ORIGINAL ARTICLE DOI: https://doi.org/10.31577/ansr.2024.66.3.2

Impact of ramadan on sleep and cognitive functions in adolescents: A quantitative study

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Submitted: 2024-08-12 Accepted: 2024-10-23 Published online: 2024-12-19

Key words: **Ramadan; sleep; cognitive functions; attention; working memory; insomnia; sleepiness; d2-R test; number span**

Act Nerv Super Rediviva 2024; **66**(3): 105–111 ANSR66324A02

Abstract

This study examines the impact of Ramadan fasting and sleep habits on cognitive functions in Moroccan high school students. Carried out over two months, the research involved 140 healthy participants (66 boys and 74 girls) divided into 2 school levels: 67 in the 1st baccalaureate year and 73 in the 2nd baccalaureate year, with an average age of 16.83±0.77 years, from a secondary school in the Skhirat-Temara, region Rabat-Sale-Kenitra. Using the d2-R test, the Trail Making Test (TMT), the digit span test, sleep diaries, and the Epworth Sleepiness Scale (ESS), the study assessed selective attention, working memory, insomnia, and daytime sleepiness during and after Ramadan. The results indicate that Ramadan fasting is associated with a high rate of daytime sleepiness and a reduction in sleep duration, with 75% of adolescents waking up for Suhour. A significant difference was also observed in performance during and after the d2-R tests: accuracy ($p < 0.001$), ability to concentrate ($p < 0.001$), processing speed ($p < 0.001$), or digit span ($p < 0.001$). These results suggest that although Ramadan can affect sleep quality and increase daytime sleepiness, it also leads to impaired attention and working memory.

Introduction

Childhood and adolescence are crucial periods for brain development, with a direct impact on cognitive functions. Cognitive functions can be influenced by various factors, including dehydration (Zhang *et al.* 2019), diet (Wesnes *et al.* 2012), and sleep (Beebe *et al.* 2008). This can lead to physiological and behavioral changes (Lotfi *et al.* 2010; Thomas *et al.* 2020). Muslims, including adolescents who have reached the maturity to fast during Ramadan, practice Islamic fasting, which is one of the five pillars of Islam, throughout the world every year during Ramadan. They abstain not only from eating and drinking between dawn and sunset throughout the month but also from smoking and other specific behaviors (such as sexual activity). (Bouhlel & Shephard 2015). The Ramadan fast is unique due to its intermittent nature;

this month takes place in a different season every nine years, as it follows the Islamic (Hijri) year calendar (lunar system). Ramadan is accompanied by a change in diet and mealtimes, with meals starting at sunset and ending with the "suhoor" at dawn, which represents their last meal before fasting.

Studies have shown that fasting during Ramadan can have contrasting effects on cognitive functions in children and adolescents. Some research suggests that certain cognitive abilities, such as visual learning, working memory, reaction times, and vigilance, may be relatively preserved despite fasting (Chamari *et al.* 2016; Green *et al.* 1995; Miladi *et al.* 2024; Tian, Aziz, Png, Yeo, *et al.* 2011). However, other studies indicate that tasks requiring a rapid reaction, such as the detection and identification of elements, may be affected, resulting in variable performance. (H. Bouhlel *et al.* 2014; Dolu *et al.* 2007; Roky *et al.* 2004; Roky, Iraki, HajKhlifa, Ghazal, *et al.* 2000; Tian, Aziz, Png, Wahid *et al.* 2011).

Studies on cognitive functions present contradictory results. Some studies show a deterioration in psychomotor performance, subjective alertness, and memory, while others suggest a relative resistance to memory. Other studies have pointed out that cognitive functions are also subject to the influence of circadian rhythm, including the sleep-wake cycle (Khemila *et al.* 2023; Ruiz-Gayo & Olmo 2020). In this sense, it has been observed that cognitive performance oscillates according to different temporal periodicities.(Khemila *et al.* 2023; Kline *et al.* 2010).

Studies on the impact of fasting during Ramadan on the cognitive functions of young people show very varied results. This variability can be attributed to several distinct methodological factors. Firstly, the diversity of measurement tools used to assess cognitive functions plays a crucial role. Secondly, the precise time at which the assessments are carried out during Ramadan can also influence the results. In addition, the age, sex, and sporting habits of the participants are all variables that can modulate the impact of fasting.

Most research focuses on the impact of adolescent fasting on physical ability. (Aloui *et al.* 2013) Only one study to date has examined the effects of fasting on cognitive function for these adolescents (Farooq *et al.* 2015). This lack of data highlights the importance of further research to better understand how Ramadan fasting affects cognitive function in adolescents, particularly during school periods.

In conclusion, the effects of fasting on young people's cognitive functions remain complex and require further research to understand the underlying mechanisms. Further studies are crucial to identify the factors influencing these contrasting results and to develop strategies to minimize the potential negative impact of fasting on young people's cognitive abilities.

Our study aims to examine the impact of Ramadan fasting on cognitive function, taking into account the influence of circadian rhythms, sleep composition, duration, and the practice of waking for suhoor. We plan to carry out tests both during and after the holy month of Ramadan to assess the influence of fasting on cognitive functions, in particular selective attention and working memory.

Materials and methods

Location and duration of the study

The study was carried out in a Moroccan secondary school that qualifies students and is located in the province of Skhirat-Temara in the Sale-Rabat-Kenitra region in central Morocco. The study lasted 2 months.

The subject of the study

A group of 140 participants in good health (66 boys, 74 girls) divided into 2 school levels 67 in 1ére baccalaureate year and 73 in 2nd baccalaureate year, with an average age of 16.83±0.77 years, took part in this study. Inclusion and exclusion criteria were established to provide a representative sample of the general population.

• **Inclusion criteria**

Qualifying secondary school students aged between 15 and 19, studying at a state school. All the participants were practicing Muslims and were aware of the requirements of Ramadan, and all the girls were outside their period.

• **Exclusion criteria**

Uncorrected visual impairment, history of neurological disease (stroke or head injury), use of medication that may cause attention deficit and/or drowsiness, severe depression, or unstable mental illness.

Duration of the study

The experiment took place during and after the month of Ramadan in 2024, from 12 March to 28 April. Participants were assessed twice: once during the first half of Ramadan and once after the end of Ramadan.

Tools used

• **Trail-making Test**

The Trail Making Test (TMT) (Battery 1944) is a standardized tool used to assess executive functions, in particular cognitive flexibility, information processing speed, and mental flexibility (Tombaugh 2004).

The TMT consists of two parts:

Part A (TMT-A): The participant must connect, as quickly as possible, a series of circles numbered from 1 to 25, arranged in a semi-random fashion on a sheet of paper. A pre-test of six items is carried out beforehand to ensure that the instructions have been understood. The time taken to complete the task is measured in seconds.

Part B (TMT-B): The participant must connect, as quickly as possible, a series of circles containing numbers (1 to 13) and letters (A to L), arranged in a semi-random fashion. The task was to link the

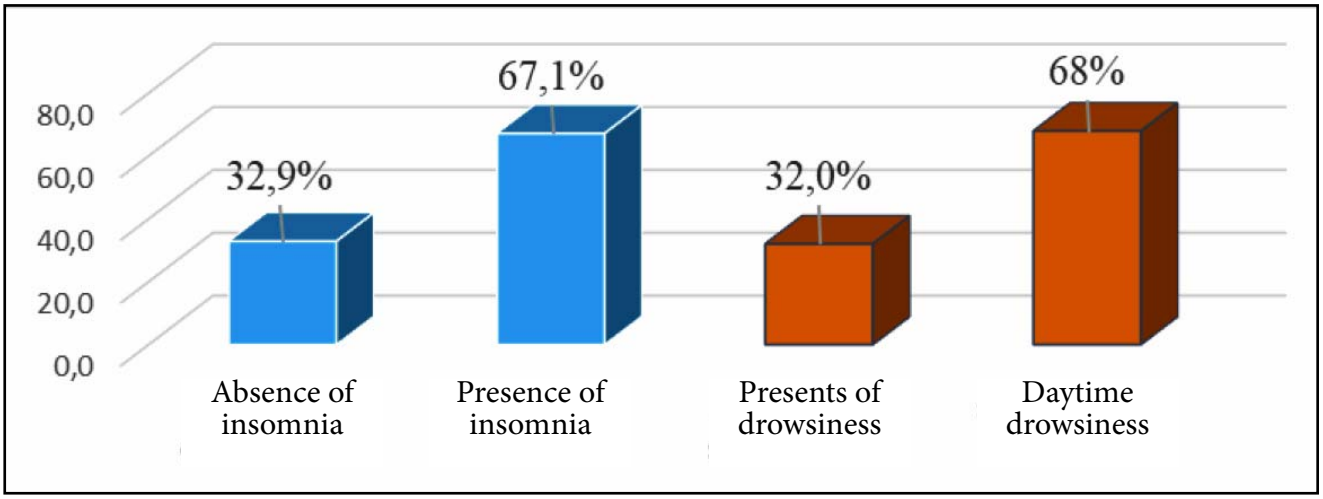

Fig. 1. Percentage distribution of insomnia and sleepiness in the month of Ramadan

elements in numerical and alphabetical order, alternating each time between a number and a letter. A pretest of six items was carried out beforehand to ensure that the instructions had been understood. The total completion time for parts A and B is recorded in seconds, representing the respective scores.

• **The Insomnia Severity Index (ISI)**
The Insomnia Severity Index (ISI), developed by (Morin 1993), is a self-administered questionnaire that measures the severity of subjective symptoms of insomnia, the consequences for daily functioning, and the level of anxiety associated with sleep disorders. Comprising seven items rated on a scale of 0 to 4, the ISI classifies individuals according to the severity of their insomnia (absence, subclinical, moderate, or severe). The total score, obtained in less than a minute, ranges from 0 to 28. The ISI, available in three versions (patient, clinician, and family member), is a quick and easy-to-use tool whose content corresponds in part to the diagnostic criteria for insomnia (Wagner *et al.* 2011). The ISI is widely used in clinical studies of insomnia as a measure of response to treatment.

• **The Epworth Sleepiness Scale (ESS)**
Daytime sleepiness during Ramadan was assessed using the Epworth Sleepiness Scale (ESS), an 8-item validated questionnaire that assesses the likelihood of falling asleep during certain activities. (Johns 1991). The questionnaire asks subjects to rate their likelihood of falling asleep on a scale of increasing probability from 0 to 3 for eight different situations that most people encounter in their daily lives. The score ranges from 0 to 24 and a score of ≥ 10 indicates increased daytime sleepiness.

• **Number span test**
The number span test is a test used in cognitive psychology to assess a person's ability to maintain and mentally manipulate a series of numbers. The participant listens to a series of numbers presented by the examiner. The series can vary in length, for example, from three to nine digits. After hearing the series, the participant must repeat it in the correct order. The participant's score is determined by the number of series he or she has correctly repeated or manipulated.

• **Concentrated Attention Test - Revised D2-R**
We administered the revised version of the d2-R test (Brickenkamp *et al.* 2010) to classes of approximately 38 students each in quiet classrooms at school. All pupils were informed that participation in the test was voluntary and that they could stop whenever they wished. They were then given a double-sided sheet of paper (containing a few questions about their profile, instructions on one side, and the d2-R test on the other). The test was carried out using a red biro (adapted to the optical reading system). The test consisted of 798 items, divided into 14 lines of 57 characters each. Each line contained the letters "d" or "p" with or without dashes (0 to 4). The task was to cross out the target objects of the test ("d" with two dashes, "3 types"), the others being used as distractors. The processing time for each line was set at 20 s, and the test was carried out without a break (4 minutes, 40 seconds). Participants were reminded to work from left to right, to start working on the next line as soon as they received the instruction "stop, next line," and to work as quickly as possible without making any mistakes. When the participants crossed out the incorrect objects (non-target objects), they were allowed to cross them out again (by making a choice). The whole experiment, including instructions, exercises, and the task, lasted about 20 minutes. The data were processed according to the following scoring indices:
• Concentration capacity (CC)
• Treatment rate (CCT)
• Accuracy (E%)

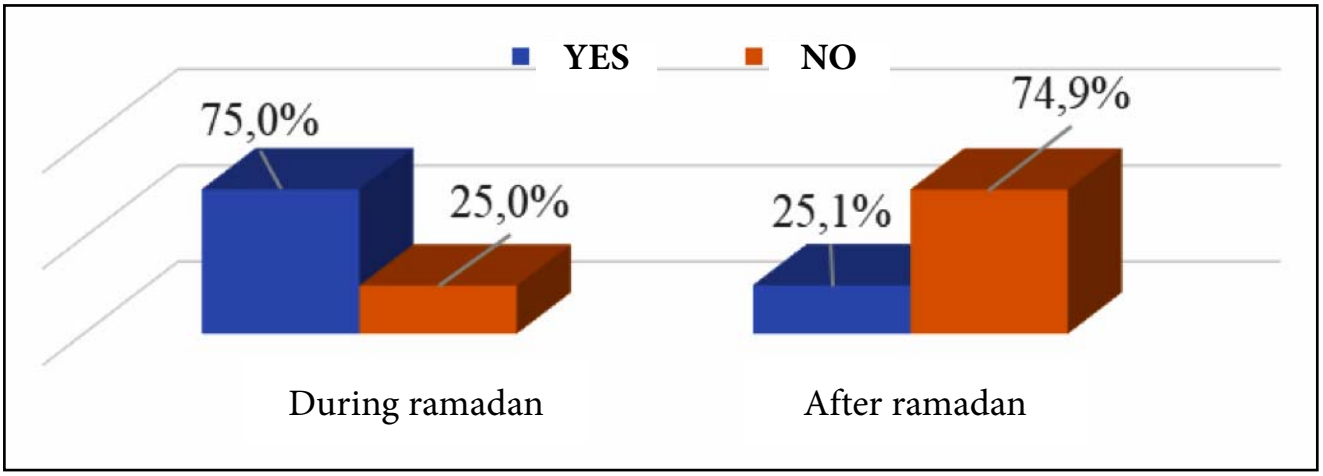

Fig. 2. Distribution of the sample according to waking up at suhoor during the month of Ramadan and waking up after the month of Ramadan

– A sleep diary was used to record bedtimes, waking times, and total sleep time each night during the study period.
– The study looked at the participants' sleep habits, asking them about waking up for Suhour (pre-dawn meal) during Ramadan and waking up at night after the end of the holy month.

Statistical analysis
Data were analyzed using SPSS statistical software. Paired-sample t-student analysis was used to compare performance on the d2R Test, digit span, ESS, insomnia, and sleep duration during Ramadan and the following month.

Results

A total of 140 healthy adolescents aged between 16 and 19 (mean age 16.82 ± 0.76) took part in the study. The sample comprised 66 boys (47.1%) and 74 girls (52.1%). Concerning their level of education, 67 adolescents (47.9%) were in their first year of secondary school, and 73 (52.1%) were in their second year of secondary school.

An analysis of insomnia and sleepiness scores among adolescents reveals that the majority (67.1%) suffer from insomnia, and 68% have daytime sleepiness. Conversely, only 32.9% of adolescents do not suffer from insomnia, and 32% do not suffer from daytime sleepiness.

Interestingly, there was a noticeable change in participants' sleep habits between the month of Ramadan and the following month. Whereas 75% of participants woke up for Suhour during Ramadan, this percentage reverses drastically after the holy month, with only 25.1% waking up during the night.

D2-R test :
- Accuracy: The mean accuracy scores were significantly ($p < 0.05$) higher during the month of Ramadan (58.83% ± 60.15%) than after (28.54% ± 33.26%).
- Concentration: The average concentration scores were significantly lower during the month of Ramadan (73.91 ± 85.82) than after (147.29 ± 72.937) with ($p < 0.05$).
- Treatment rhythm: The mean treatment rhythm scores were significantly lower during the month of Ramadan (220.04 ± 67.18) than after (239.76 ± 52.10) with ($p < 0.05$).

TMT test
The mean scores of the two parts of the TMT test (TMT A and TMT B) were significantly higher during the month of Ramadan (29.62 ± 9.28; 84.61 ± 45.72) than after (23.61 ± 7.84; 59.86 ± 22.67) with ($p < 0.05$).

Direct digit span test
The mean score of the direct digit span test was significantly lower during the month of Ramadan (4.15 ± 0.96) than after (4.86 ± 1.183) with ($p < 0.05$).
Hours of sleep: Average hours of sleep were significantly shorter during the month of Ramadan (6h06 ± 1.32) than after (7h19 ± 1.21) ($p < 0.05$).

Discussion

This study highlights the significant impact of the month of Ramadan on various cognitive aspects and the sleep habits of adolescents. It reveals a notable prevalence of insomnia and daytime sleepiness, suggesting widespread sleep disturbances among this population. Research by (Carskadon *et al.* 1993) also showed that from the age of 13 onwards, daytime sleepiness appears to a greater extent than in pre-adolescents. This is due to a reduction in sleep time in adolescents, who lose an average of two hours between the ages of ten and 20, going from nine to seven hours of sleep, even though adolescents need at least eight and a half hours of sleep (Carskadon *et al.* 1998).

This sleep disturbance is more pronounced during the month of Ramadan (Margolis & Reed 2004; Taoudi

Tab. 1. Distribution of the means of the d2-R test, TMT test, digit span test, and the number of hours of sleep during and after Ramadan.

	Variables	Mean ± Standard deviation	*t*	*Sig.*
D2-R	Accuracy (E%) (R)	58.83 % ± 60.15 %	6.87	.000
	Accuracy (E%) *AFT* (R)	28.54 % ± 33.26 %		
	Concentration capacity (R)	73.91 ± 85,82	-11.70	.000
	Concentration capacity *AFT* (R)	147.29 ± 72,937		
	Treatment rate (R)	220.04 ± 67,18	-3.81	.000
	AFT (R) treatment rate	239.76 ± 52,10		
TMT	TMT-A (R)	29.62 ± 9,28	7.87	.000
	TMT-A *AFT* (R)	23.61 ± 7,84		
	TMT-B (R)	84.61 ± 45,72	6.43	.000
	TMT-B *AFT* (R)	59.86 ± 22,67		
	Number range (R)	4.15 ± 0.96	-6.53	.000
	Range of *AFT* (R) digits	4.86 ± 1.18		
	Number of hours of sleep (R)	6h06 ± 1.32	-8.65	.000
	Number of hours of sleep *AFT* (R)	7h19 ± 1.21		

** (R): during the month of Ramadan*
** AFT (R): after the month of Ramadan*

Benchekroun *et al.* 1999), where 75% of participants wake up for Suhur, which influences and reduces the duration of nocturnal sleep, as fasters tend to delay bedtime and wake up for the Suhur meal, which takes place before dawn, adding that the delay in sleep and its reduced duration are due to the large quantities of food consumed late at night (Bogdan *et al.* 2001). As a result, sleep loss can induce changes in sleep composition and promote daytime sleepiness (Roky, *et al.* 2000). Numerous studies have shown that sleep disorders in adolescents are often associated with an increase in anxiety and depressive disorders, as well as behavioral problems (Aronen *et al.* 2000; Moo-Estrella *et al.* 2005; Morrison *et al.* 1992).

In terms of measured cognitive performance, the data show significant variations during and after Ramadan. In particular, mean accuracy scores were higher during Ramadan than after Ramadan, suggesting a potential increase in the number of errors and omissions of stimuli under conditions of fragmented sleep and food deprivation and their influences on vigilance; sleep deprivation leads to slower reaction times and attentional deficits (Dinges *et al.* 1997; Massar *et al.* 2019); and tasks dependent on speed and precision are negatively affected in the event of fluid deprivation (Petri *et al.* 2006). Similarly, in sleep-deprived subjects, blood oxygenation level-dependent functional MRI (BOLDfMRI) studies show a decrease in global and task-specific brain activation during cognitive activity (Mu *et al.* 2005).

On the other hand, concentration capacity and processing speed were significantly lower during Ramadan than afterward. This indicates that the fragmentation and disruption of sleep and changes in eating habits may alter these aspects of cognitive performance. These factors can be added to others that have a negative effect on cognitive functions, including circadian rhythm shifts and motivational disorders, as well as the dehydration and drop in blood sugar levels that are inevitable during Ramadan. (Bouhlel & Shephard 2015). The results of the TMT test, which assesses cognitive flexibility and processing speed, also show significant differences between the two periods, with a higher marked time in the Ramadan period. A slowdown in the performance of part B of the Trail Making Test in the Ramadan period compared to after may reflect a variety of cognitive difficulties. These may include obstacles in the ability to adapt and change strategy (flexibility), to organize and sequence actions (planning), to control habitual or impulsive responses (inhibition), or to execute movements fluidly and quickly (motor speed). (Lezak 2004). The causes are probably multiple: metabolic, mainly due to hypoglycemia, which itself generates functional disorders such as headaches; disruption of the circadian rhythm of sleep, eating habits, etc.; and a lack of physical activity. (El Moutawakil *et al.* 2007). Several studies carried out on non-athletic subjects have revealed significant decreases in objective (Ain-Fares 1989) and subjective (Roky *et al.* 2000) vigilance, as well as decreases in memory (Hakkou *et al.* 1988) and attention (El Moutawakil *et al.* 2007). Mathematical capacity, short-term working memory, perceptual discrimination, and hand-eye coordination are all affected by dehydration levels of between 1% and 4 (Gopinathan *et al.* 1988; Sharma *et al.* 1986). This is consistent with our results, where the direct digit span test revealed that short-term memory capacity is affected, with a lower average

during Ramadan than after the effect of disturbed sleep. The idea is that it is the structured sequence of the various sleep phases throughout the sleep cycles, rather than a particular phase, that is beneficial for memory enhancement. (Giuditta *et al.* 1995).

Conclusion

This study highlights the significant impact of the month of Ramadan on sleep and cognitive performance in adolescents. Fasting during Ramadan leads to a notable prevalence of insomnia and daytime sleepiness, exacerbating the sleep disturbances already present in adolescence. In addition, Ramadan appears to adversely affect various aspects of cognitive performance, including accuracy, concentration, processing speed, flexibility, and working memory. These changes are probably due to a combination of factors, including sleep fragmentation, changes in eating habits, dehydration, and lower blood sugar levels. However, it is important to note that these results are based on a single study and that further research is needed to confirm these findings and further explore the effects of Ramadan fasting on cognitive health and sleep in adolescents.

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