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Sleep Patterns Among Athletes and Non-Athletes During Ramadan intermittent fasting: Systematic Review, Meta-Analysis and Meta-Regression

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Keywords: Sleep; Ramadan; Athlete; Meta-analysis; Public health
Parole chiave: Sonno; Ramadan; Atleta; Meta-analisi; Sanità publica

Abstract

Background. *Ramadan fasting is a religious observance practiced regularly by Muslims and may have an effect on sleep quality, especially for athletes. Our systematic review with meta-analysis aims to identify the effect of Ramadan observance on the sleep patterns of athletes and non-athletes during Ramadan fasting over the teen years (2014-2024).*
Study design. *A systematic search of Scopus, Web of Science, and Pubmed, was conducted using the Preferred Reporting Items for Systematic Reviews and Meta-analyses.*
Methods. *After a deep search in the three databases, we downloaded all the references that respected our request. all the references were imported into the COVIDENCE platform. Two independent researchers were designated to look for the criteria inclusion and to appraise each study. A third reviewer resolved conflicts if there is a divergence of judgment. Then, we obtained an Excel file that compiles all the data collected. The meta-analysis and meta-regression were compilated.*
Results. *345 documents were found. Of these, 14 respected all the criteria. Our findings revealed that while sleep latency and disturbance remained unaffected by Ramadan, sleep duration and efficiency were negatively impacted, particularly among amateur athletes. Interestingly, the overall sleep quality, daytime dysfunction, and subjective sleep quality showed a positive impact from Ramadan, which was more evident among amateur athletes.*
Conclusions. *In the context of Ramadan fasting, these results suggest that Ramadan has a negative impact on the sleep patterns of athletes and non-athletes.*

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Introduction

An athlete's health depends on getting enough sleep, especially when training or recovering from an illness or injury. Sleep ideal for health and quality of life depends on age (adults should get between 7 and 9 hours per night) (1). For the best recuperation and most meaningful activity, athletes may need more sleep (between 9 and 10 hours) than non-athletes (2). The adverse effects of sleep deprivation on sports performance, including strength and speed, anaerobic and aerobic capacity, and psychomotor function, have been widely documented. Overall, athletes continue to experience a high prevalence of significant sleep disruptions, including insufficient sleep and poor sleep quality (3). Additionally, it was discovered that sleep deprivation impacted endurance performance but had no effect on anaerobic performance (4). Additional research demonstrated that getting enough sleep can enhance an athlete's mood, free throw and 3-point shooting ability in basketball (5), and improves service accuracy in tennis (6). According to several prior studies, diurnal fasting during Ramadan has been linked to disruptions in both quantity and quality of sleep (7). Another study found that during Ramadan, there was a noticeable significant delay in bedtime and wake time (8). Others did not note any significant fluctuations in the time spent sleeping at night throughout Ramadan (8). Nevertheless, some studies claimed no impact on physical performance (9), while others supported the opposite (10). The differences between the previous studies may be attributable to various subjective assessment methods or regional differences in culture and way of life (11). Overall, the research findings are varied, and each study revealed a different set of constraints and difficulties, making it challenging to draw broad conclusions.

In a systematic review and meta-analysis published in 2019 (12), the authors demonstrated that Ramadan and its associated practices significantly impact sleep duration and daytime sleepiness, as assessed by the Epworth Sleepiness Scale (ESS). However, this study did not present an effect size for Ramadan's impact on sleep quality or other sleep characteristics. Another meta-analysis published in 2020 (13) reported a moderate overall effect size for sleep duration, but did not conduct a meta-analysis for sleep quality or other sleep patterns. Additional recent systematic review and meta-analysis published in 2022 (14), reported that sleep duration and sleep quality altered during Ramadan, with no effect on daytime sleepiness levels. However, this study did not analyze the effect of Ramadan on all sleep patterns as measured by the Pittsburgh Sleep Quality Index (PSQI) (15) , only reporting on the global PSQI score and sleep duration.

In light of this limitations and the incongruent findings, this study aimed to conduct a systematic review with meta-analysis and meta regression to determine the effect of Ramadan fasting on sleep patterns among athletes and non-athletes who regularly practice physical activity during observance. This study is the first to examine six dimensions of sleep, as noted by PSQI (15). This meta-analysis and meta-regression will highlight new paths for future investigations.

Materials and methods

This present systematic literature review and meta-analysis adheres to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analyses) (16) and registered in PROSPERO with ID: CRD42022327245. The COVIDENCE carried out data selection and extraction.

Data sources and search strategies

The literature search was conducted across 3 databases. We searched from January 2014 to January 2024 in Scopus, PubMed, and Web Science. The citations from the identified articles were traced. The last search was carried out on 03 January 2024. The following keywords [Sleep-wake cycle] x [Sleep quality] x [Sleep] x [Physical performance] x [Athlete] x [Non-athlete] x [Exercise] x [Performance] x [Physical exercise] were used in combination with [Ramadan] x [Fasting] x [Islamic fasting] x [intermittent Fasting]. Then we used a manual screening for more relevant studies. Indeed, the reference lists of relevant publications and reviews were searched to help ensure that all relevant publications were found.

Study selection and eligibility criteria

Two independent reviewers (ZM and RM) conducted the literature search. They screened the titles and abstracts. Then they reviewed the full texts of the manuscripts to look for the criteria inclusion. In the case of non-consensus, the Supervisor (L.S.) had the final decision. All members of the research team confirmed the inclusion and exclusion criteria. We used the PICOS criteria to define the main characteristics of our research. Population Subjects: athletes or non-athletes. Intervention: intermittent fasting of Ramadan. Comparators Baseline: before, during Ramadan. Outcomes: sleep patterns assessed by PSQI

(15). Study design: observational and experimental studies.

The search and selection procedure were based on the following criteria: English studies; Peer-reviewed journal papers published from 2014 to 2024; observational studies or controlled trials with measures of sleep quality with PSQI; healthy body; fasting during Ramadan with athlete or non-athlete profile. Studies were excluded if they used the animal model or unhealthy individuals; Shift workers; jetlag cases, diet or targeting the medication field.

Data extraction

COVIDENCE conducts data extraction. It is an extraction tool developed by Cochrane and dedicated to its authors. After a deep search in the three databases, we downloaded all the references that respected our request. The next step was to enter all the references into the COVIDENCE platform. Two independent researchers were designated as reviewers. Their mission is to screen the titles and abstracts of the records independently. All papers that were not relevant research rejected it. The reviewers performed an eligibility assessment by carefully scouring the full text independently. During this phase, any conflicts were resolved by discussions among the researchers until a consensus was achieved. The strategy starts by analyzing the title and the abstract. The reviewers accept the study and go to the next step or exclude it by stating the reason. Otherwise, they send it to a full-text analysis. The second step is to make the final extraction. For this, we have previously determined the information to be collected and analyzed the articles one by one to collect all the data we were looking for. Ultimately, we obtain an Excel file that summarize the data collected (Table 1).

Quality assessment of studies

Two independent reviewers appraised each study. A third reviewer resolved conflicts. The "QualSyst" scale was used to assess the risk of bias in studies included in the present review (17). There are 14 items, and each item was rated "Yes", "No", "Partial", or "Not applicable". We give 0 to "No" or "Not applicable", 1 to "Partial", and 2 to "Yes". A study with a score of more or equal to 75% has good quality, a score between 55% - 75% has moderate quality, and those less or equal to 55% have weak quality (Table 2).

Meta-analysis

The data were analyzed using the commercial software Comprehensive Meta-Analysis (CMA V.3.3.070, Biostat, Englewood, New Jersey, USA). An estimation of pooled measures, such as "subjective sleep quality", "sleep latency", "sleep duration", "sleep efficiency", "sleep disturbances", "daytime

Table 1 - Profiles of included studies in the meta-analysis

Study	Year	Country	Fasting time length	C°	Sample size	Level of practice	Age (SD)
Aziz et al. (10)	2017	Singapore	ND	30,5	14	Professional athlete	21.8 (2.4)
Aziz et al. (25)	2018	Singapore	ND	32,1	13	Non-athlete	20.1 (0.9)
Boukhris, H et al. (26)	2019	Tunisia	16,5	31	13	Non-athlete	21.2 (2.9)
Boukhris, T et al. (27)	2019	Tunisia	16	28	14	Non-athlete	21.6 (3.3)
Hsouna et al. (28)	2019	Tunisia	16	31,5	12	Non-athlete	21.9 (2.4)
Aziz et al. (29)	2021	Singapore	14	24,5	10	Professional athlete	22.8 (3.4)
Hsouna et al. (30)	2020	Tunisia	15,6	32	14	Non-athlete	22.0 (ND)
Hsouna et al. (31)	2020	Tunisia	16	30	12	Non-athlete	21.1 (3.2)
Lipert et al. (32)	2021	Liban	15	33	32	Professional athlete	28.3 (ND)
Saddoud et al. (33)	2022	Tunisia	16	ND	14	Professional athlete	19.0 (ND)
Boukhris et al. (34)	2022	Tunisia	16,33	32	15	Non-athlete	21.0 (ND)
EL-Jaziz et al. (35)	2023	Morocco	15,5	21	50	Non-athlete	17.2 (1.15)
EL-Jaziz et al. (36)	2023	Morocco	13,5	21	96	Non-athlete	16.9 (1.09)
EL-Jaziz et al. (37)	2023	Morocco	15,5	21	117	Non-athlete	16.9 (1.07)

ND: Not determined. C°: average temperature during the month of Ramadan.

Table 2 - Quality assessment of the 14 included studies (The "QualSyst" scale)

Author	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total score (%)	Quality assessment
Aziz et al. (10)	2	2	2	2	N/A	N/A	N/A	2	2	2	1	1	2	2	90,91%	Strong
Aziz et al. (25)	2	2	2	2	N/A	N/A	N/A	2	2	2	1	1	2	2	90,91%	Strong
Boukhris, H et al. (26)	2	2	2	1	N/A	N/A	N/A	2	2	2	1	1	2	2	86,36%	Strong
Boukhris, T et al. (27)	2	2	2	2	N/A	N/A	N/A	2	2	2	1	1	2	2	90,91%	Strong
Hsouna et al. (28)	2	2	1	2	N/A	N/A	N/A	2	1	2	1	1	2	2	81,82%	Strong
Aziz et al. (29)	2	2	2	2	N/A	N/A	N/A	2	1	1	1	1	2	2	81,82%	Strong
Hsouna et al. (30)	2	2	2	2	N/A	N/A	N/A	2	2	2	1	1	2	2	90,91%	Strong
Hsouna et al. (31)	2	2	2	2	N/A	N/A	N/A	2	2	2	1	1	2	2	90,91%	Strong
Lipert et al. (32)	2	2	1	2	N/A	N/A	N/A	2	1	2	1	1	2	2	81,82%	Strong
Saddoud et al. (33)	2	2	1	2	N/A	N/A	N/A	2	1	1	2	1	2	2	81,82%	Strong
Boukhris et al. (34)	2	2	2	2	N/A	N/A	N/A	2	2	2	2	1	2	2	95,45%	Strong
EL-Jaziz et al. (35)	2	2	1	2	N/A	N/A	N/A	2	2	2	1	1	2	2	86,36%	Strong
EL-Jaziz et al. (36)	2	2	1	2	N/A	N/A	N/A	2	2	2	1	1	2	2	86,36%	Strong
EL-Jaziz et al. (37)	2	2	1	2	N/A	N/A	N/A	2	2	2	1	1	2	2	86,36%	Strong

1: Objective, 2: Design, 3: Subject selection, 4: Subject characteristics, 5: Random allocation, 6: Blinding investigators, 7: Blinding subjects, 8: Outcomes, 9: Sample size, 10: Analysis, 11: Estimate of variance, 12: Confounding, 13: Results, 14: Conclusion, NA: Not applicable

dysfunction", and the "total PSQI score", was calculated using a random-effect model, following the DerSimonian–Laird method (18), both before and during Ramadan. The interpretation of PSQI results was conducted by utilizing the reference ranges provided in the PSQI questionnaire, where a score less than 5 signifies good sleep quality and a score greater than 5 signifies poor sleep quality (15).

The meta-analysis was undertaken by doing one-group meta-analyses (pre-post) utilizing means and standard deviations (SDs) before and during Ramadan. The sample size and pre-post correlation values were adjusted for this study. The means were chosen from empirical investigations, and in instances where the correlation was not given, a cautious estimate of $r = 0.5$, as suggested by Higgins et al., (19) was utilized.

The meta-analysis employed Cohen's guidelines to determine effect sizes (ES) with 95% confidence intervals (CIs). These effect sizes represent standardized variations in averages between total sleep patterns before and during Ramadan. The scores of ES were classified into different categories, namely trivial (ES <0.2), minor (ES 0.2–0.6), moderate (ES 0.6–1.2), big (ES 1.2–2.0), very large (ES >2.0), or extremely large (ES >4.0).

In order to assess statistical heterogeneity, the Q statistic (20) and I^2 (21) were employed. The presence of significant heterogeneity was determined when the I^2 value surpassed 50%. The values were classified into levels of statistical heterogeneity, namely low (25%), moderate (50%), or high (75%) (21). Moderator analysis, including subgroup analysis for categorical variables (e.g., sports category, level of practice), and meta-regression for both integer or decimal variables (e.g., fasting time length, age, temperature, and body mass index) and categorical variables, was performed to identify potential sources of variance and heterogeneity.

Sensitivity analyses were conducted to figure out the stability of pooled ES by assessing the impact of taking out specific investigations (leave-one-out). Additionally, a cumulative meta-analysis was carried out to further establish the stability and reliability of the outcomes.

Potential publication bias was investigated by examining funnel plot asymmetry and executing Begg and Mazumdar's rank correlation test (Kendall's S statistic P–Q)(22), Egger's linear regression test (23), and Duval and Tweedie's trim-and-fill test (24). A significance level of $p < 0.05$ was utilized for all analyzes.

Results

Study Selection

A total of 345 records were found via the initial search. Of these articles, 239 were screened by titles and abstracts for eligibility, of which 73 published studies met the inclusion criteria. After a careful review, 14 articles were included in this systematic

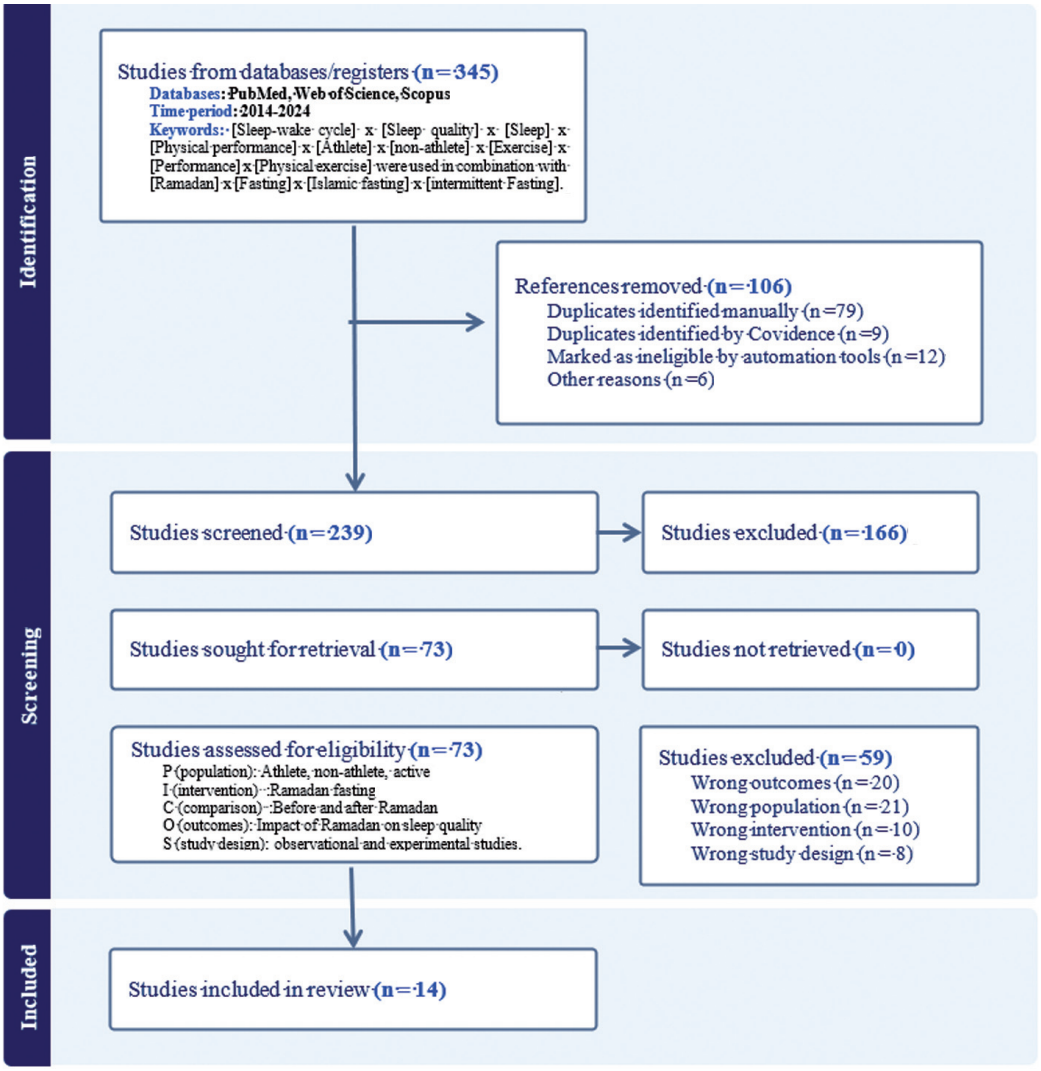

Figure 1 - PRISMA flow diagram for literature review search with a brief summary of the adopted search strategy.

review (10, 25-37). Figure 1 provides the flow diagram of this search process.

Study characteristics

A total of 14 studies, comprising 83 athletes and 343 non-athletes (non-sedentary), recruited 290 athletes from team sports and 136 from individual sports from four countries were included in this meta-analysis. All studies included fasting participants who practice regularly the training or participate in competition events during Ramadan. Three studies were conducted in Asia (Singapore), and the rest in Africa (Tunisia, Morocco, Lebanon). The average duration of fasting per day during Ramadan was 15.49 hours, with temperatures ranging between 21-33°C. The average age of participants ranged from 18 to 24 years. The highest number of participants was 117 in the study. All research papers were published between the years 2014 and 2024.

Quality Assessment

After checking the scores of 14 studies, the included research showed high methodological quality (Table 2). The most significant number of points were lost due to the lack of control of confounding factors (50%), lack of Estimating of variance (42.86%) and sample size (14.29%).

Meta-Analysis outcomes

Subjective sleep quality

The meta-analysis of subjective sleep quality before Ramadan revealed that participants obtained (1.103, 95% CI [0.799, 1.407]) with a significative heterogeneity ($Q = 231.147$, $df = 8$, $p = 0.000$; $I^2 = 96.539\%$). Analysis by subgroups found that non-athlete population had an overall pooled estimate of subjective sleep quality greater than athlete population (1.121;95% CI [0.769,1.473]) and (1, 95% CI [0.774,1.225])

respectively. However, during Ramadan, the subjective sleep quality increased to (1.777, 95% CI [1.600, 1.955]), with significant heterogeneity (Q = 58.784, df = 8, p = 0.000; I^2 = 86.391%), and it has observed among non-athlete more than athlete population (1.790, 95% CI [1.589, 1.991]) and (1.693, 95% CI [1.407, 1.980]).

Meta-analysis of pre-post subjective sleep quality indicated a significant large effect size of Ramadan (ES = 0.924, SE = 0.089, 95% CI [0.750, 1.099], Z-value = 10.389, p = 0.000), with an insignificant heterogeneity (Q = 12.806, df = 8, p = 0.119; I^2 = 37.530%); thus, a subgroup analysis and meta-regression analysis were completed. In the subgroup analysis, we computed nine research reports (27, 30-37) among two categorical variables: "level of practice", "Sports category". On one hand, the results confirmed that Ramadan fasting had a more significant effect size among individual sports participants than team sports participants (ES=1.129, SE= 0.158, 95% CI [0.820, 1.438], Z-value= 7,161, p= 0.000) and (ES= 0.789, SE= 0.069, 95% CI [0.653, 0.925], Z-value= 11.383, p= 0.000) respectively. On the other hand, the finding revealed that Ramadan observance had a more significant impact on subjective sleep quality in non-athlete population than professional athletes (ES=0.991, SE = 0.114, 95% CI [0.768, 1.215], Z-value= 8.691, p= 0.000) and (ES=0.782, SE= 0.165, 95% CI [0.458, 1,106], Z-value= 4.733, p= 0.000).

To verify if the characteristics of studies are associated with the effect size observed in this study, a meta-regression analysis performed and indicated no impact of the level of practice (coefficient= -0.184, SE= 0.25, t= -0.74, p = 0.485), fasting time length (coefficient= 0.153, SE= 0.094, 95% CI [–0.069, 0.376], t= 1.63, p= 0.073), sports category (coefficient= -0.284, SE= 0.170, 95% CI [-0.687, 0.119], t= -1.67, p= 0.069), age (coefficient= 0.011, SE = 0.027, 95% CI [-0.052, 0.075], t =0.43, p = 0.341) and temperature (coefficient= 0.026, SE= 0.019, 95% CI [-0.022, 0.074], t= 1.33, p= 0.115). However, we discovered a significant impact of the body mass index BMI (coefficient= 0.220, SE= 0.095, 95% CI [-0.013, 0.454], z= 2.31, p= 0,030).

Publication bias

The funnel plot and the results of Begg and Mazumdar's test (Kendall's S statistic P–Q = 30; tau without continuity correction = 0.833, z = 3.128, p = 0.000; tau with continuity correction = 0,805, z = 3.023, p = 0.001) and of the Egger's linear regression test (intercept = 2.173, SE = 0.450, 95% CI [1.108 to 3.239], t = 4.823, df = 7, p = 0.000) provided evidence of publication bias. Indeed, with the Duval and Tweedie trim-and-fill analysis, four studies were trimmed in the plot, and the overall effect size became 0,802 with 95% CI [0.603, 1].

Stability and Reliability

The sensitivity analyses were conducted to determine the stability of pooled ES. The effect of Ramadan on subjective sleep quality is robust and not significantly driven by any single study. In addition, the cumulative meta-analysis of the pooled effects confirmed the strong stability of the results over time.

Sleep Latency

A meta-analysis was carried out using evidence from eleven studies, and the pooled results showed no significant effect of Ramadan intermittent fasting on sleep latency (ES= -0.258, SE= 0.157, 95% CI [-0.565, 0.565], Z-value= -1.644, p = 0.100). However, the heterogeneity was highly significant (Q= 68.606, df= 10, p= 0.000; I^2= 85.424%).

Publication bias

The funnel plot and the results of Begg and Mazumdar's test (Kendall's S statistic P–Q = -2; tau without continuity correction = -0,030, z = 0,137, p = 0.445; tau with continuity correction = -0,015, z = 0,068, p = 0.0,472) and of the Egger's linear regression test (intercept = 0,288, SE = 2,097, 95% CI -4,386 to 4,962, t = 0,137, df = 10, p = 0.447) provided robust evidence of the absence of publication bias. In fact, with the Duval and Tweedie trim-and-fill analysis, one study was trimmed in the plot, and the overall effect size became -0,166 with 95% CI [-0.510, 0,177].

Stability and Reliability

The sensitivity analyses were conducted to figure out the stability of the pooled effect size. The effect of Ramadan on sleep latency is robust and not driven by any single study. In addition, a strong stability of the findings was confirmed according to the cumulative meta-analysis of the pooled effects.

Sleep duration

Meta-analysis of pre-post sleep duration indicated a significant moderate effect size of Ramadan (ES = -0.613, SE = 0.168, 95% CI [-0.943, -0.283], Z-value = -3.642, p = 0.000), with a significant heterogeneity (Q = 99.157, df = 13, p = 0.000; I^2 = 86.890%); thus, a subgroup analysis and meta-regression analysis were completed. In the subgroup analysis, we computed

fourteen research reports (10, 25-37), among two categorical variables: "Level of practice", "Sports category". On one hand, the results confirmed that Ramadan fasting had a more significant effect size among individual sports than team sports (ES= -0.726, SE= 0.281, 95% CI [-1.277, -0.176], Z-value= -2.584, p= 0.000) and (ES= -0.574, SE= 0.191, 95% CI [-0.948, -0.200], Z-value= -3.010, p= 0.003) respectively. On the other hand, the finding revealed that Ramadan observance had a significant impact on sleep duration in non-athlete but not on athlete population (ES=-0.840, SE = 0.203, 95% CI [-0.442, -0.442], Z-value= -4.141, p= 0.000) and (ES=-0.197, SE= 0.201, 95% CI [-0.590, 0.196], Z-value= -0.983, p= 0.326).

To verify if the characteristics of studies are associated with the effect size observed in this study, a meta-regression analysis performed and indicated no impact of the level of practice (coefficient= 0.622, SE= 0.452, t= 1.37, p = 0.098), fasting time length (coefficient= 0.110, SE= 0.488, 95% CI [-0.952, 1.172], t= 0.23, p= 0.443), sports category (coefficient= -0.284, SE= 0.170, 95% CI [-0.687, 0.119], t= -1.67, p= 0.069), age (coefficient= 0.079, SE = 0.072, 95% CI [-077, 0.235], t =1.11, p = 0.145), temperature (coefficient= 0.037, SE= 0.051, 95% CI [0.077, 0.150], t= 0.71, p= 0.245) and BMI (coefficient= -0.015, SE= 0.244, 95% CI [-0.551, 0.522], t= 0.06, p= 0,477).

Publication bias

The funnel plot and the results of Begg and Mazumdar's test (Kendall's S statistic P–Q = -17; tau without continuity correction = -0,187, z = 0,930, p = 0,176; tau with continuity correction = -0.176, z = 0.876, p = 0.190) and of the Egger's linear regression test (intercept = 0.575, SE = 1.686, 95% CI [-3.099, 4.248], t= 0,341, df = 12, p = 0.369) provided robust evidence of the absence of publication bias. This further strengthens the credibility of our findings. In addition, the Duval and Tweedie trim-and-fill analysis did not trim any study in the plot.

Stability and Reliability

The sensitivity analyses were conducted to figure out the stability of the pooled effect size. The effect of Ramadan on sleep duration is robust and has not been driven by any single study. In addition, the strong stability of the findings was confirmed according to the cumulative meta-analysis of the pooled effects.

Sleep Efficiency

Meta-analysis of pre-post sleep efficiency indicated a significant low effect size of Ramadan (ES = -0.375, SE = 0.085 95% CI [-0.541, -0.208], Z-value = -4.411, p = 0.000), with an insignificant moderate heterogeneity (Q = 16.223, df = 9, p = 0.062; I^2 = 44.524%); thus, a subgroup analysis and meta-regression analysis were completed. In the subgroup analysis, we computed teen research reports (26-28, 30, 31, 33-37), among two categorical variables: "Level of practice", "Sports category". On one hand, the results confirmed that Ramadan fasting had a more significant effect size among individual sports than team sports (ES= -0.578, SE= 0.129, 95% CI [-0.829, -0.322], Z-value= -4.453, p= 0.000) and (ES= -0.229, SE= 0.061, 95% CI [-0.349, -0.109], Z-value= -3.742, p= 0.000) respectively. On the other hand, the finding revealed that Ramadan observance had a significant impact on sleep duration in non-athlete population (ES= -0,332 SE = 0.080, 95% CI [-0.490, -0.174], Z-value= -4.128, p= 0.000).

To verify if the characteristics of studies are associated with the effect size observed in this study, a meta-regression analysis performed and indicated no impact of the level of practice (coefficient= -0.531, SE= 0.380, t= -1.40, p = 0.099), fasting time length (coefficient= -0.092, SE= 0.100, 95% CI [-0.323, 0.138], t= -0.93, p= 0.191), temperature (coefficient= -0.028, SE= 0.016, 95% CI [-0.065, 0.010], t= -1.75, p= 0.061) and BMI (coefficient= -0.140, SE= 0.074, 95% CI [-0.315, 0.036], t= -1.87, p= 0.051). However, there is a significant impact of sports category (coefficient= 0.343, SE= 0.140, 95% CI [0.019, 0.667], t= 2.44, p= 0.020) and age (coefficient= -0.072, SE = 0.036, 95% CI [-0.155, 0.011], t =-2, p = 0.04).

Publication bias

The funnel plot and the results of Begg and Mazumdar's test (Kendall's S statistic P–Q = -27; tau without continuity correction = -0.60, z = 2.41, p = 0.007; tau with continuity correction = -0.578, z = 2.325, p = 0.01) and Egger's linear regression test (intercept = -1.780, SE = 0.689, 95% CI [-3.368, -0.192], t = 2.584, df = 8, p = 0.0162 provided robust evidence of publication bias. In addition, the Duval and Tweedie trim-and-fill analysis did not trim any study in the plot.

Stability and Reliability

The sensitivity analyses were conducted to figure out the stability of the pooled effect size. The effect of Ramadan on sleep efficiency is robust and not driven by any single study. In addition, a strong stability of the findings was confirmed according to the cumulative meta-analysis of the pooled effects.

Sleep disturbance

A meta-analysis was carried out using evidence from teen previous studies, and the pooled results showed an insignificant low effect size of Ramadan intermittent fasting on sleep disturbance (SE= 0.186; 95% CI [-0.113, 0.484]; z= 1.220; p= 0.223). However, the heterogeneity was moderate and significant (Q= 54.891; p= 0.000; df= 9; I²= 83,604%).

Publication bias

The funnel plot and the results of Begg and Mazumdar's test (Kendall's S statistic P–Q = 21; tau without continuity correction= 0.467, z= 1.878, p= 0.030; tau with continuity correction= 0.444, z= 1.789, p= 0.036) and Egger's linear regression test (intercept= 1.031, SE= 1.568, 95% CI [-2.585, 4.646], t= 0.657, df= 8, p= 0.265 provided robust evidence of publication bias Indeed, with the Duval and Tweedie trim-and-fill analysis, one study was trimmed in the plot, and the overall effect size became 0.072 with 95% CI [-0.239, 0.383].

Stability and Reliability

The sensitivity analyses were conducted to figure out the stability of the pooled effect size. The effect of Ramadan on sleep disturbance is robust and not driven by any single study. In addition, a strong stability of the findings was confirmed according to the cumulative meta-analysis of the pooled effects.

Daytime dysfunction

The meta-analysis of daytime dysfunction before Ramadan revealed that participants obtained (0.741, 95% CI [0.462, 1.020]) with a significative heterogeneity (Q= 397.219, df= 9, p = 0.000; I² = 97.734%). Analysis by subgroups found that non-athletes had an overall pooled estimate of daytime dysfunction less than the professional athletes (0.672, 95% CI [0.365, 1.158]) and (1.010, 95% CI [0.861, 1.158]), respectively. However, during Ramadan, daytime dysfunction increased to (1.145, 95% CI [0.793, 1.498]), with significant heterogeneity (Q = 381.301, df = 9, p = 0.000; I² = 97.640%), and it has observed among professional athletes more than non-athlete population (1.262, 95% CI [0.618, 1.905]) and (1,121, 95% CI [0.722, 1.519]).

Meta-analysis of pre-post daytime dysfunction indicated a significantly small effect size of Ramadan (ES = 0.731, SE = 0.0.173, 95% CI [0.392, 1.070], Z-value = 4.225, p = 0.000), with a significant high heterogeneity (Q = 58.366, df= 9, p= 0.000; I²= 84.580%); thus, subgroup analysis and meta-regression analysis were completed. In the subgroup analysis, we computed teen reports (27, 28, 30-37), among two categorical variables: "Level of practice", "Sports category". On one hand, the results confirmed that Ramadan fasting had a significant effect size among team sports more than individual sports participants (ES= 0.912, SE = 0.072, 95% CI [0.771, 1.052], Z-value= 12.680, p= 0.000) and (ES=0.713, SE= 0.336, 95% CI [0.055, 1.371], Z-value= 2.124, p = 0.034) respectively. On the other hand, the finding revealed that analysis by subgroup of level of practice showed a significant impact on daytime dysfunction in non-athletes more than professional athletes respectively (ES= 0.831, SE= 0.185, 95% CI [0.468, 1.194], Z-value= 4.486, p= 0.000) and (ES= 0.327, SE= 0.573, 95% CI [-0.797, 1.450], Z-value= 0.570, p= 0.000).

To verify if the characteristics of studies are associated with the effect size observed in this study, a meta-regression analysis performed and indicated no impact of the level of practice (coefficient = -0.496, SE= 0.664, t= -0.75, p= 0.238), fasting time length (coefficient= -0.20, SE= 0.344, 95% CI [-0.992, 0.592], t= -0.58, p= 0.288), sports category (coefficient= 0.274, SE= 0.571, 95% CI [-1.043, 1.592], t= 0.48, p= 0.322), age (coefficient= 0.006, SE= 0.082, 95% CI [-0.185, 0.197], t= 0.07, p= 0.471), temperature (coefficient= -0.007, SE= 0.075, 95% CI [-0.109, 0.237], t= 0.85, p= 0.209) and BMI (coefficient= 0.074, SE = 0.306, 95% CI [-0.650, 0.799], t= 024, p= 0.407).

Publication bias

The funnel plot and the results of Begg and Mazumdar's test (Kendall's S statistic P–Q = -5; tau without continuity correction= -0.111, z = 0.447, p = 0.327; tau with continuity correction = -0.088, z= 0.357, p= 0.360) and of the Egger's linear regression test (intercept= -0.760, SE= 1.854, 95% CI [-5.037, 3.516], t= 0.410, df = 8, p= 0.346) provided no evidence of publication bias. Indeed, with the Duval and Tweedie trim-and-fill analysis, two study was trimmed in the plot, and the overall effect size became 0.538 with 95% CI [0.172, 0.904].

Stability and Reliability

The sensitivity analyses were conducted to determine the stability of pooled ES. The effect of Ramadan on daytime dysfunction is robust and not significantly driven by any single study. In addition, the cumulative meta-analysis of the pooled effects confirmed the robust stability of the results over time.

Total PSQI score

The meta-analysis of total PSQI scores before Ramadan revealed that participants obtained (4.497, 95% CI [3.796, 5.199]) with a significative heterogeneity (Q= 211.903, df= 10, p= 0.000; I²= 95.281%). Analysis by subgroups found that non-athletes had an overall pooled estimate of total PSQI Scores less than the professional athletes (4.366, 95% CI [3.572, 5.160]) and (5.084, 95% CI [4.561, 5.607]) respectively. However, during Ramadan, total PSQI scores increased to (6.253, 95% CI [5.395, 7.110]), with significant heterogeneity (Q= 312.144, df= 10, p= 0.000; I² = 96.796%), and it has observed among athletes more than non-athlete population respectively (6.537, 95% CI [5.957, 7.116]) and (6.203, 95% CI [5.228, 7.178]).

Meta-analysis of pre-post total PSQI scores indicated a significantly high effect size of Ramadan (ES= 0.809, SE= 0.226, 95% CI [0.366, 1,152], Z-value= 3.579, p= 0.000), with a significant high heterogeneity (Q= 100.728, df= 10, p= 0.000; I²= 90.072%) (Figure 2); thus, subgroup analysis and meta-regression analysis were completed. In the subgroup analysis, we computed eleven reports (26-28, 30-37), among two categorical variables: "Level of practice", "Sports category". On one hand, the results confirmed that Ramadan fasting had a significant effect size among individual sports participants more than team sports participants (ES= 1.092, SE= 0.477, 95% CI [0.157, 2.027], Z-value= 2.289, p= 0.022) and (ES= 0.862, SE = 0.071, 95% CI [0.723, 1.001], Z-value= 12.173, p= 0.000) respectively. On the other hand, the finding revealed that Ramadan observance had a significant impact on total PSQI scores in non-athlete more than professional athletes respectively (ES=0.888, SE= 0.280, 95% CI [0.340, 1.437], Z-value= 3.174, p= 0.002) and (ES= 0.696, SE= 0.204, 95% CI [0.297, 1.095], Z-value= 3.417, p= 0.001).

To verify if the characteristics of studies are associated with the effect size observed in this study, a meta-regression analysis performed and indicated no impact of the level of practice (coefficient= -0.211, SE= 1.217, t= -0.17, 95% CI [-2.664, 2.541], p = 0.433), fasting time length (coefficient = -0.203, SE = 0.598, 95% CI [-1.556, 1.150], t= -0.34, p= 0.371), sports category (coefficient= 0.026, SE= 0.1.042, 95% CI [-2.331, 2.383], t= 0.02, p= 0.490), age (coefficient= 0.007, SE= 0.148, 95% CI [-0.327, 0.340], t= 0.05, p= 0.482), temperature (coefficient= -0.003, SE= 0.095, 95% CI [-0.2033, 0.227], t= 0.13, p= 0.90) and BMI (coefficient= 0.148, SE = 0.583, 95% CI [-1.197, 1.492], t = 0.25, p = 0.403).

Publication bias

The funnel plot and the results of Begg and Mazumdar's test (Kendall's S statistic P–Q= 7; tau without continuity correction= 0.127, z= 0.544, p= 0.34; tau with continuity correction= 0.109, z= 0.467, p= 0.320) and the Egger's linear regression test (intercept= 0.416, SE= 1.864, 95% CI [-3.800, 4.633], t= 0.223, df= 9, p= 0.414) provided no evidence of publication bias. Indeed, with the Duval and Tweedie trim-and-fill analysis, three studies were trimmed in the plot, and the overall effect size became 0,385 with 95% CI [-0.105, 0.877] (Figure 3).

Study name	Std diff in means	Standard error	Lower limit	Upper limit	Z-Value	p-Value
Boukhris et al. (26)	-0,776	0,310	-1,384	-0,169	-2,504	0,012
Boukhris et al. (27)	1,380	0,366	0,663	2,097	3,771	0,000
Hsouna et al. (28)	-1,718	0,445	-2,590	-0,845	-3,860	0,000
Hsouna et al. (30)	4,508	0,875	2,793	6,222	5,153	0,000
Hsouna et al. (31)	5,879	1,209	3,509	8,249	4,861	0,000
Lipert et al. (32)	0,862	0,203	0,464	1,260	4,250	0,000
Saddoud et al. (33)	0,447	0,275	-0,092	0,985	1,626	0,104
Boukhris et al. (34)	1,176	0,329	0,531	1,821	3,574	0,000
EL-Jaziz et al. (35)	0,732	0,156	0,426	1,037	4,689	0,000
EL-Jaziz et al. (36)	0,869	0,117	0,639	1,099	7,405	0,000
EL-Jaziz et al. (37)	0,919	0,108	0,707	1,130	8,505	0,000
	0,809	0,226	0,366	1,252	3,579	0,000

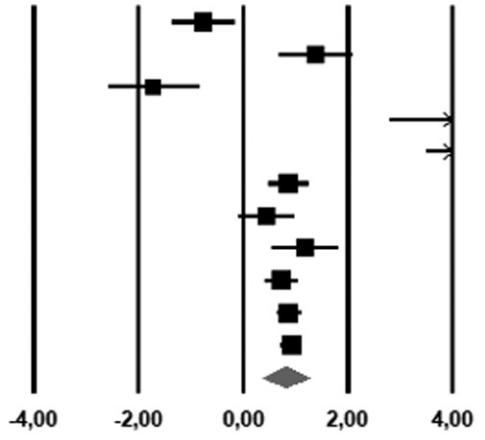

Figure 2 - Forest plot of the total PSQI Score

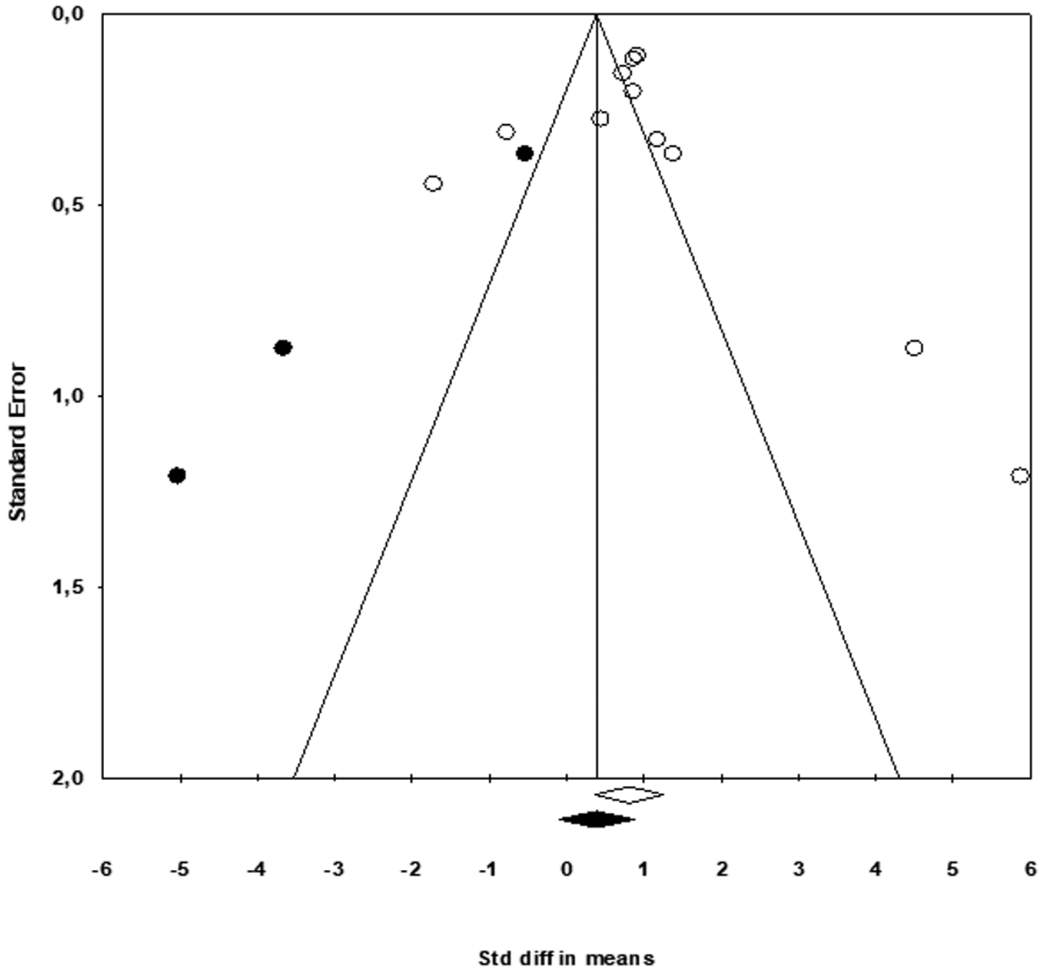

Figure 3 - Funnel plots of the total PSQI score

Stability and Reliability

The sensitivity analyses were conducted to determine the stability of pooled ES. The effect of Ramadan on total PSQI Scores is robust and not significantly driven by any single study. In addition, the cumulative meta-analysis of the pooled effects confirmed the robust stability of the results over time.

Discussion and conclusions

This systematic review and meta-analysis, crucial for researchers, coaches, and athletes, delved into the sleep quality of athletes (professional/amateur) before and during intermittent fasting of Ramadan. Our findings revealed that while sleep latency and disturbance remained unaffected by Ramadan, sleep duration and efficiency were negatively impacted, particularly among amateur athletes. Interestingly, the overall sleep quality, daytime dysfunction, and subjective sleep quality showed a positive impact from Ramadan, which was more pronounced among amateur athletes.

In this meta-analysis, the significant finding was that Ramadan does not impact sleep disturbance for non-athlete and athlete population. Lipert et al. (38) confirmed this outcome and showed that the sleep disturbance was the same before and during Ramadan. However, this result does not align with previous studies suggesting that Ramadan is associated with dietary changes that could induce gastrointestinal disorders and impair sleep interruption (39-41). In addition, other studies suggested that the risk of this interruption is due to the late Suhoor meal (the

last meal before starting the day fast) (42) or to the excess drinking water during night-time which may lead the athlete to wake-up at night many times to urinate (43).

The analysis yielded no discernible impact of Ramadan on sleep latency among non-athlete and athlete population. Our findings align with previous research (44). This consistency persisted even after controlling for various circadian moderators, including the sleep/wake schedule, prior sleep duration, caloric intake, energy expenditure, and light exposure (45). One potential explanation for these results is that athletes may compensate for daytime fasting by incorporating naps into their routine, thus regulating their sleep patterns and mitigating any potential impact on latency. However, contrasting findings from other recent studies (46, 47) suggest the opposite. It is conceivable that alterations in the timing of nocturnal meal consumption and delays in nocturnal training or competitions contribute to changes in sleep patterns, promoting nocturnal wakefulness.

The research findings indicate that Ramadan has a negative impact on sleep efficiency among non-athlete, while professional athletes do not experience significant changes. Our findings diverge from previous research outcomes. According to clinical guidelines, a sleep efficiency >85% reflects good sleep efficiency during Ramadan (48), and many studies found that the average sleep efficiency values were higher than this cut-off. Therefore, there was no significant change in sleep efficiency during the fasting period compared to baseline (42, 44, 49-51).

The meta-analysis findings suggest that Ramadan negatively affects the sleep duration in non-athlete population, whereas professional athletes do not undergo significant alterations. Our results are in accordance with another meta-analysis that found the Total sleep time decreased during Ramadan (27) in athletes and non-athlete people (12). Nevertheless, not with others (26, 28, 52) that they reported a need for more change in sleep duration during Ramadan. In the present meta-analysis, the total studied population was 7.65 h, which decreased by 62 minutes during Ramadan; this result is in line with the last meta-analysis (12), which found the average was 7.2 h, which decreased by ~60 min during Ramadan observance. One possible explanation for this reduced sleep duration may be the increased exposure to nocturnal light (53) resulting from heightened nighttime social activities during Ramadan (12, 54). BaHammam (55) also proposed another explanation, suggesting that sleeping with a full stomach after the late Suhoor meal could lead to gastroesophageal reflux and reduced diet-induced thermogenesis, affecting sleep duration. Moreover, future analyses should consider factors such as mental and psychological stability throughout the month when training and competing activities are undertaken, as these parameters are likely to influence total sleep duration significantly.

The current study found that subjective sleep quality and the total PSQI score are positively impacted by Ramadan, particularly among non-athletes compared to professionals. Our findings are consistent with previous studies that demonstrated a significant increase in subjective sleep perception during Ramadan compared to before (47, 56, 57), especially towards the end (57). However, these results differ from some published meta-analyses (14) that did not find any change in global PSQI scores, especially among individuals who continued to train during Ramadan. This discrepancy may be attributed to the fact that Ramadan observance is generally associated with changes in training programs, sleep routines (39, 58), alterations in food composition and quantity, as well as meal timing and frequency (59). These dietary changes could induce gastrointestinal disorders (39), which have been previously suggested to impair athletes' sleep quality through sleep interruption (40). It is pertinent to highlight that while physical activity during Ramadan influences sleep quality, it remains elusive to discern whether specific forms of physical exercise exert a differential impact on sleep quality during this period. Hence, there is a necessity for future studies centred on Ramadan to adopt experimental designs, transcending reliance on subjective assessments.

The results of this study indicate that daytime dysfunction was positively influenced by Ramadan, particularly among non-athletes compared to professionals. These findings appear to align with previous meta-analyses that documented a substantial increase in daytime sleepiness during Ramadan (12, 54). Other research corroborated these findings, suggesting that Ramadan leads to a significant, substantial, and robust increase in daytime dysfunction among athletes (46). This observed increase in daytime dysfunction may arise from the cumulative effects of sleep deprivation during Ramadan, compounded by daytime fatigue associated with training schedules or competition schedules, which may be further exacerbated by inadequate hydration throughout the day. However, other meta-analyses did not support our results and reported no significant effect of Ramadan on daytime sleepiness (14). A possible explanation might be that athletes take daily naps or employ other adaptive

responses to counteract daytime sleepiness (13). In future investigations, it might be possible to explore different forms of sleep recuperation during Ramadan observance.

Practical implications

The findings of this review have several practical and research implications. It would be advisable for Sports psychologists, Sports nutritionists, Coaches, adolescent university students and athletes to conduct regular assessments of the effect of Ramadan intermittent fasting on their sleep quality to increase physical performance and anticipate the effects of possible coping strategies and overcome sleep disturbance. Thus, we suggested the need for self-help management strategies and program training for athletes to identify and enhance sleep quality, especially before competitions.

Limitations and strengths

The current review possesses several strengths. It represents the first systematic review with meta-analysis and meta-regression, reporting pooled effect sizes for six dimensions of sleep among both athletes and non-athletes. While the majority of previous meta-analyses have presented information solely on sleep duration and the total score of the PSQI, no study - to our knowledge- has addressed all dimensions previously comprehensively. However, it is crucial to acknowledge the limitations of the present study when assessing the effect of Ramadan intermittent fasting on sleep patterns. Firstly, during the realization of this meta-analysis, other authors have published similar projects, necessitating several modifications to ensure the originality of our study. This process led to a considerable time investment, with occasional revisions required to our inclusion and exclusion criteria. Secondly, due to the relatively small number of studies included in this meta-analysis and an insufficient representation of athlete participants compared to non-athletes, caution should be exercised in generalizing the conclusions of the current review. Thirdly, certain research studies may not be included in this meta-analysis, even if published between 2014 and 2024, despite using MeSH keywords and various databases. Fourthly, we were constrained to rely on the published data available to extract information regarding participants' sleep and level of practice during Ramadan. However, the data was sometimes insufficient or unavailable, so we did not verify physical performance as a moderator variable susceptible to association with sleep quality during Ramadan.

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Riassunto

Modelli di sonno tra Atleti professionisti e Atleti dilettanti durante il digiuno intermittente del Ramadan Systematic Review, Meta-Analysis and Meta-Regression

Contesto. Il digiuno del Ramadan è un'osservanza religiosa osservata periodicamente dai musulmani praticanti e può avere un effetto sulla qualità del sonno, in particolare per gli atleti. La nostra revisione sistematica con meta-analisi (2024-2024) mira a identificare l'effetto dell'osservanza del Ramadan sui modelli di sonno di atleti e non atleti durante il digiuno del Ramadan negli anni dell'adolescenza.

Disegno dello studio. È stata condotta una ricerca sistematica su Scopus, Web of Science e Pubmed, utilizzando gli elementi di reporting preferiti per revisioni sistematiche e meta-analisi.

Metodi. Dopo una ricerca approfondita nei tre database, abbiamo scaricato tutti i riferimenti che rispettavano la nostra richiesta. Tutti i riferimenti sono stati importati nella piattaforma COVIDENCE. Due ricercatori indipendenti sono stati designati per definire i criteri di inclu/esclusione e valutare ogni studio. Un terzo revisore ha risolto i conflitti in caso di divergenza di giudizio. Quindi, abbiamo ottenuto un file Excel con in evidenza tutti i dati raccolti. Sono state compilate la meta-analisi e la meta-regressione.

Risultati. Sono stati recuperati 345 documenti. Di questi, 14 rispettavano tutti i criteri. I nostri risultati hanno rivelato che - mentre la latenza e i disturbi del sonno non sono stati influenzati dal Ramadan - la durata e l'efficienza del sonno sono state influenzate negativamente, in particolare tra gli atleti amatoriali. È interessante notare che la qualità complessiva del sonno, la disfunzione diurna e la qualità soggettiva del sonno hanno mostrato un impatto positivo da parte del Ramadan, che è stato più evidente tra gli atleti amatoriali.

Discussione e Conclusioni. Nel contesto del digiuno del Ramadan, questi risultati suggeriscono che il Ramadan ha un impatto negativo sui modelli di sonno degli atleti e dei non atleti.

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