled by an autonomic mechanism responsible for the circadian difference in the metabolic rate, which is associated with the endogenous clock [26, 27]. The sleep/wake cycle, the food intake and physical activity affects also the circadian rhythm of body temperature [28–30]. During Ramadan, it appear clearly that meals taken exclusively at night, were responsible for the daytime decrease and the nighttime increase in oral temperature. This hypothesis is supported by the findings of El-Ati et al. [1], who found that the resting metabolic rate and the energy expenditure measured at 3-hour intervals from 08.00 to 23.00 h decreased from 11.00 to 17.00 h. Similarly, Sweileh et al. [6] found that during Ramadan, resting VO_2 decreased in the afternoon but not in the morning. Therefore, the afternoon drop in oral temperature during Ramadan fasting is suggestive of an afternoon decrease in body metabolism which may represent an energy saving mechanism. Moreover, the slight decrease in daily mean of is consistent with the finding that the average daily metabolism rate and energy intake during Ramadan remained comparable with nonfasting days [1].

The nocturnal increase of oral temperature during Ramadan fasting, may explain the delay in sleep schedules as the onset and the duration of sleep depend of the circadian rhythm of body temperature [31]. A drop of body temperature precedes sleep onset by 40 min [32, 33].

Concerning alertness and mood evaluation, the VAS ratings were summed algebraically to give single global values of alertness and mood as described by Monk [23] who demonstrated the sensibility, reliability and validity of this technique in different situations: time of day effect, jet lag and depression. The daily distribution of alertness was affected by Ramadan fasting. The decrease in alertness at 09.00 h could be related to two factors, the delay in rising time, and the absence of breakfast with its usual coffee drink content. Breakfast and caffeine improve performance [34, 35]. During Ramadan, the diurnal fasting prevented the postlunch impairment of alertness observed in habitual conditions. Therefore, the mid day dip in performance depends on meal consumption rather than on the endogenous circadian rhythm as it was also shown by Monk et al. [36]. The 23.00 h improvement of alertness is consistent with the finding that late evening meals improve cognitive performance and mood [37].

The largest decrease in global alertness occurred at 16.00 h, just before the fasting break meal and this decrease was observed throughout the month of Ramadan, suggesting that there was no adaptation to fasting. This result does not confirm the finding of Lagarde et al. [9] who reported that the time-of-day effects on subjective alertness which disappeared during the 2 first weeks of Ramadan, reappeared at the end of this month, suggesting an adaptation to day time fasting at the end of Ramadan.

Changes in oral temperature and alertness were related, since they decreased concomitantly at (09.00 and 16.00 h). Similarly, when oral temperature increased alertness increased at (23.00 h). This result is consistent with the idea that changes in body temperature and alertness are correlated [17].

The concomitant decrease of mood and alertness at 09.00 and 16.00 h during Ramadan may be related to the increase in traffic accident observed in the afternoon during the month [12]. This study may be also relevant in choosing optimal working hours for fasting Moslems.

No change in CFF was found in our study. In the contrary, a decrease in CFF has been demonstrated during Ramadan [8] in 40 young adults assigned randomly to fasting or nonfasting conditions, so that each subject took the test only one time during the entire experiment [8]. In our study, each subject was his own control and took the test 30 times during the experiment which may explain the differences in the results of the two studies.

MRT was increased only at the beginning of Ramadan suggesting that sleepiness during Ramadan fasting is not excessive, since it was demonstrated that subjective measure of sleepiness predict the objective measure only when the sleepiness is excessive [38]. Nevertheless, the use of objectives test such as the Multiple Sleep Latency Test and the spectral analysis of the waking electroencephalogram are needed to confirm this observation.

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