Joint consensus statement of the Saudi Public Health Authority on the recommended amount of physical activity, sedentary behavior, and sleep duration for healthy Saudis: Background, methodology, and discussion

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Abstract:
The Saudi Public Health Authority recently prepared a Consensus Statement regarding how much time a person should spend engaged in physical activity, sedentary behavior, and sleep to promote optimal health across all age groups. This paper describes the background literature, methodology, and modified RAND Appropriateness Method and Grading of Recommendations Assessment, Development, and Evaluation (GRADE)-ADOLOPMENT approach that guided the development process. A Leadership Group and Consensus Panels were formed, and credible existing guidelines were identified. The Panel identified clear criteria to choose the best practice guidelines for the set objectives after evaluation, based on GRADE table evidence, findings table summaries, and draft recommendations. Updating of the selected practice guidelines was performed, and the Consensus Panels separately reviewed the evidence for each behavior and decided to adopt or adapt the selected practice guideline recommendations or create de novo recommendations. Data related to cultural factors that may affect the studied behaviors, such as prayer times, midday napping or “Qailulah,” and the holy month of Ramadan, were also reviewed. Two rounds of voting were conducted to reach a consensus for each behavior.

Keywords:
Adults, Grading of Recommendations Assessment, Development and Evaluation-ADOLOPMENT, infants, preschoolers, public health recommendations, toddlers

International studies have consistently shown that daytime movement behaviors – involving not only physical activity, but also sedentary behavior and sleep duration – are major health indicators. [1-3] These behaviors are strongly interrelated; however, several guidelines regarding factors associated with movement focus on each activity separately, which, when taken in isolation, may be insufficient for the purpose of developing and implementing recommendations needed to achieve optimal physical and mental health. A consolidated approach considers overall...
activity across 24 h and accounts for periods of physical activity, sedentariness, and sleep.

Current evidence supports the need for regular and adequate physical activity and sleep duration as a means to longer and healthier lives and disease prevention.\cite{1,2,4} Physical activity may decrease cardiovascular risks, improve lipid profile, control Type 2 diabetes, prevent the incidence of certain types of cancer, increase bone density, improve psychological health, cognitive function, and well-being, and reduce mortality.\cite{9} In addition, regular physical activity may decrease inflammatory responses throughout the body. It has been established that inflammation can increase the risk of heart diseases – it accelerates aging and depression and can also lead to major neurocognitive disorders.\cite{5} Physical activity can also improve brain health and neuroplasticity and enhance cognitive function.\cite{6} Moreover, it may improve learning and cognitive function in children as well.\cite{7}

On the other hand, sedentary behavior is a significant factor associated with several noncommunicable diseases and total mortality.\cite{3,5} It is estimated that sedentary behavior is globally responsible for 9% of premature mortality, or more than 5.3 million deaths annually.\cite{8} According to the WHO’s global statistics, one in four adults is not active enough, and more than 80% of the world’s adolescent population is not sufficiently physically active.\cite{9} Several studies have linked sedentary behavior to cardiometabolic biomarkers such as increased waist circumference, triacylglycerol and HbA1c levels, and systolic blood pressure and decreased high-density lipoprotein cholesterol levels; it is also associated with increased risk of metabolic syndrome and diabetes.\cite{9,11} A meta-analysis has also reported evidence of a significant positive association between sedentary behavior and the risk of type 2 diabetes and all-cause mortality.\cite{12}

Insufficient sleep or irregular sleep patterns have also been linked to increased morbidity and mortality.\cite{13-15} For instance, sleep deprivation or short sleep duration has been found to be associated with greater risks of developing heart diseases,\cite{16} stroke,\cite{17} type 2 diabetes,\cite{18} hyperlipidemia,\cite{19} high blood pressure,\cite{20} cancer,\cite{21} systemic inflammation,\cite{22} and obesity.\cite{23,24} Not getting the required amount of sleep can lead to dangerous health outcomes that may affect almost all bodily organs and systems, such as cognitive impairment, poor academic performance, hypertension, and insulin resistance, in addition to other health problems.\cite{25} The body’s immune system is negatively affected by inadequate sleep, in addition to an increase in systemic inflammation, inflammatory marker levels, and the occurrence of hormonal disturbances. Evidence suggests that insufficient sleep alters gene expression in the human blood cells and decreases circadian rhythm amplitude in gene expression. Furthermore, shorter sleep duration is associated with increased mortality, increased risk of motor vehicle accidents and industrial accidents, and deteriorating job performance.

According to national population-based data, Saudi Arabia has one of the lowest physical activity rates and the world’s highest sedentary behavior rate.\cite{26} In addition, local-level studies have demonstrated that Saudi Arabia has one of the lowest levels of nocturnal sleep duration.\cite{27-31}

A few countries have developed specific 24-h movement guidelines regarding regular physical activity, screen time, and sleep for subjects in their early years, children and adolescents, adults, and older adults. However, there are no practice guidelines for the regulation of physical activity, sedentary behavior, and sleep over 24 h for all age groups in Saudi Arabia. Furthermore, Saudi Arabia is culturally different from Western countries, and national practice guidelines need to account for cultural factors, such as prayer times, the Ramadan month, and the habit of siesta (midday napping or “Qailulah”), that may affect behavior. This calls for the urgent need to establish specific Saudi 24-h Movement Practice Guidelines. Such guidelines will help healthcare providers prescribe the optimal amount of daily physical activity and sleep to promote a healthier lifestyle. In addition, public policy initiatives addressing worker fatigue and transportation safety are similarly hampered by the absence of evidence-based national practice guidelines that address healthy habitual physical activity and sleep duration. Local health societies and organizations have repeatedly stressed the importance of increasing physical activity, reducing sedentary behavior, and getting adequate sleep for good health; however, their message is undermined by the lack of national guidelines for physical activity, sedentary behavior, and healthy sleep duration. Therefore, health practitioners, public policymakers, and public health activities would benefit from these evidence-based guidelines and recommendations addressing the daily levels of physical activity, sedentary behavior, and sleep needed to support optimal health and functioning.

This paper describes the background literature, methodology, and modified RAND Appropriateness Method (RAM) and Grading of Recommendations Assessment, Development, and Evaluation (GRADE)-ADOLOPMENT approach that guided the development process. The recommendations are published in a concomitant paper in this issue of the Journal.\cite{22}
Methods

Working committees and their roles

In February 2020, the Saudi Public Health Authority constituted a National Committee to develop the 24-h Movement Practice Guidelines for Saudi Arabia by integrating the relevant information on physical activity, sedentary behavior, and sleep duration. The committee comprised seven-panel members from various specialties (physical activity specialists, exercise physiologists, epidemiologists, nutrition and diet experts, sleep medicine specialists, and guideline-development methodologists) and was supported by three subcommittees (Core Panels) for each addressed topic.

The development process for each practice guideline involved two interdependent groups: a Core Panel and an Expert Panel. The Core Panel guided the Expert Panel through the voting process (in accordance with the RAM) and provided formulated recommendations to it. The Expert Panel used the data and evidence provided by the Core Panel to come to a consensus.

The Saudi Public Health Authority was responsible for communications, logistics, and final approval of guideline topics. The National Committee was responsible for supervising each guideline's development, communicating with the guideline panels, conducting the literature searches, updating the systematic review-related information, and chairing the guideline panel meetings.

The guideline core panel members were involved in:

- Prioritization of questions related to the guideline topics
- Formulation of recommendations for physical activity, sedentary behavior, and sleep duration for healthy children, adolescents, adults, and older adults during panel meetings and drafting a practice guideline manuscript for peer-reviewed publication. Summaries of the guideline development process were narrated through online presentations
- Formulation of recommendations regarding unique cultural and religious factors that may affect nighttime sleep duration, such as prayer times, daytime napping, and the Ramadan month.

Research questions defined by the Core Panel committees for physical activity, sedentary behavior, and sleep duration with respect to their duties

- Question 1: What is the dose (i.e., duration, frequency, intensity, and type) of physical activity, as measured using both objective and subjective methods, needed for optimal health?
- Question 2: What is the dose (i.e., duration, patterns [frequency, interruptions], and type) of sedentary behavior, as measured using both objective and subjective methods, needed for optimal health?
- Question 3: What is the nocturnal sleep duration needed for optimal health?

The Grading of Recommendations Assessment, Development, and Evaluation-ADOLOPMENT method

One way of developing guidelines is to use the work of previously established societies. This “GRADE-ADOLOPMENT” methodology detailed by Schünemann et al. in 2017[33] combines the advantages of adoption, adaptation, and de novo development of recommendations based on the GRADE evidence to decision frameworks.

Due to time restraints, the panel agreed to limit the selected practice guidelines to the best available guidelines that addressed the research questions. The screened guidelines were evaluated using the Appraisal of Guidelines for Research and Evaluation II (AGREE II) instrument, and the practice guidelines that received the highest quality scores based on this instrument were chosen for the adaptation process. A guideline methodologist Ali M. Dobia (AMD) was also invited to be part of the guideline development team.

Moreover, each of the selected practice guidelines was updated by reviewing published systematic reviews and conducting systematic reviews of randomized controlled trials (RCTs) published after the adopted practice guidelines.

A systematic search of RCTs and non-RCTs and observational studies was performed for cultural factors that may influence nocturnal sleep duration (i.e., prayer times, naps, and the Ramadan month) as well.

Figure 1 presents the timeline and sequence of steps involved in the development of the Saudi 24-h Movement Guidelines.

Searching for guidelines and other relevant evidence

Core Panel members performed a systematic search using Medline/PubMed and Scopus to find all pertinent articles and practice guidelines published from January 2015 to April 2020 for presentation to the panel members. The keywords for each topic used in the search strategy were as follows:

- Physical activity and sedentary behavior: “physical activity,” “physical activity guidelines,” “movement guidelines,” “chronic diseases,” “review,”
Eligibility criteria for the adopted practice guidelines

The Core Panels for each topic decided to include structured practice guidelines that were based on systematic reviews of the related research evidence. The following criteria were used to select the adopted practice guidelines: (1) published in the past 5 years; (2) addressed the research questions (covered all Population, Intervention, Comparator, and Outcome [PICO] elements); (3) followed the GRADE process; and (4) included existing and accessible GRADE tables and summaries of findings.

Information about the evidence-based methods used in the practice guidelines was obtained from the Methods sections and search strategies reported in the guidelines and grading strength of evidence.

The selected practice guidelines

For physical activity, the Core Panels adopted the UK Chief Medical Officers’ Physical Activity Guidelines and supplemented them with Canadian and US Practice Guidelines to cover all age groups when needed, as these guidelines met the criteria set by the panel.[34-37] The panel used eight health indicators – adiposity, motor development, psychosocial health, cognitive development, fitness, bone and skeletal health, cardiometabolic health, and risks/harm.[3,5,6] The Saudi physical activity guidelines have been developed based on national evidence from the literature, including systematic review, RCTs, as well as recently available reports from the General Authority of Statistics, and were reviewed by the physical activity Consensus Panel. The selected guidelines and evidence were appraised by three independent reviewers based on the AGREE II instrument. Thereafter, the scores for each guideline were aggregated, and the highest scoring guideline in each age group was selected for guideline adaptation. In addition, the culture of the Saudi population, related to religion and lifestyle, was considered while adapting the selected physical activity recommendations.

For sedentary behavior, the Core Panels adopted the Australian 24-h Movement Guidelines for the Early Years (birth to 5 years), the Australian 24-h Movement Guidelines for Children (5–12 years) and Young People (13–17 years), and the UK Chief Medical Officers’ Physical Activity Guidelines,[34,36,39] as these guidelines met the criteria set by the Panel. The Panel used the following health indicators: adiposity, motor development, psychosocial health, cognitive development and performance, fitness, bone and skeletal health, cardiometabolic health, cancer, pain, mortality, and risks/harm.

For sleep duration, the draft “Recommended amount of sleep for healthy adult and pediatric populations: A joint
A conditional recommendation was indicated between brackets after the recommendation.

**Preparing the draft-adopted guidelines**

A qualitative exploratory descriptive study was conducted to integrate the cultural factors and local customs based on the available data. In addition, the chosen guidelines were not the only sources used. Specifically, new updates from published systematic reviews and RCTs published after the publication of the adopted practice guidelines were used to develop a thorough guideline that accounted for new updates and cultural factors [Figure 2]. The search was restricted to studies conducted in human adults and published in English. Systematic reviews of longitudinal studies and RCTs published after the publication of the adopted practice guidelines were performed [A summary of the studies is available in Supplement I].

Similar work was carried out for all studies that assessed the interaction between sleep and Ramadan, sleep and prayer times, and sleep duration and daytime naps [Supplement II].

The Core Panel members for each topic developed expository drafts of the proposed guidelines in each field (physical activity, sedentary behavior, and sleep duration). Thereafter, the organizing committee clarified

The Grading of Recommendations Assessment, Development, and evaluation recommendation system

The following criteria were used to grade the evidence:
- Category A: RCTs (with narrow confidence intervals)
- Category B: Low-quality RCTs
- Category C: Nonrandomized trials and observational studies
- Category D: The Saudi Public Health Authority Expert Panel consensus judgment. This category was only used when insufficient evidence was available in the literature and the provision of a recommendation was considered important.

Although the level of recommendation confidence is a continuum, the GRADE system describes two levels of evidence: “strong” and “conditional.” When feasible, we indicated the level of evidence.

A “strong” recommendation was defined as a recommendation when the panel was confident that the desirable effects of adherence to the recommendation outweighed the undesirable effects. A “conditional” recommendation was defined as a recommendation when the panel inferred that the desirable effects of adherence to the recommendation probably outweighed the undesirable effects, but the panel was not confident about the trade-offs.

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Figures:
- **Figure 2:** Integrating the recommendations extracted from the literature review, selected practice guidelines, recommendations from randomized controlled trials and systematic reviews published after the selected practice guidelines, and Expert Panel judgments.
all ambiguous and incomprehensible phrases, removed redundant sentences, and ensured the overall coherence of all practice guidelines. The panel also took into consideration the traditions and culture of Saudi Arabia.

**Expert Panel selection**

The main selection criteria considered for selecting the expert panelists were acknowledged leadership in the panel member’s specialty, absence of conflicts of interest, regional diversity (when feasible), and diversity of practice settings (academic vs. clinical practice). The experts were not chosen just because they were easily accessible or friendly.[42] The Expert Panels permitted sufficient diversity while ensuring that all members had a chance to participate.[42] This, of course, depended on the availability of specialists in each of the three addressed specialties (names of the experts are included in the Acknowledgment Section). For the physical activity Expert Panel, the panelists included specialists in exercise science, physical therapy, physical education, and exercise physiology, clinical specialists from the leading institutions in Saudi Arabia, and a research methodology expert. For the sedentary behavior Expert Panel, the panelists included specialists in sedentary behavior, exercise science, physical therapy, physical education, and exercise physiology, clinical specialists from leading institutions in Saudi Arabia, and a research methodology expert. For the sleep duration Expert Panel, the panelists included experts in sleep medicine and related specialties (family medicine, psychiatry, child development, and behavioral sleep medicine), clinical specialists from the leading institutions in Saudi Arabia and the Saudi Sleep Medicine Group, and a research methodology expert.

**The modified RAND appropriateness method**

Consensus on the formulated recommendation was reached using the RAM, wherein experts used the current scientific evidence in conjunction with expert opinion to reach an agreement.

The RAM utilizes crucial scientific literature, together with two turns of voting (the first of which was anonymous), to establish agreement on the suitability of approval and to avoid any ego effects or dominance that might impact the group decision-making process.

**Round 1 voting**

In round 1, the Expert Panel members received the recommendations via an online link and were asked to rate each recommendation’s appropriateness (on a 1–5 Likert scale). They did not interact to ensure that there was no interference during voting. However, they were allowed to use the synthesized evidence provided by the Core Panel overseeing the consensus process. An Expert Information Sheet was sent to the participants in the Expert Panel for each topic (specialty) by e-mail and WhatsApp to give a brief overview of the project to all selected experts who agreed to participate in both voting rounds.

The Saudi Public Health Authority Ethics Committee approved the RAM study before its first round was initiated (approval number SCDC-IRB-A013-2020). Expert Panel member participation in the two rounds was considered as consent.

Members of each Core Panel reviewed the results of round 1 voting and the available evidence, and the Expert Panel members were provided with feedback to refine their answers. This iterative process was used to guarantee credibility.

**Round 2 voting**

Round 2 voting aimed to give the Expert Panel members the chance to discuss their ratings face to face over 1 day after considering their knowledge of how all the other experts had rated. Round 2 voting was conducted via a Zoom meeting and was led by an experienced moderator for each discussed topic. The moderator focused on recommendations where there was significant disagreement in the experts’ ratings to find out whether there was genuine clinical disagreement about appropriateness or if there was a problem with the rating structure.[42]

**Data analysis for rounds 1 and 2**

The answers were aggregated, and frequencies and percentages were calculated for the answers using the online questionnaire itself before the data were tabulated with the qualitative responses as feedback for round 2.

Each indication was classified as “appropriate,” “uncertain,” or “inappropriate” for the procedure under review in accordance with the experts’ median score and the level of disagreement among the experts. Indications with median scores in the 1–2 range were classified as inappropriate and those in the 4–5 range as appropriate; a score of 3 was classified as uncertain. Each statement that achieved 80% or higher from the summation of scores 4 and 5 on the Likert scale was considered to be in agreement. Consensus was defined as an 80% or higher agreement.

**After round 1**

For physical activity, one recommendation had <80% agreement in round 1, and the rest scored above 80%.

For sedentary behavior, 13 out of 16 statements achieved 80% or higher agreement. Three statements received a score <80% agreement – statement 2 received 64% agreement; statement 3 received 75% agreement; and statement 9 received 73% agreement.
For sleep duration recommendations, all statements achieved 80% or higher agreement.

After round 2
For physical activity recommendations, all statements achieved more than 80% agreement.

For sedentary behavior, all recommendations achieved more than 80% agreement.

For sleep duration recommendations, all statements achieved 90% or higher agreement.

Voting in the second round led to the establishment of the final Consensus Recommendations. After all panel members approved the phrasing and language of the final statements, they were submitted to the Saudi Public Health Authority Boards of Directors for their endorsement.

Summary of Literature

Summary of the literature published after the publication of the adopted practice guidelines
Research gaps were identified through the updates of the systematic reviews of studies published after the publication of the adopted practice guidelines.

A summary of these systematic reviews is presented in Supplement I. Twenty-six systematic reviews that assessed the impact of sleep duration on health were identified: 15 reviews in adults and 11 in children and adolescents. Thirteen RCTs assessed the effects of sleep duration on health.

The evidence extracted from the recent systematic reviews and RCTs supported the AASM/NSF recommendations; therefore, the Core Panel adopted the AASM/NSF recommendations.

Sixteen systematic reviews that assessed the impact of sedentary behavior on health were identified: Five reviews in adults, nine in children and adolescents, and two that included both children and adults.

Based on the evidence from the recent systematic reviews, the National Committee agreed to initially adopt the Australian 24-h Movement Guidelines for the Early Years (birth to 5 years), the Australian 24-h Movement Guidelines for Children (5–12 years) and Young People (13–17 years), and the UK Chief Medical Officers’ Physical Activity Guidelines recommendations without major changes in the physical activity and sedentary behavior recommendations.

A few minor changes to the wording of the guidelines were made by the Saudi Consensus Panel, not to the guideline recommendations as such but more precisely to the wording of the Good Practices statements.

Although a few studies specific to the Saudi population have been published on the relationship between physical activity level and health outcomes, there is a lack of robustness in terms of both the quantity and quality of the studies. Most of the local studies were cross-sectional, and only four studies were RCTs or had a large sample size. The local studies did not address all health outcomes determined in the search methods. Only eight studies used objective measures, such as those related to the use of accelerometers or pedometers. Thus, none of the local studies could be used to modify the recommendations. Thus, a strategic national plan to develop national evidence to investigate the relationship between physical activity levels/sedentary behavior and health outcomes is strongly needed.

Summary of literature related to the interaction between Ramadan fasting, prayer times, and daytime naps on the one side and nocturnal sleep duration on the other

Daytime naps

Summary of evidence
Cross-sectional and longitudinal studies have shown that several factors other than sleep duration can affect the relationship between sleep and health outcomes, such as bedtime and rise time, self-reported sleep quality, daytime napping, and comorbid sleep disorders.[43-45] Although the current practice guidelines address sleep duration only, other factors that can affect sleep duration in Saudi culture also need to be addressed.

Napping (afternoon/midday sleep or a siesta) is a culturally driven behavior that is a common practice, especially in some Mediterranean cultures, primarily for climatic reasons.[44] In addition, daytime napping in Saudi Arabia also has a religious dimension.[46,47] Qailulah, the term used in Islamic literature to define a midday nap, is a well-established Islamic habit.[47] One Hadith by the Prophet Mohammed peace be upon him (PBUH) says, “Take a short nap, for Devils do not take naps” (Sahih Aljamie, Alalbani 1647). Another Hadith by the Prophet (PBUH) presents specifics about the proper timing for a nap: “Sleeping early in the day betrays ignorance, in the middle of the day is right, and at the end of the day is stupid” (Fath Al-Bari). Many Saudis take a daytime nap in an attempt to abide by these hadiths of the prophet. A third Hadith by the Prophet (PBUH) also points to the time of the daytime nap in Islamic culture: “We used to offer the Jumua (Friday) prayer with the Prophet and then take the afternoon nap” (Sahih Al-Bukhari SB 5923). Therefore, these inherent cultural factors should be considered when formulating the relevant guidelines.
indicate that napping may improve naps that coincide with the circadian drop in core body wakefulness, which causes sleepiness. In core body temperature associated with extended time were more beneficial than those taken after 30 h, or ≥90 min) were associated with a higher risk of incident coronary heart diseases, hypertension, type-2 diabetes, and metabolic syndrome. However, in Saudi Arabia, studies have shown that napping continues in children in elementary school; a study in elementary schoolchildren reported that 41% of them were taking a daytime nap more than three times per week. Napping was found to be highly prevalent in Saudi adolescents as well, with approximately 60% of participants taking daytime naps more than three times per week. Another study that assessed sleep patterns among Saudi adolescents reported that 59% of the study group participants had an occasional daytime nap, and 30% reported daily napping. Napping in Saudi children could be explained by going to bed late and getting up early for school, and hence not getting enough nocturnal sleep, which is compensated by daytime napping. A systematic review also demonstrated that napping after the first 2 years of life correlated with reduced night sleep and hence a redistribution in 24 h sleep timing. Thus far, there is no agreement on the timing of cessation of daytime napping in children. Lack of this information makes it difficult to formulate a clear opinion about the role of napping in the development of children in different age groups and the role of daytime napping in supplementing 24-h sleep in children.
A recent systematic review of napping patterns in children aged 0–12 years revealed two time points in the transition to napping cessation. In children <24 months of age, napping is common, and the cessation rate is <2.5%.\[77\] After this age, an evident acceleration in the cessation rate was noted, combined with an extraordinary variation in prevalence across studies and global regions.\[77\] Finally, after 5 years of age (equivalent to school-going age), the majority of children stopped daytime napping.\[77\]

However, the currently available data have major limitations, as nearly all longitudinal studies on napping have been reported from Western societies, with limited studies from our region. Therefore, the present understanding of the practice of napping among children is limited to certain geographical locations and cultures and may not necessarily be applicable to our culture. More local studies on the health effects of napping in schoolchildren are needed.

**Prayer times and sleep**

**Summary of evidence**

The sleep pattern of Saudis is significantly influenced by prayer times. Muslims are required to perform five daily obligatory prayers (As-Sala¯t) at certain times of the day. The Saudi culture is a religious culture where a good proportion of Saudis adhere to the exact prayer times. For those who strictly follow these prayer times, sleep time and pattern and light exposure are affected by these prayer times as well.\[47\]

Prayer times were formerly timed according to the movement of the sun. Because of the tilting of the earth, its rotation around the sun, and the various latitudes of the earth’s locations, the times for the prayers are not fixed and are influenced by the season and the location.\[47\] Prayer times are referred to in one verse of the Qur’an as follows: “Perform As-Sala¯t (prayer) from mid-day till the darkness of the night (i.e., the Dhuhr, Asr, Maghrib, and Isha prayers), and recite the Qur’an in the early dawn (i.e., the morning Fajr prayer)” (17.78).

A field study of adult Omanis that objectively assessed sleep duration and pattern reported that 11% of the studied population wake up for Fajr prayer and then go back to sleep after prayer.\[78\] In addition, the same group reported the results of a field study that assessed the effect of sleep pattern in adults on inflammation and oxidative stress as reflected by the levels of the antioxidant glutathione (GSH), malondialdehyde (MDA), and C-reactive protein (CRP) in the plasma.\[79\] The levels of GSH, MDA, and CRP in biphasic dawn-sleepers were comparable to those in subjects with a monophasic sleep pattern; the levels were worse in subjects with a polyphasic sleep pattern, who also had more systemic inflammation.\[79\]

During summer, nights become shorter as days dawn earlier; hence, the Fajr (dawn) prayer comes at an earlier time, especially as Saudi Arabia does not apply daylight saving time.\[68\] Therefore, some of those who wake up for Fajr prayer in summer may sleep after prayer until they have to work; in other words, they split their sleep.\[80\] A study that assessed nocturnal sleep architecture and objective daytime sleepiness in subjects who split their sleep due to the Fajr prayer revealed no differences in sleep architecture or daytime sleepiness in the consolidated and split-sleep schedules when the total sleep duration was maintained.\[80\]

Laboratory studies indicate that having a constrained sleep period at night followed by a daytime nap has comparable recovery value to the same amount of consolidated one block-sleep taken at night.\[81,83\] However, most of these were short-term studies. Space simulation studies also suggest that splitting sleep into two phases does not disturb cognitive function, sleepiness, or inflammatory responses to sleep deprivation.\[82,83\] However, these studies are conducted under special conditions, making it difficult to extrapolate their results to the general population.

A recent study assessed hippocampal function in four groups of young adults by evaluating short-term topographical memory using the Four Mountains Test. Group 1 had 5 h of nocturnal sleep (n = 30), group 2 had 6.5 h of nocturnal sleep (n = 29), group 3 had 6.5 h of sleep split into 5 h of nocturnal time in bed and 1.5 h daytime nap (n = 29), while the control group 9 h of nocturnal sleep (n = 30).\[84\] Compared to the control group, Groups 1 and 2 had significantly impaired performance, while the performance of participants on the split sleep schedule (5.0 ± 1.5 h) did not significantly differ from that of controls.\[84\] Although the split-sleep protocol cannot be considered a replacement for adequate consolidated nocturnal sleep, this demonstrates the benefits of a long daytime nap (split sleep) in subjects who do not get enough nocturnal sleep.

A field study with junior doctors reported that adopting a split sleep protocol with napping during night shifts led to a similar amount of total sleep per 24 h as obtained by day shift doctors.\[85\] Nevertheless, based on the above observations, the evidence cannot be considered strong enough to draw any strong conclusions, and more studies are needed to assess the long-term effects on health outcomes.

**Ramadan and sleep**

**Summary of evidence**

Diurnal intermittent fasting during the holy month of Ramadan is the fourth pillar of Islam. This practice is anticipated to foster performers to wake-up early (at
predawn) for an important meal that has a religious dimension. Ramadan is a Hijri month that follows the lunar system, and hence, the month occurs in a different season every 9 years, which in turn affects the duration of daytime fasting and possibly influences nocturnal sleep duration. During Ramadan, there is a sudden shift of mealtime to the dark phase of the day. Increasing evidence shows that mealtimes interact closely with the circadian rhythm. Eating during the dark phase of the day causes desynchronization between the peripheral circadian clock and the central biological clock in the suprachiasmatic nucleus. The resulting misalignment increases the risk of developing cardiometabolic disorders. A recent systematic review and meta-analysis of 10 observational and experimental studies that assessed the effect of meal timing on obesity and metabolic alterations in humans reported a negative impact of late meal timing on weight and metabolism. Eating and staying awake for the whole night and sleeping in the daytime does not equate with getting enough nocturnal sleep. Studies on shift workers who work and eat at night and sleep in the daytime have demonstrated that a considerable percentage of them develop “shift work disorder,” a circadian rhythm sleep disorder characterized by excessive sleepiness, insomnias, or both.

A few studies in Saudi Arabia consistently showed a significant and sudden delay in bedtime and rise time during Ramadan. Interestingly, the delay in bedtime during Ramadan was also documented in non-Muslim residents of Saudi Arabia, suggesting that this delay is related to the lifestyle changes that occur during Ramadan. This shift delay in the sleep/wake pattern is partially ascribed to the delay in the start of work times during the month of Ramadan in Saudi Arabia. A Saudi study that objectively assessed sleep patterns during Ramadan reported a delay in bedtime and wake times and a reduction in nocturnal sleep duration during the holy month, from 5.9 h at baseline to 4.9 h at the end of the 1st week of Ramadan and 4.8 h at the end of the 2nd week of Ramadan. Another recent study demonstrated an objective reduction in nocturnal sleep duration in Saudis during Ramadan. A recent meta-analysis of 24 studies demonstrated a 1 h reduction in total sleep time, with the reduction being most significant in adolescents.

A study that assessed the alterations in the circadian rhythm of proximal skin temperature as a marker of core body temperature in a sample of young Saudis in an otherwise free-living unconstrained environment during Ramadan reported a delay in the acrophase of the proximal skin temperature, signifying a shift-delay in the circadian clock. This finding was supplemented by two Saudi studies that demonstrated a flattening of the melatonin rhythm, suggesting that the Ramadan month could be associated with a disruption of the circadian rhythm. Excessive eating at night and exposure to bright light, in addition to the delay in work and school times, have been proposed to cause this delay in bedtime and rise time and the reduction in nocturnal sleep.

A summary of studies is shown in Supplement II.

Discussion

This paper describes the methods used to develop the Saudi 24-h Movement Practice Guidelines for all age groups with regard to physical activity, sedentary behavior, and sleep duration. These combined guidelines reflect the complementary and integrated interactions between these three behavioral aspects and shift our thinking away from individual guidelines for each behavior. This approach has been used in new guidelines in several developed countries and has been well received by stakeholders.

These guidelines will help Saudis achieve a balance of movement behaviors and encourage a shift from unhealthy behaviors (e.g., excessive screen time) to healthier behaviors (e.g., adequate age-appropriate physical activity and sleep duration), resulting in improved overall health, wellbeing, and quality of life, regardless of age. This will also help Saudis understand what a healthier day looks such as overall by shifting their focus from incorporating physical activity only into their waking hours to an understanding of what a healthy 24-h period consists of. The guidelines will also assist health professionals and policymakers as they work to support Saudis of all ages in attaining optimal health.

The current guidelines made use of recently published practice guidelines while also accounting for newly published data and adjusting for cultural factors when needed and when the relevant data were available. The methods used for developing these practice guidelines are well-established, comprehensive, and appropriate methods that are transparent and meticulous. The composition of the Core Panel members, which included specialized academics and a methodologist who guided all aspects of the development process, is a major strength of the current practice guidelines. The methodologist ensured that the Core Panels followed the GRADE system and directed the ADOLOPMENT approach. Another strength of the approach used was the diversity of the Expert Panels, which included academics, practitioners, and stakeholders related to the practice guidelines, such as general practitioners, psychiatrists, a specialist in child developmental behavior, and specialists in behavioral sleep medicine.
The current practice guidelines involved adopting previously published practice guidelines that used the GRADE approach; this method is known as the GRADE-ADOLPMENT approach.[33,102] Based on this approach, and after reviewing the recently published evidence, the Saudi practice guidelines Expert Panels did not find sufficient changes that required altering the directions or strength of the recommendations of the adopted practice guidelines. The advantage of this approach is that it reduces time and cost; therefore, the GRADE-ADOLPMENT approach is especially recommended when a reliable set of guidelines and related materials, such as PICOs that implement transparent processes, are available to avoid duplicates.[39

Nevertheless, this development process is not without its challenges, as the Core Panels had to systematically review recent evidence published after the publications of the selected practice guidelines. In addition, Saudi Arabia is culturally distinct from Western societies, particularly when it comes to sleep duration, and several unique factors may affect sleep habits and hence nocturnal sleep duration. The Sleep Duration Core Panel identified the following factors that may affect sleep duration: Prayer time, including dawn (Fajr) prayer, the Ramadan month, and the cultural habit of taking a daytime nap.

The Core Panels discussed whether to include cross-sectional and observational studies in the updated systematic reviews; it was decided to include only recent systematic reviews and RCTs published after the publication of the adopted practice guidelines for the development of the Saudi recommendations, because even if several studies had been found, the level of evidence was not expected to have been enough to change the overall recommendation. However, for local and cultural factors that may influence behaviors, cross-sectional and observational studies were included due to a lack of high-quality and robust RCTs.

The use of online assessment for both round 1 and round 2 voting and telecommunication software availability made it easy to conduct both rounds of voting in a relatively short time.

An Arabic version of the recommendations was developed and approved by the Saudi Public Health Authority and will be promoted, which will allow the assessment of community ownership and the impact on the community.

**Updating the guidelines**

The National Organizing Committee recommends that these practice guidelines be reviewed and updated at least every 5 years or when significant new evidence emerges.

**Strengths of the Saudi practice guidelines**

The strengths of these practice guidelines include the review of evidence published after the publication of the adopted practice guidelines and cultural and religious factors being accounted for when needed. In addition, recommendations related to sleep duration during Ramadan and the interaction between nocturnal sleep and prayer times are useful for all Muslims and can serve more than 1.5 billion Muslims worldwide.

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**Conflicts of interest**

There are no conflicts of interest.

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## Table 1: A summary of systematic reviews and meta-analyses that assessed the relationship between sedentary behavior and health outcomes

| Study | Design and study population | Study details |
|-------|-----------------------------|---------------|
| Wiersma *et al.*[1] | A meta-analysis of 48 studies were included that assessed the association between total PA, SB, or different PA intensities and adiposity in children aged 2-7 years | No significant associations were SB with BMI or waist circumference |
| Sousa-Sá *et al.*[2] | A systematic review included 26 studies were included, involving 24,448 children and adolescents aged 0-18 years, from 12 different countries. The review assessed the associations between PA, SB, and/or adiposity and retinal microvasculature | Vessel width parameters were negatively associated with higher adiposity, lack of PA, and high levels of SB |
| Sampasa-Kanyinga *et al.*[3] | A systematic review included 13 studies, involving 115,540 children and adolescents from 12 countries which assessed the relationship between the combinations of PA, SB, and sleep duration to depressive symptoms and other mental health indicators among children and adolescents (5-17 years) | There were positive associations between meeting PA, SB, and sleep Canadian 24-h movement recommendations and better mental health indicators when compared with meeting none of the recommendations. A dose-response gradient between an increasing number of recommendations met and better mental health indicators was observed. Results should be interpreted with caution because the quality of evidence reviewed was “very low” according to the GRADE framework |
| Königstein *et al.*[4] | A systematic review aimed to assess the associations of SB with large artery structure and function in pediatric populations found 8 studies to complete a qualitative analysis | There was small body of evidence (7 cross-sectional studies) that shows no association of SB with large artery structure and function |
| Jones *et al.*[5] | A meta-analysis of 112 studies that assessed the effectiveness of school-based interventions in increasing PA and/or reducing SB in children aged 5-11 years | Assessment of studies using a whole-day accelerometer measure for SB showed a large but nonsignificant effect for SB (effect size=1.15; 95% CI: -1.03-3.33); the meta-analyses demonstrated low precision, considerable inconsistency, and high heterogeneity |
| Van de Kolk *et al.*[6] | A systematic review aimed to evaluate the effectiveness of parental involvement in childcare-based interventions on the children’s weight status and behavioral outcomes found 22 studies to review | Intervention group showed positive results in 61.1% of the studies on weight status, 73.3% on PA, 88.9% on SB, and all on nutrition-related behavior |
| Smith *et al.*[7] | A systematic review aimed to assess the associations between muscular fitness (i.e., strength/power, local muscular endurance) and SB in children and adolescents found 25 studies to review | For both muscular fitness components (strength/power, local muscular endurance), associations with SB were inconsistent irrespective of measurement method (subjective or objective) |
| Parajára *et al.*[8] | A systematic review aimed to assess the association between SB outcomes in adolescents (10-19 years) and neighborhood characteristics found 16 studies to review | The evidence has great variability in the SB cutoff points and methodology used for evaluating SB and neighborhood characteristics among studies Higher levels of SB was associated with insecurity during daytime hours, crime incidence, physical and social disorders, a higher neighborhood socioeconomic level, and time spent with peers Lower levels of SB was associated with traffic, availability of a favorable environment for physical activity, and higher residential density |
| Bedard *et al.*[9] | A meta-analysis of 20 studies, involving 842 students, assessed the impact of active classrooms compared to traditional sedentary classrooms on educational outcomes of school-aged children | Pooled results show that there is a small positive effect of active classrooms compared with traditional, sedentary classrooms (SMD=0.28, 95% CI: 0.09-0.47) on academic performance |
| Study | Design and study population | Study details |
|-------|-----------------------------|---------------|
| Zabatiero et al.\(^{[10]}\) | A meta-analysis of 9 RCT studies that assessed the effectiveness of interventions to reduce SB among people with overweight or obesity, involving 1859 participants | Pooled results indicate that intervention decrease SB compared to the control group: −0.33 [−0.59−−0.08] overall and−0.53 [−0.95−−0.11] in adults. Subgroup analyses indicated: Only interventions that included active components reduced time spent in SB (−0.54 [−0.88−−0.20]) and increased time spent in MVPA (1.29 [0.02-2.56]). Interventions only reduced BMI in studies of children (−0.09 [−0.18−−0.00]) and in those with no active component (−0.09 [−0.18−−0.01]). |
| Stanczykiewicz et al.\(^{[11]}\) | A meta-analysis of 17 studies that assessed the relationships SB and anxiety, involving 27,443 participants | Pooled results indicated that overall average effects were small: Higher levels of symptoms of anxiety were associated with higher levels of SB (weighted $r=0.093$, 95% CI [0.055-0.130], $P<0.001$). Moderator analyses indicated that trends for stronger effects were observed among adults, compared to children/adolescents ($P=0.085$) |
| Yan et al.\(^{[12]}\) | A meta-analysis of 18 cohort studies, involving 250,063 participants and 2269 patients with dementia | Pooled result showed that SB was significantly associated with increased risk of dementia (RR=1.30; 95% CI: 1.12-1.51) |
| Peachey et al.\(^{[13]}\) | A meta-analysis of 35 intervention studies aimed to reduce SB, involving 5983 participants | The pooled effect indicated a significant reduction in daily sitting time of 30.37 min/day (95% CI=40.86−19.89) favoring the intervention group. Reductions in sitting time were similar between workplace (−29.96 min/day; 95% CI=−44.05−−15.87) and other settings (−30.47 min/day; 95% CI=−44.68−−16.26), which included community, domestic, and recreational environments. Environmental interventions had the largest reduction in daily sitting time (−40.59 min/day; 95% CI−−61.65−−19.53), followed by multicomponent (−35.53 min/day; 95% CI−−57.27−−13.79) and behavioral (−23.87 min/day; 95% CI−−37.24−−10.49) interventions |
| Olanrewaju et al.\(^{[14]}\) | A systematic review of 18 studies involving 40,228 participants that assessed the association of SB with cognitive function in older adults without dementia | Due to considerable methodological, participant, outcome, and exposure heterogeneity, a meta-analysis could not be conducted; thus, a conclusion of the status of SB association with cognitive function cannot be drawn |
| Lutz et al.\(^{[15]}\) | A systematic review aimed to perform a critical appraisal and synthesis of health economic evaluations of interventions aiming to increase PA and/or decrease SB at the workplace found 18 studies to review | From these 18 studies, only 3 studies measured SB and all found positive effects. However, effects were small and their relevance is questionable. No particular intervention type was found to be more effective |
| Landais et al.\(^{[16]}\) | A systematic review aimed to summarize studies on microenvironmental choice architecture interventions that encouraged PA or discouraged SB in adults found 88 studies to review | Only 2 studies targeted SB; thus, no conclusion can be formed |

\(^{5}\)Five reviews in adults, nine in children and adolescents, and two included both children and adults. SB=Sedentary behavior, PA=Physical activity, GRADE=Grading of recommendations assessment, development and evaluation, CI=Confidence interval, SMD=Standardized mean differences, RR=Relative risk, RCT=Randomized controlled trials, BMI=Body mass index
| Author          | Design and study population                                                                 | Study details                                                                                                                                 |
|-----------------|---------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| Cancer/mortality|                                              |                                                                                                                                             |
| Stone et al.[17] | A meta-analysis of 32 studies were included representing over 73,000 deaths in cancer survivors | Pooled hazards ratios for short and long sleep duration (≥9-10 h) for all cancer-specific mortality were 1.03 (95% CI 1.00-1.06) and 1.09 (95% CI 1.04-1.13) (≤5-6 h), respectively. These associations were maintained when stratified by sex and sampling frame. |
| Chen et al.[18]  | A meta-analysis of 65 studies from 25 articles, involving 1,550,524 participants and 86,201 cancer cases | The categorical meta-analysis revealed that neither short (≤6 h) nor long sleep duration (≥ was associated with increased cancer risk. Subgroup analysis revealed that short sleep duration was associated with cancer risk among Asians (OR=1.36; 95% CI: 1.02-1.80) and long sleep duration significantly increased the risk of colorectal cancer (OR=1.21; 95% CI: 1.08-1.34). |
| da Silva et al.[19] | A meta-analysis of 27 cohort studies of >70,000 elderly individuals and followed up from 3.4 to 35 years | Long (>10 h) and short sleep (<6 h) duration was associated with increased all-cause mortality (RR=1.33 and RR=1.07, respectively), compared with the reference category. For cardiovascular mortality, the pooled relative risks were 1.43 for long sleep and 1.18 for short sleep. Daytime napping ≥30 min was associated with risk of all-cause mortality (RR=1.27), but longer sleep duration (≥2.0 h) was not. |
| Lu et al.[20]     | A meta-analysis of 10 studies including 415,865 participants                               | A J-shaped nonlinear trend was found between sleep duration and breast cancer incidence (P=nonlinear=0.012); compared with the reference hours (6 h or 7 h), with increasing sleep hours, the risk of breast cancer increased (P-trend=0.028). |
| Jike et al.[21]   | A meta-analysis of 137 prospective cohort studies, including 5,134,036 participants         | Long sleep was significantly associated with mortality (RR, 1.39; 95% CI, 1.31-1.47), incident type 2 diabetes (1.26, 1.11-1.43), cardiovascular disease (1.25, 1.14-1.37), stroke (1.46, 1.26-1.69), coronary heart disease (1.24, 1.13-1.37), and obesity (1.08, 1.02-1.15). Long sleep was not significantly related to incident hypertension (1.01, 0.95-1.07). |
| Itani et al.[22]  | A meta-analysis of 153 studies comprising 5,172,710 participants                           | Short sleep was significantly associated with the mortality outcome (RR, 1.12; 95% CI, 1.08-1.16). Similar significant results were observed in Type 2 diabetes (1.37, 1.22-1.53), hypertension (1.17, 1.09-1.26), cardiovascular diseases (1.16, 1.10-1.23), coronary heart diseases (1.26, 1.15-1.38), and obesity (1.38, 1.25-1.53) |
| Yin et al.[23]   | A meta-analysis of 67 articles with 141 independent reports                               | U-shaped associations were indicated between sleep duration and risk of all outcomes, with the lowest risk observed for short sleep duration (<7 h sleep duration per day), which was varied little by sex. For all-cause mortality, the RR was 1.06 (95% CI, 1.04-1.07) per 1 h reduction below 7 h; when sleep duration was>7 h per day, the pooled RR was 1.13 (95% CI, 1.11-1.15) per 1 h increment. For total cardiovascular disease, the pooled RR was 1.06 (95% CI, 1.03-1.08) per 1 h reduction and 1.12 (95% CI, 1.08-1.16) per 1 h increment of sleep duration. For coronary heart disease, the pooled RR was 1.07 (95% CI, 1.03-1.12) per 1 h reduction and 1.05 (95% CI, 1.00-1.10) per 1 h increment of sleep duration. For stroke, the pooled RR was 1.05 (95% CI, 1.01-1.09) per 1 h reduction and 1.18 (95% CI, 1.14-1.21) per 1 h increment of sleep duration. |
| Kwok et al.[24]  | A meta-analysis of 74 studies including 3340 684 participants with 242,240 deaths among 2,564,029 participants | Self-reported duration of sleep>8 h was associated with a moderate increased risk of all-cause mortality, with risk ratio, 1.14 (1.05-1.25) for 9 h, risk ratio, 1.30 (1.19-1.42) for 10 h, and risk ratio, 1.47 (1.33-1.64) for 11 h No significant difference was identified for periods of self-reported sleep <7 h |
| Other meta-analyses in adults |                                                |                                                                                                                                             |
| Xi et al.[25]    | A meta-analysis of 12 studies involving 18,720 participants with metabolic syndrome and 70,833 controls | Short sleep duration was associated with increased risk of MS (OR=1.27, 1.09-1.47). |
| Author       | Design and study population                                                                                                                                                                                                                                                                                                                                 | Study details                                                                                                                                                                                                 |
|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Kruisbrink et al.[26] | A meta-analysis of 13 studies that assessed the longitudinal relationships between sleep disturbances (of quantity and quality) and dyslipidemia in the general population                                                                                                                                                                                                 | Short sleep (≤5-7 h) was associated with a risk of 1.01 (95% CI 0.93-1.10) of developing dyslipidemia; long sleep (≥9 h) was associated with a risk of 0.98 (95% CI 0.87-1.10) for dyslipidemia                                                                                           |
| Irwin et al.[27] | A meta-analysis of studies (>50,000 participants) that assessed the effects of sleep disturbance, sleep duration, and inflammation in adult humans                                                                                                                                                                                                                  | Long sleep duration (>8 h), but not short sleep duration (<8 h), are associated with increases in markers of systemic inflammation                                                                                    |
| Anothaisintawee et al.[26] | A meta-analysis of 36 studies (1,061,555 participants) on sleep duration and diabetes type 2                                                                                                                                                                                                                                                             | Pooled RRs of sleeping ≤5 h and 6 h were, respectively, 1.48 (1.25,1.76), and 1.18 (1.10,1.26)                                                                                                               |
| Wang et al.[26] | A meta-analysis of 17 articles involving 17,841 incident cases of CAD among 517,440 participants                                                                                                                                                                                                                                                             | A U-shaped relationship was detected between sleep duration and risk of coronary heart disease, with the lowest risk at 7-8 h/day                                                                                     |
| He et al.[30] | A meta-analysis of 16 prospective studies, involving 528,653 participants with 12,193 stroke events                                                                                                                                                                                                                                                     | The lowest risk observed with sleeping for 7 h/day                                                                                                                                                             |
| Li et al.[31] | A meta-analysis of 11 articles with 16 independent reports (sleep duration and stroke)                                                                                                                                                                                                                                                                      | Short sleep durations were only significantly associated with nonfatal stroke                                                                                                                                  |
| Lo et al.[32] | A total of 35 independent samples (n=97,264) from 11 cross-sectional and seven prospective cohort studies of adults >55 years were included Sleep durations ranged from 5 to 9 h across studies, 7 h, 8 h, and 7-8 h were most commonly used                                                                                                                                               | Long sleepers had a higher predicted risk of total stroke than short sleepers (the pooled RR: 4 h: 1.17 [0.99-1.38]; 5 h: 1.17 [1.00-1.37]; 6 h: 1.10 [1.00-1.21]; 8 h: 1.17 [1.07-1.28]; 9 h: 1.45 [1.23-1.70]; 10 h: 1.64 [1.4-1.92]) |
| Meta-analyses in children | |                                                                                                                               | A U-shaped dose-response relationship was observed between sleep duration and risk of type 2 diabetes, with the lowest risk observed at a sleep duration category of 7-8 h/day                                                                 |
| Shan et al.[33] | A meta-analysis of 33 studies (including 3 randomized controlled trials and 30 observational studies)                                                                                                                                                                                                                                                       | The pooled relative risks for type 2 diabetes were 1.09 (95% CI 1.04-1.15) for each 1 h shorter sleep duration (<7 h/day) and 1.17 (1.14-1.20) for each 1 h increase of sleep duration (>7 h/day) |
| Felső et al.[24] | A systematic review 33 studies (including 3 randomized controlled trials and 30 observational studies Most of the studies were conducted in America Objective assessment of sleep duration via wrist worn accelerometer in 9 and waist worn accelerometer in 14 studies | Negative relationship between sleep time and different measures of adiposity                                                                            |
| Krietsch et al.[35] | A systematic review of 86 studies of youth (0-18 years), which investigated the relationship between sleep and dietary intake, altered eating behavior, physical/sedentary activity, or hormones regulating hunger/satiety                                                                                                                                              | No cross-sectional association between sleep duration and caloric intake and shorter or later sleep associating with greater sedentary or screen time                                                        |
| Author          | Design and study population                                                                 | Study details                                                                                                                                                                                                 |
|-----------------|---------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Chiu et al.     | This is a systematic review of 13 reports that included a total of 598,281 participants for a systematic review, and 12 reports were further used for a dose-response meta-analysis that assessed the association between sleep duration and suicidality in adolescents | Strong curvilinear dose-response associations were obtained for both suicidal ideation and attempts, with the lowest suicidal ideation and attempt risks at sleep durations of 8 h and 8-9 h/day (all P-nonlinearity <0.001) A linear dose-response relationship between sleep duration and suicide plans (pooled OR=0.89, 95% CI=0.88-0.90) was obtained, indicating that the risk of suicide plans statistically decreased by 11% for every 1 h increase in sleep duration |
| Short et al.    | A meta-analysis of 19 studies that objectively assessed the relationship between sleep duration and cognitive function in children aged 5-13 years | A significant effect (r=0.06) was found between sleep duration and cognition, suggesting that longer sleep durations were associated with better cognitive functioning |
| Miller et al.   | A meta-analysis of 52 studies that assessed the prospective relationship between sleep and obesity in a pediatric population | Short sleep was associated with a greater risk of developing overweight or obesity in infancy (RR: 1.40; 95% CI 1.19-1.65; P<0.001), early childhood (RR: 1.57; 1.40-1.76; P<0.001), middle childhood (RR: 2.23; 2.18-2.27; P<0.001), and adolescence (RR: 1.30; 1.11-1.53; P<0.002) |
| Anothaisintawee et al. | A meta-analysis of 12 prospective cohort studies that estimated the associations between sleep duration and obesity/BMI in children | Short sleep duration was significantly associated with obesity (RR: 1.45; 95% CI: 1.14-1.85). |
| Chaput et al.   | A systematic review of 69 studies (included 148,524 unique participants from 23 countries) that assessed the association sleep duration and health indicators in children (0-4 years) | Despite important limitations in the available evidence, longer sleep duration was generally associated with better body composition, emotional regulation, and growth in children aged 0-4 years Shorter sleep duration was also associated with longer screen time use and more injuries |
| Wu et al.       | A meta-analysis of 13 articles were included, involving 35,540 children and adolescents from around the world | The OR in short sleepers for obesity of the pooled was 1.71 (1.36-2.14) |
| Zhang et al.    | His systematic review aimed to summarize correlates of sleep duration in children under 5 years of age One-hundred and sixteen studies, representing 329,166 children, met the inclusion criteria, with a high risk of bias in 62 included studies | Among the associations studied four or more times, correlates of nap duration were child's age and nighttime sleep onset/bedtime; correlates of nighttime sleep duration were household income, parent marital status, parental adiposity level, nighttime sleep duration at younger age, nighttime sleep onset/bedtime, nighttime sleep wakeup time, and frequency of current bedtime routine; correlate of total sleep duration was screen time |
| Morrissey et al.| A systematic review of multiple sleep dimensions: 12 were included for detailed review. | A significant inverse association between sleep duration and measured weight status |

CI=Confidence interval, OR=Odds ratio, RR=Relative risk, BMI=Body mass index, MS=Multiple sclerosis, CAD=Coronary artery disease
Table 3: A summary of randomized controlled trial that assessed the impact of sleep duration on health after 2015

| Authors          | Study design               | Study group                      | Intervention                                                                                           | Measurement                                                                                         | Results                                                                                           |
|------------------|----------------------------|----------------------------------|--------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------|
| Spaeth et al.    | Randomized controlled      | Healthy adults (21-50 years)     | An experimental (n=36; 4 h sleep/night for five nights followed by one night with 12 h recovery sleep) or control condition (n=11; 10 h sleep/night) | Resting metabolic rate and respiratory quotient in the morning after overnight fasting             | Sleep restriction decreased morning resting metabolic rate in healthy adults                        |
| Santisteban et al. | Randomized controlled  | Healthy participants aged 18-34 years | An experimental (n=48; elimination of 1 h of sleep relative to the baseline habitual sleep duration) versus placebo (n=45; exposure to a lamp with no known therapeutic effect) | Working memory, sustained attention, response inhibition, and decision making                      | Cumulative partial sleep deprivation negatively affects performance on a test of working memory capacity but does not affect performance on tests of sustained attention, response inhibition, or decision-making |
| Cros et al.     | Randomized controlled      | Healthy adults (21-50 years)     | 10 subjects exposed to a 6-day overfeeding period (130% daily energy needs, with 15% extra energy as sucrose and 15% as fat), with normal sleep (8 h sleep opportunity time) or sleep restriction (4 h sleep opportunity time), according to a randomized, crossover design. Crossover design was studied on 2 occasions, separated by a 4-8-week washout period | At baseline and after intervention, intrahepatocellular lipid concentrations were measured by proton magnetic resonance spectroscopy, and a dual intravenous [6, 6-2H2]-, oral 13C-labeled glucose tolerance test and a polysomnographic recording were performed | 6 days of a high-sucrose, high-fat overfeeding diet significantly increased IHCL concentrations and increased endogenous glucose production, suggesting hepatic insulin resistance. These effects of overfeeding were not altered by sleep restriction |
| Ritland et al.  | Randomized-controlled      | Young healthy athletes’ adult (aged 18-30 years) | 50 participants (experimental n=25) wore actigraphs for 15 consecutive nights and completed a cognitive/ motor battery after seven habitual sleep nights, after four sleep extension nights (goal of spending 10 h in bed each night), and after the resumption of habitual sleep for four nights. The control group (control n=25) remained on habitual sleep schedules for the entire study | Performance testing took place after the first seven nights of habitual sleep (pretest), after the four-night intervention period (posttest), and after the four nights following the intervention period (follow-up) | Increasing sleep duration in military tactical athletes resulted in immediate performance benefits in psychomotor vigilance, executive functioning, standing broad jump distance, and motivation levels. Benefits on motor performance were evident 4 days after resumption of habitual sleep schedules |
| Tajiri et al.   | Randomized crossover design | Healthy women aged 21-22 years  | Participants were 16, short sleep condition: 4 h/night (2:00-6:00) and a control sleep condition: 7 h/night (23:00-6:00); each condition comprised 3 consecutive nights | Energy intake and physical activity                                                                 | Physical activity increases in the short sleep condition were attributed to differences in awake time between the conditions. However, there were no differences in energy intake |

Contd...
| Authors                     | Study design                  | Study group                                                                 | Intervention                                                                                      | Measurement                                                                                          | Results                                                                                     |
|-----------------------------|-------------------------------|------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| Hibi et al.                  | Randomized crossover study    | Healthy men aged 23±2 years                                                   | Nine healthy men were evaluated under two conditions: a 3.5-h sleep duration and a 7-h sleep duration for three consecutive nights followed by one 7 h recovery sleep night | Energy expenditure, substrate utilization, and core body temperature were continually measured for 48 h using a whole-room calorimeter. Appetite questionnaire every hour while in the calorimeter | Shortened sleep increased appetite by decreasing gastric hormone levels but did not affect energy expenditure, suggesting that greater caloric intake during a shortened sleep cycle increases the risk of weight gain |
| McNeil and St-Onge          | Randomized crossover trials   | Healthy adult (18-45 years of age)                                            | All participants (n=43); sleep restriction (3.5-4 h in bed per night) and habitual sleep (7-9 h in bed per night) | Ad libitum, 24-h energy intake was objectively assessed following sleep restriction and habitual sleep conditions | Large interindividual variations in energy intake following sleep restriction were noted, suggesting that not all participants were negatively impacted by the effects of sleep restriction |
| Al Khatib et al.            | Randomized controlled pilot study | Healthy men and women aged 18-64 years and with a BMI (in kg/m²) of 18.5-<30 | The sleep extension group (n=21) received a behavioral consultation session targeting sleep hygiene. The control group (n=21) maintained habitual short sleep | Sleep measured by wrist actigraphy. Assess the effects of extended sleep on dietary intake and quality measured by 7 days food diaries, resting and total energy expenditure, physical activity, and markers of cardiometabolic health | Showed the feasibility of extending sleep in adult short sleepers. Sleep extension led to reduced free sugar intakes and may be a viable strategy to facilitate limiting excessive consumption of free sugars in an obesity-promoting environment |
| Yang et al.                 | Randomized crossover study    | Women who reported habitually sleeping 7-9 h/night were aged 18-55            | 24 participants, sleep conditions in this study consisted of a normal night and a curtailed night where time in bed was reduced by 33% | Hunger, tiredness, sleep quality, sleepiness, and food cravings | Increased hunger, food cravings, food reward, and portion sizes of food after a night of modest sleep curtailment. These maladaptive responses could lead to higher energy intake and, ultimately, weight gain |
| Smith et al.                | Randomized controlled         | Healthy males (ages 30-45 years)                                             | Study 1 (n=14) involved severe, acute sleep restriction (4 h time in bed) versus habitual sleep (9 h time in bed) for 5 nights; Study 2 (n=13) consisted of mild, long-term sleep restriction (HS 1.5 h of sleep/night) versus habitual sleep for 6 weeks | Plasma testosterone levels | Sleep restriction does not adversely affect plasma testosterone levels in healthy young men |
| Wilms et al.                | Experimental Randomized control study | Fifteen healthy men aged 18-30 years                                          | Fifteen healthy participants were studied. In randomized, balanced order, they underwent three separate nights with regular sleep duration (8 h of sleep between 11:00 PM and 7:00 AM), sleep restriction (4 h of sleep between 3:00 AM and 7:00 AM), and sleep deprivation (no sleep at all) | Sleep was polysomnographically evaluated. White adipose tissue biopsy samples were taken twice at 9:00 PM and 7:00 AM to assess morning-to-evening differences. White adipose tissue transcriptome profile was assessed by RNA sequencing, and expression of relevant | Acute sleep loss induces a profound restructuring of morning-to-evening WAT transcriptome with uncoupling from the local clock machinery, resulting in increased WAT carbohydrate turnover and impaired glucose homeostasis. |
Table 3: Contd...

| Authors       | Study design          | Study group                                                                                   | Intervention                                                                 | Measurement                                                                 | Results                                                                 |
|---------------|-----------------------|------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------|------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| **Full et al.**[54] | Cross-sectional study | 18 years of age or older, uncontrolled type 2 diabetes (A1C >7%)                                 | 317 Hispanic adults with uncontrolled type 2 diabetes who participated in an RCT testing a peer support intervention to improve diabetes control through improvements in management behaviors and utilization of healthcare services among patients with type 2 diabetes compared with a usual care condition | Glycemic control was assessed by A1C ascertained through medical chart review. Sleep duration, diabetes control behaviors, and demographics were obtained by interviewer-administered questionnaire | Our data support an optimization of sleep duration and timing to prevent metabolic disorders such as obesity and type 2 diabetes |
| **Ward et al.**[55] | Randomized controlled trial | Children aged 8-12 years with normal reported sleep duration of 8-11 h/night                    | 110 children will undergo 2 weeks of sleep manipulation; seven nights of sleep restriction by going to bed 1 h later than usual, and seven nights of sleep extension going to bed 1 h earlier than usual, separated by a washout week | 24-h movement behaviors (sleep, physical activity, sedentary behavior) will be measured via actigraphy; dietary intake and context of eating by multiple 24-h recalls and wearable camera images; and eating behaviors via objective and subjective methods. At the end of each experimental week, a feeding experiment will determine energy intake from eating in the absence of hunger | Determining how insufficient sleep predisposes children to weight gain should provide much-needed information for improving interventions for the effective prevention of obesity, thereby decreasing long-term morbidity and healthcare burden |

BMI=Body mass index, IHCL=Intrahepatocellular
| Study                  | Design                                                                                           | Assessment                                                                                           | Results                                                                                                                                                                                                 |
|------------------------|--------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Tietzel and Lack[56]   | 16 healthy adults                                                                                | Subjective alertness, objective alertness, fatigue, vigor, and cognitive performance                  | The 10-min nap resulted in significantly improved alertness and cognitive performance relative to 30 s, 90 s, or a no-nap control                                                                                                     |
| Tietzel and Lack[57]   | 12 young health adults                                                                           | Objective and subjective alertness measures and cognitive performance measures were taken before, then 5, 35, and 60 min | The 10 min nap resulted in immediate improvement in subjective alertness and cognitive performance which was sustained for the h of post nap testing. Immediately following the 30 min nap, most measures of alertness and performance declined but showed some recovery by the end of testing |
| Brooks and Lack[58]    | 24 healthy, young adults slept for 5, 10, 20, or 30 min in the afternoon or participated in a no-nap condition, all following a night restricted to 5 h of sleep | Assessment of the underlying EEG changes that accompanied restorative nap benefits                    | The 5 min nap produced few benefits in comparison with the no-nap control. The 10 min nap produced immediate improvements in all outcome measures. The 20 min nap produced a period of impaired alertness and performance immediately after napping. The 30 min nap produced a period of impaired alertness and performance immediately after napping, indicative of sleep inertia. |
| Hayashi and Hori[59]   | Participants went to bed at 12.20 h and were awakened after they slept for 20 min                 | The EEG recordings of relaxed wakefulness, mood, performance, and self-rating of performance level were measured every 20 min from 10.00 to 18.00 h | The nap improved subjective sleepiness and self-rating of task performance and suppressed EEG alpha activity                                                                                           |
| Hayashi et al[60]      | 7 health adults underwent nap (14:00-14:20) and no-nap conditions at intervals of 1 week after a nocturnal sleep recording (00:00-08:00 h) | EEG recordings during relaxed wakefulness, and their mood, performance, and self-ratings of performance level were measured every 20 min from 10:00 to 18:00 h | The 20 min nap improved the subjective sleepiness, performance level, and self-confidence of their task performance. The nap also suppressed EEG alpha activity during eyes-open wakefulness. |

EEG=Electroencephalography
| Study                        | Study design       | Definition of physical activity                                                                 | Age          | Sample size | Health status (1=healthy, 2=unhealthy) | Physical activity assessment methods | Regional location | Data collection years | MVPA Results                          | Notes                                                                 |
|------------------------------|--------------------|-------------------------------------------------------------------------------------------------|--------------|-------------|----------------------------------------|-------------------------------------|-------------------|----------------------|----------------------------------------|----------------------------------------------------------------------|
| Al-Rasheed and Ibrahim²⁶⁷    | Cross-sectional    | At least 60 min of MVPA/day                                                                     | 12-15 years old | 62          | 1                                       | Objective Accelerometer             | Dammam           | 2018                 | MVPA=80.7-98.3 min/d                  | Normal sleep versus poor sleep                                       |
| Mattoo et al²⁶⁸             | Comparative study  | WHO guidelines                                                                                                               | 19-35 years old | Male=147 Female=93 Total=240 | 1 and 2                                | Subjective Questionnaire           | Riyadh           | 2018-2019             | MVPA=20%                               | Unclear results for physical activity                               |
| Alkhaldy et al²⁶⁹           | Cross-sectional    | Very active (≥40 point), active (39-30 point), moderately active (29-20 point), and inactive (<20 point) (Al-Hazzaa and Al-Ahmidi, 2003) | 20-30 years old | Female=42    | 1                                       | Subjective Questionnaire           | Jeddah           | 2019                 | MP=21%                                | 0% of vigorous physical activity                                    |
| Alzahrani et al²⁷⁰          | Cross-sectional    | ≥150 min of MPA or ≥90 min of VPA per week                                                      | 25-75 years old | Male=92 Female=155 Total=247    | 2                                       | Subjective Questionnaire           | Jeddah           | 2018                 | MVPA=35.6%                             |                                                                       |
| Aljuhani and Sandercock²⁷¹  | Cross-sectional    | At least 60 min of MVPA per day                                                                                                   | 12-14 years old | Male=123    | 1                                       | Objective Accelerometer           | Riyadh           | 2019                 | MVPA=3080 METs-min/week, non-PE class days=40%, non-PE class days=24% | On physical education class days=40%, non-PE class days=24%          |
| Al-Hazzaa and Albawardi²⁷²  | Cross-sectional    | METs-min/week (above or below 1680 METs-min/week)                                                                                   | 15-19 years old | Male=1388 Female=1500 Total=2888 | 1                                       | Subjective Questionnaire           | Riyadh, Jeddah and AL-Khobar | 2018                 | Male=3080 METs-min/week, Female=1376 METs-min/week                     | Moderate/intense=34.9%                                               |
| Almuzaini and Jrad²⁷³        | Cross-sectional    | GPAQ classification, (1) low, (2) moderate, (3) intensive                                                                                 | 18-60 years old | Male=395    | 1 & 2                                   | Subjective Questionnaire           | AL-Madinah       | 2018                 | MVPA=77.6%                             |                                                                       |
| Alharbi²⁷⁴                  | Cross-sectional    | The PAQ-C, categorized PA as low (≤2.3), moderate (2.4-3.7), and high (≥3.8) levels of PA                                                                 | 10-15 years old | Female=464  | 1                                       | Subjective Questionnaire           | Riyadh           | 2018                 | MVPA=54.2                              |                                                                       |
| Alzamil et al²⁷⁵            | Cross-sectional    | ≥150 min of MVPA per week                                                                                                               | 18-28 years old | Female=456  | 1                                       | Subjective Questionnaire           | Riyadh           | 2018                 | MVPA=49.6%                             | (600+METs-min/week)                                                   |
| Alhakbany et al²⁷⁶           | Cross-sectional    | Active (600+METs-min/week) Inactive (<600 METs-min/week)                                                                                   | 20.3±1.5 years old | Female=454  | 1                                       | Subjective Questionnaire           | Riyadh           | 2017                 | Active=49.6% Inactive=50.4 (<600 METs-min/week)                       |                                                                       |

Contd...
| Study | Study design | Definition of physical activity | Age | Sample size | Health status (1=healthy, 2=unhealthy) | Physical activity assessment methods | Regional location | Data collection years | MVPA Results | Notes |
|-------|--------------|---------------------------------|-----|-------------|----------------------------------------|-------------------------------------|------------------|----------------------|--------------|-------|
| Al-Hazzaa[^71] | Systematic review | Adults= ≥ 150 min of MVPA/week Children and adolescents= ≥60 min of MVPA per day | 5-70 years old | Total children=520, adolescents=9672, adults=26174 | 1 | Objective and subjective | Riyadh, Jeddah, Al-Khobar, Abha, Dammam, Al-Ahsa region, National sample, Aseer Province | 2018 | The prevalence of physical activity, in general, ranged from 15% to 74% among Saudi males and from 9% to 57% among Saudi females, depending on the population measured, region, age, gender, the type of PA instrument utilized |
| Alosaimi et al[^72] | Cross-sectional study | Aerobic activity ≥ 20 min twice weekly | 38.0±13.0 | Male=647 Female=538 Total=11185 | 2 | Subjective Mini-interview form | Riyadh, Zulfi, Jeddah, Dammam, Ajouf, Abha Makkah | July 2012 and June 2014 | Aerobic activity ≥20 min twice per week Male=15.9% Female=9.6% Total=12.9% |
| Al-Kutbe et al[^73] | Cross-sectional | Evenson cut points | 8-11 years | Female=78 | 1 | Objective, accelerometer | Makkah 2017 | Time in MVPA was 22.2, 20.9, 18.6, and 18.4 for UW, HW, OW, and OB, respectively |
| Bajamal et al[^74] | Cross-sectional | 60 min of MVPA per day | 13-18 | Female=405 | 1 | Subjective Questionnaire | Jeddah 2017 | Mean PA level was low 2.1 |
| Alkahtani[^75] | Convergent validity | Freedson cut-points | 20±1.1 years | Male=62 | 1 | Objective Accelerometer | Dammam 2016 | Time in MVPA was 273.5 m/w |
| Albawardi et al[^76] | Cross-sectional | Low: <600 MET min/week; moderate: 600-2999 MET min/week; high: ≥1500 MET min/week vigorous PA or ≥3000 MET min/week moderate/vigorous PA | 18-58 | Female=420 | 1 | Subjective Questionnaire | Riyadh 2015 | 47.3% of sample were physically active |

Contd...
| Study                        | Study design     | Definition of physical activity                                                                                                                                                                                                 | Age  | Sample size          | Health status (1=healthy, 2=unhealthy) | Physical activity assessment methods | Regional location | Data collection years | MVPA Results | Notes                                                                 |
|------------------------------|------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|----------------------|----------------------------------------|--------------------------------------|-------------------|-----------------------|--------------|-----------------------------------------------------------------------|
| El Bcheraoui et al.[77]     | Cross-sectional  | PA classified into 4 groups: (a) met VPA, or a minimum of 300 metabolic equivalent minutes (MET-min)/week; (b) met MPA, or 150-300 MET min/week; (c) do not meet VPA or MPA levels, or 0 to <150 MET-min/week | 15+  | Total male and female=10,735 | 1 and 2                              | Subjective Questionnaire              | KSA                | 2013                  | 1.7 million (12.9%) meet the recommended levels of MPA             |
| Alghadir et al.[78]         | Cross-sectional  | Physical activity level: mild (≤500 METs-min/week), moderate (500-2500 METs-min/week), or active (≥2500 METs-min/week)                                                                                                            | 8-18 | Male=90, Female=90   | 1                                     | Subjective Questionnaire              | Riyadh             | 2013-2014             | Mild (n=40 (male=10, female=30); 22.2%), moderate (n=35 (male=15, female=20); 19.4%), active (n=105 (male=65, female=40); 58.3%) |            |
| Al-Sobayel et al.[79]       | Cross-sectional  | 60 min of MVPA/day                                                                                                                                                                                                                   | 14-19| Male=1,388, Female=1,500 | 1                                     | Subjective Questionnaire              | Riyadh, Jeddah, and Al-Khobar | 2009-2010             | All sample spent 90 in LTPA and 77 in non-LTPA. LTPA in male was 395 (m/w) and 101 (m/w) in female Non-LTPA in male was 139 (m/w) and 145 (m/w) in female |            |
| Alkahtani et al.[80]        | Cross-sectional  | Freedson cut-points                                                                                                                                                                                                                  | 37.6±8.8 | Male=84               | 1                                     | Objective Accelerometer               | Dammam             | 2015                  | Daily MVPA was 34.0 m/d                                           |            |

MVPA=Moderate to vigorous physical activity, MPA=Moderate physical activity, PA=Physical activity, PE=Physical education, GPAQ=Global physical activity questionnaire, VPA=Vigorous physical activity, MET=Metabolic equivalents
| Study                              | Study design                  | Sample details                                      | Assessment methods          | Health outcomes Results                                                                                                                                                                                                 | Type of disease            |
|-----------------------------------|-------------------------------|-----------------------------------------------------|----------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|
| Al-Kutbe et al.[73]               | A cross-sectional observational study | 266 females, (8-11 years) Only 78 complete physical activity measurement | Objective Accelerometer     | Total energy expenditure per kg of body weight had a significant negative influence on body weight ($\beta =-0.661, P<0.001$)                                                                                                                       | Obesity                   |
| Alhusaini et al.[81]              | Cross-sectional study         | 85 children (8-12 years)                            | Objective Pedometer        | Obesity and physical inactivity among Saudi Arabian children with and without down syndrome are major health concerns                                                                                            | Obesity in healthy and mental disable children |
| Ahmed et al.[82]                  | Cross-sectional study         | 299 males and females (10-15 years)                 | Subjective Questionnaire   | Physical activity was significantly and inversely associated with overweight and obesity in boys, but not in girls                                                                                                      | Obesity                   |
| Al-Nakeeb et al.[83]              | Cross-sectional study         | 1,138 males and females (15-17 years)               | Subjective Questionnaire   | Higher BMI reported lower levels of physical activity                                                                                                           | Obesity                   |
| Al-Nuaim et al.[84]               | Cross-sectional study         | 1270 males and females (15-19 years)                | Subjective Questionnaire   | Normal weight males reported the highest levels of physical activity compared to overweight and obese                                                                                                                    | Obesity                   |
| Mattoo et al.[82]                 | Comparative study             | 240 males and females (18-35 years)                 | Subjective Questionnaire   | A high prevalence of inactivity was observed among families in the overweight/obese group                                                                                                                                  | Obesity                   |
| Alramadan et al.[85]              | Cross-sectional study         | 1111 males and females (75.6±11.1 years)            | Subjective Questionnaire   | Low level of physical activity was independent risk factors for inadequate glycemic control                                                                                                                               | Diabetes                  |
| Wani et al.[86]                   | 12-month two-arm randomized controlled study | 300 males and females, (20-73 years)                | Subjective Questionnaire   | Intensive lifestyle program implemented in a primary health care setting was effective in decreasing weight and improving glycemic status predominantly. Overweight/obese Saudi adults with prediabetes. | Diabetes                  |
| Alkahtani et al.[80]              | Cross-sectional study         | 84 healthy men (37.6±8.8 years)                     | Objective Accelerometer    | Low physical activity and 10-min of MVPA were associated with elevated HDL levels among Saudi men                                                                                                                          | Metabolic syndrome        |
| Al-Hamdan et al.[87]              | Cross-sectional study         | 4758 males and females, (15-64 years old)           | Subjective Questionnaire   | Hypertension was significantly negatively associated with total levels and duration of physical activity in leisure, transport, and work                                                                                     | Hypertension              |
| Alsareii et al.[88]               | An online-based, anonymous, self-rating, cross-sectional and survey-based study | 300 females (232 college students and 68 faculty staff) | Subjective Questionnaire   | Lack of physical activity (66.3%) and family history of breast cancer (18%) were the most substantial nonobstetric risk factors of breast cancer                                                                                   | Breast cancer             |
| Alkahtani et al.[89]              | Cross-sectional study         | 497 males, (32.2±10.4 years)                        | Subjective Questionnaire   | Physical activity independent of exercise intensity was directly associated with appendicular lean mass and indirectly associated with bone mineral density through increased muscle mass and strength | Sarcopenia                |
| Alenazi et al.[90]                | Randomized Controlled Trial   | 181 (males and females), (60.7±11.8 years)          | Objective StepWatch        | Physical activity level was not contributing factors to falls in elderly with chronic stroke                                                                                                                                | Injury                    |

Contd...
| Study                        | Study design       | Sample details                               | Assessment methods     | Health outcomes Results                                                                                                                                                                                                                                                                                                                                                       | Type of disease          |
|------------------------------|-------------------|---------------------------------------------|------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|
| Al-Rasheed and Ibrahim[61]   | Cross-sectional study | 62 males and females, (12-15 years old) | Objective Accelometer | Physical activity parameters including the total steps count, total activities count, activity rate, and the vigorous activity time were significantly lower in poor sleep group                                                                                                                                                                                                 | Poor sleep               |
| Al-Eisa et al.[91]           | Cross-sectional study | 67 females (20.9±1.4 years)         | Objective Pedometer   | Physical activity was negatively correlated with insomnia severity index (r=−0.74) and Beck depression inventory (r=−0.78) and positively correlated with attention span test (r=0.69)                                                                                                                                                                           | Psychological diseases   |
| Al-Hariri[92]                | Cross-sectional study | 60 males, (18-60 years old)             | Subjective Interview survey | Patients who exercise running or jogging activities have better feeling while they run                                                                                                                                                                                                                                                                                      | Psychological diseases   |
| Al-Eisa and Al-Sobayel[93]   | Cross-sectional study | 105 males (26.3±7.1 years)             | Objective Pedometer   | There is an association between physical activity and health beliefs. Step count had strong correlation with self-efficacy (r=0.75), mild correlation with internal health locus of control (r=0.42), and mild negative correlation with external health locus of control (r=−0.35)                                                                                       | Psychological factors    |
| Al-Eisa E. et al.[94]        | Experimental study  | 62 females, (21±1.5 years)                | Objective Pedometer   | Moderate negative correlation between physical activity and insomnia severity index scores after the 3 weeks motivation program                                                                                                                                                                                                                                               | Psychological diseases   |
| Al-Zoughool et al.[95]       | Cross-sectional study | 303 males and females (53.7±12.2)      | Subjective Questionnaire | Moderate occupational PA was associated with >60% reduction in coronary heart disease risk                                                                                                                                                                                                                                                                                  | Coronary heart disease   |
| Aljuhani and Sandercock[65]  | Cross-sectional study | 123 males, (12-14 years old)           | Objective Accelometer | On physical education class days=40%, Non-PE class days=24%. Active schoolchildren obtained a higher cardiorespiratory fitness                                                                                                                                                                                                                                                                                            | General health           |

BMI=Body mass index, MVPA=Moderate to vigorous physical activity, PE=Physical education, PA=Physical activity, HDL=High-density lipoprotein
### Table 7: Review of available Saudi studies characteristics (design, demographics, and location and time of data collection) reporting on sedentary behavior

| Study                  | Study design            | Study details                                                                 | Study sedentary behavior definition                                                                 | Total sedentary behavior* | Assessment method      | Regional location | Special conditions                                                                 |
|------------------------|-------------------------|-------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|---------------------------|------------------------|-------------------|-----------------------------------------------------------------------------------|
| Al-Baghli et al.[96]   | Screening campaign for the early detection of DM and hypertension | Included people aged>29 from both sexes, excluding pregnant women (n=197,681) | No physical activity (completely sedentary lifestyle, e.g., reading, watching TV)                    | NA                        | Subjective questions     | Eastern province     | Sample included people with DM and HTN                                           |
| Al-Hazzaa et al.[66,79,97] | Cross-sectional         | Included people aged 14-19 from both sexes (n=2908)                           | Typical daily time spent on sedentary activities, including time spent viewing TV, playing video games, and computer and Internet use | Female: 6.6b Male: 5.3b | Subjective questions     | Riyadh, Jeddah, and Al-Khobar | NA                                                                |
| Al-Nakeeb et al.[83]   | Cross-sectional         | Included people aged 15-17 from both sexes (n=1138)                           | Typical daily time spent on sedentary activities, including time spent viewing TV, playing video games, and computer and Internet use | Female: 5.78±2.57 Male: 4.99±3.02 | Subjective questions | Alhasa              | NA                                                                |
| Alkahtani et al.[93]   | Cross-sectional         | Included men aged ≥20 (n=84)                                                 | Sedentary behavior is any activity during which energy expenditure is ≤1.5 METs, such as sitting or standing | 8.9c                      | Objective sedentary; ActiGraph 0-99 counts           | Dammam and Al-Khobar | Office workers                                                                  |
| Alghadir et al.[79]    | Cross-sectional         | Included people aged 8-18 from both sexes (n=180)                            | TV viewing time: The time spent watching TV, videotapes, or DVDs, while computer time: The time spent on a home computer or playing video games | 5.45c                     | Internet based survey | Not specified         | Students                                                          |
| Moradi-Lakeh et al.[98] | Cross-sectional national multistage survey | Included people aged ≥15 from both sexes (n=10,735) | In a typical week, how much time do you usually spend in front of the television or on the computer? | NA                        | Subjective             | All                | NA                                                                |
| Al-Agha et al.[90]     | Retrospective cross-sectional | Included people aged 2-18 from both sexes (n=541)                           | Parents were asked how long their children spent watching TV, how often they used other electronic devices, such as tablets, cell phones, video game consoles, and computers | NA                        | Subjective             | Jeddah              | NA                                                                |
| Alkahtani[73]          | Cross-sectional comparison of measures design | Included men aged ≥18, (n=96)                                                 | Sedentary was 0-99 counts/min based on ActiGraph                                                   | 6.0c                      | Objective and subjective | Dammam             | 1st year college students                                                      |
| Albawardi et al.[100]  | Cross-sectional         | Included women aged 18-60 (n=420)                                            | Sitting and low levels of energy expenditure (1-1.5 METs)                                          | Workday: 11.35±3.65 Nonworkday: 9.43±4.52 | Subjective             | Riyadh             | Office-based (necessitating little physical work)                               |
| Khabaz et al.[101]     | Cross-sectional         | Included men aged 18-26, (n=116)                                             | Hours spent on watching TV, using internet, Play station per day                                    | NA                        | Subjective             | Rabigh              | Healthy students                                                 |

Contd...
Study: Al-Zoughool et al. (2011)  
Study design: Cross-sectional  
Study details: Included people from both sexes (n=303) (146 CHD cases aged 53.7±9 and 157 controls aged 49.4±7)  
Study sedentary behavior definition: Number of h/day of sedentary behavior  
Total sedentary behavior: C: 4.52±2.57 CHD: 6.7±3.61  
Assessment method: Subjective  
Regional location: Riyadh  
Special conditions: CHD cases and controls

Study: Alyami et al. (2012)  
Study design: Cross-sectional  
Study details: Included men aged ≥40, n=66 (COPD: 34 aged 61.9±5.2, C: 32, aged 63.1±3.6)  
Study sedentary behavior definition: Sedentary behavior was defined as 0 steps/min  
Total sedentary behavior: C: 8.67±1 COPD: 10.48±1.33  
Assessment method: Objective  
Regional location: Riyadh  
Special conditions: COPD

Study: Alhakbany et al. (2013)  
Study design: Cross-sectional  
Study details: Included women aged ≥18, (n=454)  
Study sedentary behavior definition: Typical daily time spent on sedentary activities, including time spent viewing TV, playing video games, and computer and Internet use  
Total sedentary behavior: Normal BMI: 5.6±2.5 BMI>25: 5.4±2.5  
Assessment method: Subjective  
Regional location: Riyadh  
Special conditions: Health colleges students

Study: AlQuaiz et al. (2013)  
Study design: Cross-sectional  
Study details: Included people aged 30-75 from both sexes (n=2997)  
Study sedentary behavior definition: Sitting time, which was considered an indicator of time spent in sedentary activity  
Total sedentary behavior: 6.0±3.5  
Assessment method: Subjective  
Regional location: Riyadh  
Special conditions: Non-Saudis, pregnant women and those with cognitive impairment were not included

Table 7: Contd...

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### Supplement II

**Table 1: A summary of the studies that assessed daytime cognitive function during Ramadan fasting**

| Authors                  | Study population                          | Assessment tool          | Findings                              | Study details                                                                 |
|--------------------------|-------------------------------------------|--------------------------|---------------------------------------|-------------------------------------------------------------------------------|
| Bahammam                | 56 healthy medical students               | ESS                      | Increase in daytime sleepiness        | Subjective assessment Assessment was conducted in a nonconstrained environment |
| Taoudi Benchekroun et al. | 264 young subjects                        | ESS                      | Increase in daytime sleepiness        | Subjective assessment Assessment was conducted in a nonconstrained environment |
| Bahammam                | 101 healthy fasting and nonfasting subjects | ESS                      | No change in daytime sleepiness       | Subjective assessment Assessment was conducted in a nonconstrained environment |
| Margolis and Reed        | 109 healthy medical students              | ESS                      | No change in daytime sleepiness       | Subjective assessment Assessment was conducted in a nonconstrained environment |
| Roky et al.              | 10 healthy young subjects                 | Visual analog scale MRT  | Decreased daytime alertness           | Controlled for sleep/wake pattern Compared with baseline, volunteers slept 1 h less during Ramadan Controlled for meal composition and physical activity |
| Roky et al.              | 16 fasting and nonfasting                 | JDS to assess sleepiness | No decrease in alertness              | Assessed sleep duration objectively using SenseWear Pro Armband™. There was a significant reduction in sleep duration during Ramadan in the fasting group Assessment was conducted in a nonconstrained environment |
| Bahammam et al.          | 8 healthy young male subjects             | JDS Infrared reflectance for blink total duration and a visual reaction time test | No decrease in alertness              | Controlled for sleep/wake schedule, sleep duration, caloric intake, energy expenditure, and light exposure Actigraphy to assure adequate sleep duration in days before the study |
| Chamari et al.           | 11 healthy trained cyclists               | CANTAB, RTI and RVP tests | No decrease in alertness              | Sleep duration was not assessed during the 24 h Tests were conducted at different times during and out of Ramadan |
| Roky et al.              | 8 healthy young subjects                  | Portable MSLT Visual analog scale | Increase in daytime sleepiness        | Portable device used; programmed to end test after 20 min of recording Sleep duration was significantly lower during Ramadan Meals during baseline and Ramadan were according to a fixed schedule and composition Did not rule out possible sleep deprivation in nights before study |
| Authors                | Study population       | Assessment tool                      | Findings                                                                 | Study details                                                                                                                                 |
|------------------------|------------------------|---------------------------------------|---------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------|
| Bahammam               | 8 healthy young subjects | ESS and standard MSLT                 | No change in daytime sleepiness                                            | Did not rule out possible sleep deprivation in nights before study MSLT was preceded by an overnight in laboratory PSG                     |
| Bahammam et al.        | 8 healthy young subjects | ESS and standard MSLT Actigraphy to assess sleep duration in days prior to the study | No change in daytime sleepiness during Islamic intermittent fasting        | Sleepiness was assessed while the volunteers were performing intermittent fasting during and outside Ramadan Controlled for sleep duration in nights prior to study and when at home by objective measurements (actigraphy) |
| Tian et al.            | 18 male athletes       | Computerized neuropsychological testing | Performance in functions requiring sustained rapid responses was better in the morning and declined in the late afternoon Performance in nonspeed-dependent accuracy measures was more resilient | Standardized meals were provided Participants' lifestyle and training in between test sessions were not controlled for Sleep duration was significantly shorter during Ramadan Previous night's sleep and daytime naps, as well as the time of awakening, were not controlled for in this study Participants answered questionnaires regarding diet and sleep duration in the previous 24 h |

ESS=Epworth Sleepiness Scale, MRT=Movement reaction time, CCF=Critical flicker fusion, CANTAB=Cambridge Neuropsychological Test Automated Battery, RTI=Reaction Time Index, RVP=Rapid visual information processing; JDS=John Drowsiness Scale, IR=Infrared reflectance, MSLT=Multiple sleep latency test, PSG=Polysomnography
Table 2: A summary of the studies that objectively assessed changes in the circadian pattern of body temperature during diurnal intermittent fasting for Ramadan

| Authors          | Study population                          | Study design | Assessment tool          | Study setting                  | Findings                          | Study details                                                                 |
|------------------|-------------------------------------------|--------------|--------------------------|--------------------------------|----------------------------------|--------------------------------------------------------------------------------|
| Roky et al.[13]  | 8 healthy young adults (20-28 years old)  | Case cross-over study with repeated measures | Rectal thermistor probe for at least 24 h | Monitoring at home Controlled for meal composition and time, as well as bedtime and rising time | Delay in acrophase and bathyphase | The participants were of the intermediate chronotype as determined by the morningness-eveningness questionnaire Dinner was served 1 h before bedtime during Ramadan and 3 h before bedtime at baseline No objective assessment of prior sleep pattern |
| Roky et al.[5]   | 10 healthy young adults (20-28 years old) | Case cross-over study with repeated measures | High-precision medical oral thermometer at 09:00, 11:00, 13:00, 16:00, 20:00, and 23:00 | Monitoring at home Controlled for meal composition and time, and bed and rise time | Reversal of circadian pattern of temperature | Subjects were of the intermediate chronotype as determined by the morningness-eveningness questionnaire Sleep duration was 1 h shorter during Ramadan than at baseline No objective assessment of prior sleep pattern |
| Bahammam[10]     | 8 healthy young adults (age: 31.8±2 years) | Case cross-over study with repeated measures | High-precision medical oral thermometer at 08:00, 16:00, and 00:00 | Monitoring in the laboratory Controlled for meal composition | No change | No objective assessment of prior sleep pattern Subjects stayed in the laboratory during monitoring |
| Bahammam et al.[14] | 6 healthy young adults with DSPD (18-24 years old) | Case cross-over study with repeated measures | Case cross-over study with repeated measures | SenseWear Pro Armband™ that measures proximal skin temperature during the last week of Shaban and the first 2 weeks of Ramadan | Free-living environment | Further delay in temperature acrophase Subjects belonged to the evening chronotype Sleep patterns were monitored for 2 weeks before the study by use of sleep diaries (no objective assessment) Sleep/wake schedule and sleep duration during the study were assessed objectively via Armband Participants lived in an unconstrained environment during the study |

DSPD=Delayed sleep phase disorder
Table 3: A summary of the studies that objectively assessed changes in melatonin during diurnal intermittent fasting for Ramadan

| Authors          | Study population | Study design                                    | Assessment tool                                      | Study setting                                                                 | Findings                                                                 | Study details                                                                                       |
|------------------|------------------|------------------------------------------------|-----------------------------------------------------|-------------------------------------------------------------------------------|--------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| Bogdan et al.[15] | 10 healthy male  | Case cross-over study with repeated measures   | Blood samples were obtained every 4 h, omitting the 02:00 time point, before and on the 23rd day of Ramadan | Free-living environment                                                      | A decreased and delayed night peak and a flattened slope of serum melatonin concentration in Ramadan | Volunteers slept 1 h less during Ramadan than before Ramadan. Melatonin concentrations were not measured late at night, which fails to address the possibility of a late peak in melatonin concentration |
|                  | volunteers (32-40 years old) | Location: France |                                                     | Controlled for light exposure, sleep schedule, or social habits that accompany Ramadan |                                                                          |                                                                                                      |
| Bahammam[10]     | 8 healthy young adults (age: 31.8±2 years) | Case cross-over study with repeated measures | Saliva samples were collected at three time points over a 24-h period (08:00, 16:00, and 00:00) before and on the 7th and 21st days of Ramadan | In-laboratory monitoring                                                      | A significant decrease in melatonin concentrations at 00:00 and 16:00 during Ramadan. Melatonin profiles continued to show the same trend during Ramadan, but with a flatter slope | Melatonin concentrations were not measured late at night, which fails to address the possibility of a late peak in melatonin concentration |
|                  | Location: Saudi Arabia |                                         |                                                     | Controlled for meal timing and composition                                  |                                                                          |                                                                                                      |
| Almeneessier et al.[19] | 8 healthy young adults (a mean age of 26.6±4.9) | Case cross-over study with repeated measures | Blood samples were collected at 22:00, 02:00, 04:00, 06:00, and 11:00 before Ramadan and while performing fasting outside Ramadan month and on the 2nd week of Ramadan | In-laboratory monitoring                                                      | Intermittent fasting during Ramadan has no significant effects on the circadian pattern of melatonin | Assessed melatonin level when volunteers were fasting outside Ramadan month to control for lifestyle changes that accompany Ramadan |
|                  | Location: Saudi Arabia |                                         |                                                     | Controlled for light exposure, sleep schedule, sleep duration, energy expenditure, and meal composition |                                                                          |                                                                                                      |
Table 4: A summary of the studies that assessed sleep architecture using polysomnography during diurnal intermittent fasting for Ramadan

| Authors | Study population | Study design | Test used for assessment | Study details | Findings |
|---------|------------------|--------------|--------------------------|---------------|----------|
| Roky et al.\[13\] | 8 young healthy adults (20-28 years old) Location: Morocco | Case cross-over study with repeated measures | Ambulatory 8-channel unattended PSG | Unattended PSG Dinner was served at 22:30, and PSG recording started at 23:30 Did not objectively account for the prior sleep sleep/wake pattern before assessing sleep Did not monitor for daytime naps before overnight sleep study Meals during and outside Ramadan were according to a fixed schedule and composition | Significant increase in sleep latency and reduction in total sleep time Increase in stage N2 and reduction in slow-wave sleep Reduced REM sleep |
| Bahammam\[10\] | 8 young healthy adults (age: 31.8±2 years) Location: Saudi Arabia | Case cross-over study with repeated measures | Full attended level 1 in-laboratory PSG | Controlled for sleep schedule, naps, and caloric intake Did not objectively account for the prior sleep/wake pattern before assessing sleep in the laboratory | Significant drop in sleep latency at the end of Ramadan, with no change in total sleep time Reduced REM sleep at the end of Ramadan No significant changes in NREM sleep |
| Bahammam et al.\[11\] | 8 young healthy adults (a mean age of 26.6±4.9 years) Location: Saudi Arabia | Case cross-over study with repeated measures | Full attended level 1 in-laboratory PSG | Controlled for sleep schedule, naps, light exposure, caloric intake, and energy expenditure Assessed the effect of fasting during and outside Ramadan Controlled for sleep/wake and naps for 2 weeks before assessing sleep in the laboratory via actigraphy | Reduced REM sleep during intermittent fasting (during and outside Ramadan) No significant changes in NREM sleep No differences in sleep latency, arousal index, or sleep efficiency |
| Chamari et al.\[8\] | 11 young healthy trained cyclists (a mean age of 21.6±4.8 years) Location: Qatar | Case cross-over study with repeated measures | Portable PSG | Unattended PSG Did not control for sleep/wake pattern or sleep duration During Ramadan, volunteers slept during daytime and at night before and after Ramadan During Ramadan, the volunteers slept in the morning after eating a main meal Naps were not controlled for Did not account for the prior sleep/wake pattern before assessing sleep Participants were cyclists at a training camp The portable device used in the study had relative weakness at the level of the number of awakenings Data regarding sleep duration were highly heterogeneous | Significant increases in the number of awakenings and light sleep in Ramadan Progressive decrease in duration of deep and REM sleep stages that became significant 2 weeks after Ramadan |

NREM=Nonrapid eye movement sleep, REM=Rapid eye movement sleep, PSG=Polysomnography
Table 5: A summary of the studies that assessed daytime sleepiness and daytime alertness during diurnal intermittent fasting for Ramadan

| Authors | Study population | Study design | Assessment tool | Findings | Study details |
|---------|------------------|--------------|-----------------|----------|---------------|
| **Subjective assessment** |
| Bahammam[1] | 56 healthy medical students (a mean age of 22.6±1.3 years) Saudi Arabia | Case cross-over study with repeated measures | ESS | Increase in daytime sleepiness | Subjective assessment. Assessment was conducted in an unconstrained environment |
| Taoudi Benchekroun et al.[2] | 264 young subjects (20-30 years) Location: Morocco | Case cross-over study with repeated measures | ESS | Increase in daytime sleepiness | Subjective assessment. Assessment was conducted in an unconstrained, free-living environment |
| Bahammam[3] | 101 healthy fasting and nonfasting subjects (a mean age of 31.3±2.1) Location: Saudi Arabia | Case-control study with repeated measures | ESS | No change in daytime sleepiness | Subjective assessment. Assessment was conducted in an unconstrained, free-living environment |
| Margolis and Reed[4] | 109 healthy medical students (19-23 years old) Location: United Arab Emirates | Case cross-over study with repeated measures | ESS | No change in daytime sleepiness | Subjective assessment. Assessment was conducted in an unconstrained, free-living environment |
| Nugraha et al.[17] | Among young healthy adults Fasting group (n=25) (age: 26.12±0.98 years); nonfasting group (n=25) (age: 26.2±0.98 years) Location: Germany | Case-control with repeated measures | ESS | No difference in daytime sleepiness between the two groups. However, the ESS score among the fasting group was significantly lower in the last week of Ramadan than in the 1st week | Subjective assessment. Assessment was conducted in an unconstrained, free-living environment |
| **Objective assessment** |
| Roky et al.[5] | 10 healthy young subjects (20-28 years old) Location: Morocco | Case cross-over study with repeated measures | Visual Analogue Scale MRT CFF All measurements taken at 6 different times of the day: 09:00, 11:00, 13:00, 16:00, 20:00, and 23:00 | Decreased daytime alertness MRT increased at the beginning of Ramadan CFF did not change | Controlled for sleep/wake pattern. Volunteers slept 1 h less during Ramadan than at baseline. Controlled for meal composition and physical activity |
| Bahammam et al.[6] | 16 fasting and non-fasting subjects 8 fasting (mean age: 36.25±4.46 years) 8 nonfasting (mean age: 34.75±3.33 years) Location: Saudi Arabia | Case-control with repeated measures | Johns Drowsiness Scale to assess sleepiness Visual reaction time test ESS | No decrease in alertness No change in daytime sleepiness | Assessed sleep duration objectively using the SenseWear Pro Armband™. There was a significant reduction in sleep duration during Ramadan in the fasting group. Assessment was conducted in an unconstrained environment |
| Bahammam et al.[7] | 8 healthy young male subjects (a mean age of 25.3±2.9 years) Location: Saudi Arabia | Case cross-over study with repeated measures | Johns Drowsiness Scale Infrared reflectance for total blink duration and a visual reaction time test | No decrease in alertness | Controlled for sleep/wake schedule, sleep duration, caloric intake, energy expenditure, and light exposure. Actigraphy to assure adequate sleep duration in days before the study |

*Contd...*
| Authors | Study population | Study design | Assessment tool | Findings | Study details |
|---------|------------------|--------------|----------------|----------|--------------|
| Chamari et al. | 11 young healthy trained cyclists (a mean age of 21.6±4.8 years) Location: Qatar | Case cross-over study with repeated measures | CANTAB, RTI, and RVP tests | No decrease in alertness RTI was not affected by Ramadan intermittent fasting or time of day Overall, RVP accuracy increased during and after Ramadan compared with baseline; in the last week of Ramadan, accuracy was highest at the end of the day | Sleep duration was not assessed during the 24 h Tests were conducted at different times during and outside Ramadan |
| Roky et al. | 8 healthy young subjects (20-28 years old) Location: Morocco | Case cross-over study with repeated measures | Portable MSLT Visual analogue scale | Increase in daytime sleepiness Subjective alertness decreased at 12:00 on day 11 of Ramadan but did not change on day 25 On the MSLT, sleep latency was decreased on day 11 and day 25 of Ramadan | Portable device used; programmed to end test after 20 min of recording Sleep duration was significantly lower during Ramadan than at baseline Meals during baseline and Ramadan followed a fixed schedule and composition Did not rule out possible sleep deprivation in nights before study |
| Bahammam et al. | 8 healthy young subjects (age: 31.8±2 years) Location: Saudi Arabia | Case cross-over study with repeated measures | ESS and standard MSLT | No change in daytime sleepiness | Did not rule out possible sleep deprivation in nights prior to study MSLT was preceded by an overnight in-laboratory PSG |
| Bahammam et al. | 8 healthy young subjects (a mean age of 26.6±4.9 years) Location: Saudi Arabia | Case cross-over study with repeated measures | ESS and standard MSLT Actigraphy to assess sleep duration in days before the study | No change in daytime sleepiness during Islamic intermittent fasting | Sleepiness was assessed while the volunteers were performing intermittent fasting during and outside Ramadan Controlled for sleep duration in nights before study and when at home by objective measurements (actigraphy) Standardized meals were provided Participants’ lifestyle and training in between test sessions were not controlled for sleep duration was significantly shorter during Ramadan than at baseline Previous night’s sleep and daytime naps, as well as the time of awakening, were not controlled for in this study Participants answered questionnaires regarding diet and sleep duration in the previous 24 h |
| Tian et al. | 18 male athletes (17-29 years old) Location: Singapore | Case cross-over study with repeated measures | Computerized neuropsychological testing | Performance in functions requiring sustained rapid responses was best in the morning and declined in the late afternoon Performance in nonspeed-dependent accuracy measures was more resilient | |

MRT=Movement reaction time, CFF=Critical flicker fusion, ESS=Epworth Sleepiness Scale, CANTAB=Cambridge Neuropsychological Test Automated Battery, RTI=Reaction Time Index, RVP=Rapid Visual Information Processing, JDS=John Drowsiness Scale, IR=infrared reflectance, MSLT=Multiple sleep latency test, PSG=Polysomnography
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