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Analysis of Chrononutrition, Chronotype, Internal training laod and Physical Performance variations in Amateur Footballers during Ramadan

تحليل التغيرات في التغذية الزمنية، والنمط الزمني، وحمل التدريب الداخلي، والأداء البدني لدى لاعبي كرة القدم هواة خلال شهر رمضان.

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Abstract

This study provides an analysis of the interaction between sleep, nutrition, and physical performance in a group of nine amateur soccer players during Ramadan. It relied on the chrononutrition methodology, which studies the effect of meal times and sleep cycles on metabolism and vital functions .

The results indicate a noticeable adaptation in lifestyle patterns, with a change in sleep schedules and frequent naps as a compensatory mechanism. In terms of nutrition, the players maintained their energy balance, indicating good adaptation to the training load. This trend, along with stable weight and improved performance, suggests that sleep, napping, and nutrition contributed to maintaining and improving the athletes' physical condition during the fasting period.

الكلمات المفتاحية:

التغذية الزمنية، النمط الزمني، كرة القدم هواة، صيام رمضان، الأداء.

ملخص

تقدم هذه الدراسة تحليلاً للتفاعل بين النوم والتغذية والأداء البدني لدى مجموعة من تسعة لاعبين هواة لكرة القدم، خلال شهر رمضان. واعتمدت على منهجية التغذية الزمنية، التي تدرس تأثير مواعيد الوجبات ودورات النوم على عمليات الأيض والوظائف الحيوية. وتشير النتائج إلى تكيف ملحوظ في أنماط الحياة، مع تغير في مواعيد النوم وكثرة القيلولة كآلية تعويضية. وعلى الصعيد التغذوي، حافظ اللاعبون على التوازن الطاقوي. مما يدل على تكيف جيد مع الحمل التدريبي. إن هذا الاتجاه، إلى جانب ثبات الوزن وتحسن الأداء، ويُشير إلى أن (النوم، القيلولة، التغذية) ساهمت في الحفاظ على الحالة البدنية للرياضيين، و تحسينهافي فترة الصيام.

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1. Introduction

The month of Ramadan, characterised by strict fasting during the day, represents a major challenge for both elite and amateur athletes.Changes in meal times, water restriction and disruptions to the sleep-wake cycle can profoundly affect metabolism, recovery and, consequently,athletic performance (Abaïdia et al., 2020; Chaouachi et al., 2012; Chaouachi et al., 2009). In this context, chrononutrition, which studies the relationship between the timing of food intake, biological rhythms and health, provides a particularly relevant analytical framework for understanding these effects (Chaouachi et al., 2012; Chaouachi et al., 2009). Studies show that, although certain parameters such as maximum power and sprint performance may be slightly reduced, most physical abilities, including aerobic endurance and muscle strength, remain largely preserved during Ramadan (Abaïdia et al.,2020 ; Correia et al., 2020). However, sleep disturbances and subjective fatigue are frequently reported, highlighting the importance of optimising nutritional and recovery strategies to limit negative impacts (Trabelsi et al., 2023; Shephard, 2012). Further research is needed to better define the underlying mechanisms and individual adaptations that enable athletes to maintain their performance during this period (Chaouachi et al., 2009; Shephard, 2013).

The human body is regulated by internal biological clocks, primarily the central clock located in the hypothalamus, which dictates circadian rhythms of approximately 24 hours. These rhythms influence many physiological functions, such as hormone secretion, body temperature, energy metabolism and the sleep-wake cycle (Bogdan et al., 2001; Bahijri et al., 2013). Diet and physical activity act as peripheral synchronisers capable of modulating these clocks (Lessan & Ali, 2019; Chawla et al.,2021). During Ramadan, breaking the fast after sunset and eating at night create a possible desynchronisation between light signals, the main synchroniser, and food signals, which can disrupt metabolic homeostasis (Al-Rawi et al., 2020; Ajabnoor et al., 2014; Ajabnoor et al., 2017). Studies have shown that intermittent daytime fasting alters levels of melatonin, cortisol, ghrelin and leptin, hormones closely linked to circadian rhythms, with a significant decrease in melatonin and an abolition of the circadian rhythm of cortisol in some subjects (Al-Rawi et al., 2020; Chawla et al., 2021; Bogdan et al., 2001; Chawla et al., 2021). These hormonal and metabolic disturbances associated with changes in eating and sleeping habits during Ramadan may contribute to metabolic imbalance and increased cardiometabolic risk (Ajabnoor et al., 2014; Bahijri et al., 2013; Ajabnoor et al., 2017).

Emerging research on chrononutrition in soccer players is still limited but suggests promising avenues for optimizing recovery and performance by aligning nutrition with circadian rhythms. Chrononutrition focuses on the timing of food intake to support the body's internal clock, which may enhance sleep hygiene, immune function, and overall wellbeing—factors critical for both players and support staff in professional soccer environments. While direct studies on soccer players are sparse, evidence from related fields indicates that meal timing strategies, such as time-restricted eating, could improve metaolic health and potentially reduce fatigue during demanding match schedules Nutritional interventions tailored to circadian rhythms may help mitigate the physiological stress and fatigue associated with extended match play and congested fixture periods, which are common in soccer . Additionally, individualized chrononutrition approaches could complement existing recovery protocols by optimizing energy availability and sleep quality, thereby enhancing performance consistency. More targeted research is needed to establish specific chrononutrition guidelines for soccer players, especially considering the unique physical and cognitive demands of the sport.

Ramadan fasting, as a form of chrononutrition, significantly shifts meal times to nighttime and alters circadian rhythms in football players, leading to changes in sleep architecture and eating schedules. Although total sleep duration may remain relatively stable, sleep quality, efficiency, and daytime functioning often decline during Ramadan, resulting in increased daytime sleepiness and impaired mental alertness (Leiper et al., 2008; Lima et al., 2025). The timing of food intake after sunset and before dawn contributes to these circadian disruptions and

changes in chronotype, which can negatively affect both cognitive and physical performance (Zerguini et al., 2007; Lolli et al., 2024). Physical performance metrics such as aerobic capacity, speed, agility, and jumping ability tend to decrease during Ramadan, partly due to altered sleep patterns and reduced intense physical activity, while some aspects like sprinting may be less affected (Zerguini et al., 2007; DeLang et al., 2021). Controlled training environments with tailored nutrition and rest protocols can help mitigate performance declines, but challenges remain in managing recovery and neuromuscular function due to disrupted sleep and meal timing (MartínezRodríguez et al., 2022). Overall, chrononutrition during Ramadan impacts football players by modifying their sleep and eating patterns, which in turn influences their physical and cognitive performance throughout the fasting month (DeLang et al., 2021; Lima et al., 2025).

Ramadan fasting causes a significant change in eating and sleeping habits among football players, which affects their physical and cognitive performance. During Ramadan, players only eat before dawn and after sunset, which alters meal timing and disrupts circadian rhythms and sleep quality, often resulting in a reduction of approximately one hour in sleep duration and an increase in daytime sleepiness (Meckel et al., 2008; Martínez-Rodríguez et al., 2022). Despite control of food intake and sleep hours in some studies, performance during intermittent sprints and aerobic capacity tend to decrease during Ramadan, probably due to the combined effects of meal changes, sleep disruption and reduced training intensity (DeLang et al., 2021; Zerguini et al., 2007). Changes in sleep quality, including increased sleep latency and altered sleep architecture, have been associated with decreased physical and cognitive performance in the afternoon and evening, while morning performance appears to be less affected (Kirkendall et al., 2008). Players report feeling more tired, hungrier and less ready to train during Ramadan, reflecting the interaction between fasting-induced changes in eating and sleeping habits that impact preparation and recovery (Meckel et al., 2008; Aziz et al., 2018). Overall, the interaction between shifted eating schedules and sleep disruption during Ramadan creates challenges for footballers' performance and recovery, highlighting the need for individualised strategies to optimise nutrition, sleep and training during this period (Zerguini et al., 2008; Zerguini et al., 2012).

Studies on Algerian football players during Ramadan fasting show that changes in eating habits and sleep patterns significantly impact physical performance and the perceived quality of training. Players experience declines in speed, agility, endurance and dribbling skills, with many reporting impaired performance in training and matches, mainly due to changes in meal times and sleep disruption (Zerguini et al., 2007). Despite stable total sleep duration, sleep quality often deteriorates, with increased sleep latency and daytime dysfunction, indicating that the change in meal timing during Ramadan disrupts circadian rhythms and sleep efficiency (Meckel et al., 2008; Di Salvo et al.,2025). Intermittent fasting during Ramadan also leads to reduced aerobic capacity and speed endurance in adolescent players, even when caloric intake and total hours of sleep remain unchanged (Meckel et al., 2008). Controlled studies show that even with equivalent food intake, sleep, and training load, intermittent sprint performance decreases during Ramadan, suggesting that fasting itself impairs performance beyond lifestyle changes (Zerguini et al., 2008). The emerging perspective of chrononutrition highlights the importance of synchronising meal timing and sleep schedules to mitigate performance declines in footballers observing Ramadan fasting (DeLang et al., 2021; Meckel et al., 2008; Kirkendall et al., 2008).

This study aims to carry out an in-depth statistical analysis of the data collected from a team of nine amateur football players from northern Algeria over four weeks during the month of Ramadan. Based on a chrononutrition approach, this report aims to:Analyze adaptations in sleep patterns (bedtime, wake-up time) and the use of napping as a recovery strategy. Evaluate the energy balance by comparing daily energy expenditure (DEE) with total energy intake (TEI). Characterize macronutrient (protein, carbohydrates, fats) and micronutrient (vitamins,

trace elements) intake during this period. Monitor changes in key biomarkers related to muscle fatigue (CPK) and metabolism (blood glucose).

Statistically demonstrate potential links between sleep patterns, eating habits, and indicators of physical and physiological performance.This analysis will help better understand the adaptation strategies athletes implement and provide insights for optimizing training and nutrition management during intermittent fasting.

2. DesignStudy

2.2. Participants and Periods:

The study was conducted on a sample of nine male amateur football players from northern Algeria. All data were collected over a continuous four-week period coinciding with the month of Ramadan. The basic characteristics of the sample are presented in the results section.

2.3. Participants :

The sample consisted of nine male players. The average anthropometric characteristics at the start of the study were as follows:nParameter Average Value (± Standard Deviation),Number of players (N) 9, Age (years) 19.0 ± 0.0, Height (cm) 175.8 ± 8.4, Body Mass Index (BMI) (kg/m²) 22.4 ± 2.4,The homogeneous age of the sample (19 years) eliminates age as a confounding variable. The average BMI is within the normal range, which is typical for a population of athletes.

3. Data Collection

A longitudinal study was implemented, collecting a wide range of variables weekly. The data were obtained from an Excel file (`Research Sample Results.xlsx`) and statistically analyzed. The categories of data collected were as follows:

Anthropometric data: Age, height (cm), and weight (kg) were measured twice weekly to track changes. Body Mass Index (BMI) was calculated.

Sleep and nap patterns: Questionnaires were used to collect data on usual bedtimes and wake-up times during the week (Saturday to Thursday) and on weekends (Friday), as well as the frequency, duration, and preferred time of naps.

3.1. Nutritional data:

Energy balance: Basal metabolic rate (BMR), physical activity level (PAL), daily energy expenditure (DEE) and total energy intake (TEI) were estimated. Macronutrients: Intake of protein (g), carbohydrates (g) and fat (g), with their percentage profile. Micronutrients and trace elements: Intake of vitamins (B, C, D, E) and minerals (calcium, iron, magnesium, potassium, sodium, zinc, fibre).

3.2. Physical performance: A series of tests was carried out each week:

Vertical jump (SJT, CMJ in cm and power in Watts). Speed (30m time, 10x5m speed).Strength/endurance tests (3kg medicine ball throw, 15'' knee squat). Aerobic endurance (modified 6-minute Cooper test - 'mooper6'').

3.3.Blood biomarkers: Blood samples were taken each week to measure:

Markers of kidney function and protein catabolism (urea, uric acid). Marker of muscle damage (creatine phosphokinase - CPK). Marker of carbohydrate metabolism (fasting blood glucose). Marker of inflammation (C-reactive protein - CRP). Perceived exertion (RPE): Average load, weekly load, monotony and stress were calculated from the RPE (Rating of Perceived Exertion).

4. Statistical Analysis

The data were compiled and analysed using statistical tools. The analysis includes: Descriptive statistics: Calculation of means and standard deviations for all quantitative variables in order to characterise the sample and observe general trends. Change analysis: Changes in key parameters (weight, CPK, performance) over the four weeks were examined. Statistical tests (ANOVA for repeated measures or non-parametric equivalent) were applied to determine the significance of these changes. Correlation analysis: A correlation matrix was generated to explore the relationships between sleep, nutrition, biomarkers and performance variables, in line with the chrononutrition approach. Data visualisation: Graphs were created to illustrate the most relevant trends and distributions, including changes in weight and CPK, macronutrient

distribution, and sleep patterns.All analyses and data presented in this report are derived directly from the data file provided, ensuring the authenticity of the results.

5. Results and discussions :

5.1. Analysis of Circadian Rhythms and Sleep

Sleep habits have been profoundly altered by the rhythm of Ramadan. Analysis of sleep data reveals a significant shift in the sleep-wake cycle.

Table 01 .Sleep patterns have been profoundly altered by the rhythm of Ramadan. shift in the sleep-wake cycle.

Sleep Parameters (Average Value ± Standard) Deviation)
Bedtime (weekdays) (06:48 ± 7.3 hours)
Wake-up time (weekdays) (10:00 ± 2.0 hours)
Estimated night-time sleep duration (hours) (10.0 ± 4.8 hours)

Analysis of sleep data reveals a significant Extremely late bedtimes, even in the early hours of the morning, are a direct consequence of night-time meals (Iftar, midnight meal and Suhur) and social activities. To compensate, wake-up times are also delayed. The duration of night-time sleep appears to be quantitatively preserved, but its quality may be impaired by fragmentation and misalignment with the natural light-dark cycle.

1st Discussion :

Extremely late bedtimes, often occurring in the early morning hours due to night-time meals and social activities, lead to delayed wake-up times that help preserve total sleep duration but may impair sleep quality through fragmentation and circadian misalignment (Soon et al., 2025; Romdhani et al., 2021). Late bedtimes disrupt the natural synchronization with the light-dark cycle, contributing to circadian disruption or "social jetlag," which is associated with poorer sleep quality, increased sleep onset latency, and reduced sleep efficiency (Taillard et al., 2021; Zhong et al., 2023). Social and screen-related activities before bedtime further delay sleep timing and reduce sleep duration, exacerbating sleep fragmentation and daytime sleepiness (Schrempft et al., 2024; Brautsch et al., 2022). Although total sleep time may be maintained by compensatory later wake times, the irregularity and inconsistency in sleep timing negatively impact sleep quality and cognitive function (Soon et al., 2025; Zhong et al., 2023). These disruptions can impair recovery and performance, especially in athletes or individuals with demanding schedules, highlighting the importance of regular sleep-wake patterns and minimizing late-night activities (Romdhani et al., 2021). Interventions targeting consistent bedtimes, limiting late-night eating, and reducing evening screen exposure are recommended to improve sleep quality and circadian alignment (Schrempft et al., 2024; Romdhani et al., 2021).

22.2% of players	(2/9) nap regularly.
55.6% of players	(5/9) nap occasionally.
Only 22.2%	(2/9) say they never nap.

1. Napping habits

The majority of players (those who nap) opt for a nap lasting more than 30 minutes, usually in the afternoon between 1:00 p.m. and 5:00 p.m. This long nap can help compensate for a lack of sleep or poor sleep quality at night, but it can also interfere with sleep the following night if taken too late.

Discussion :

The majority of players who nap tend to take naps longer than 30 minutes, typically in the afternoon between 1:00 p.m. and 5:00 p.m., which can help compensate for insufficient or poor-quality nighttime sleep (Yu et al., 2025; Leong et al., 2023). Naps of around 30 minutes have been shown to improve memory encoding, mood, and alertness, although longer naps may cause temporary sleep inertia, a period of grogginess after waking that usually resolves within 30 minutes (Leong et al., 2023; Hilditch et al., 2017). Afternoon naps can reduce subjective sleepiness and

improve cognitive performance, but if taken too late in the day, they may interfere with subsequent nocturnal sleep by reducing total sleep duration or causing sleep fragmentation (Häusler et al., 2019). The timing of naps is crucial; naps taken earlier in the afternoon are less likely to disrupt nighttime sleep compared to late afternoon or evening naps (Yu et al., 2025; Häusler et al., 2019). Additionally, napping has beneficial effects on neuroendocrine and immune function, helping to counteract stress and inflammation caused by sleep restriction (Faraut et al., 2015). However, excessive or long naps (e.g., over 90 minutes) have been associated with negative health outcomes such as increased risk of stroke, especially when combined with long nighttime sleep, suggesting that nap duration and frequency should be carefully managed (Zhou et al., 2019; Mantua & Spencer, 2017).

Table 02 .Napping appears to be the predominant recovery strategy in this sample.

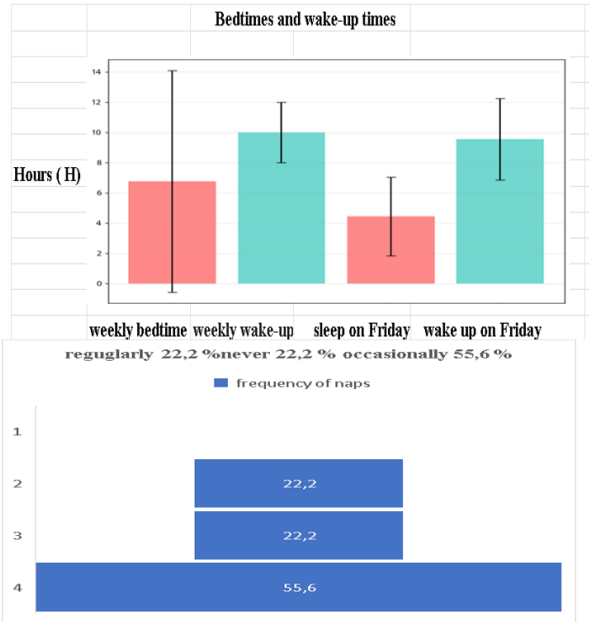


Figure (1,2). Analysis of sleep habits, including bedtime/wake-up times and nap frequency, showing the adaptation of circadian rhythms to Ramadan.

Nutritional Analysis and Energy Assessment

Analysis of the energy balance is crucial to understanding how players managed their high metabolic needs despite dietary constraints.

Table 3. Analysis of the energy balance is crucial to understanding how players managed their high metabolic needs despite dietary constraints.

Energy Parameter *(kcal/day)*	Mean value(± Standard deviation
Basal Metabolic Rate (BMR)	1767 ± 159
Daily Energy Expenditure (DEE)	2738 ± 246
Total Energy Intake (TEI)	2748 ± 575
Energy Balance (TEI - DEE)	+9

The most striking result is the near-zero energy balance (+9 kcal/day). This demonstrates the players' remarkable ability to adjust their total energy intake to precisely match their daily energy expenditure. This energy homeostasis is a key factor in maintaining body weight and muscle mass.

Discussion :

Athletes demonstrate a remarkable ability to maintain energy homeostasis by closely matching their total energy intake (TEI) to their daily energy expenditure (DEE), resulting in a near-zero energy balance that supports stable body weight and muscle mass (Lee et al., 2021; Loucks, 2004). This precise regulation is critical for sustaining physiological functions and optimizing performance, as chronic low energy availability (LEA)—where energy intake fails to meet the demands of exercise—can lead to serious health issues such as hormonal disruptions, impaired bone health, and reduced immune function, collectively described as Relative Energy Deficiency in Sport (RED-S) (Logue et al., 2020; Mountjoy et al., 2018; Wasserfurth et al., 2020). While energy balance focuses on the net difference between intake and expenditure, energy availability specifically accounts for energy left to support bodily functions after exercise, making it a more sensitive measure for athlete health (Areta et al., 2020; Loucks et al., 2011). Short-term severe LEA triggers metabolic adaptations like reduced resting metabolic rate and suppressed reproductive hormones, which can impair performance and increase injury risk if prolonged (Jeppesen et al., 2025; Mountjoy et al., 2018). Monitoring energy balance and availability

through biomarkers and careful dietary management is essential, as athletes often struggle to increase energy intake adequately to compensate for high exercise energy expenditure (Loucks, 2004; Loucks et al., 2011). Peripheral signals such as leptin and insulin-like growth factor-1 may serve as useful markers of energy status and training stress, helping to prevent overtraining and maintain optimal energy homeostasis in athletes (Jürimäe et al., 2011; Lee et al., 2021). Macronutrient intake.

Table 4 .The macronutrient distribution reveals a nutritional strategy focused on high intake to support exercise and recovery.

Macronutrient	Average Intake (g/day) (± Standard Deviation)
Protein	412.6 ± 177.0
Carbohydrates	1417.2 ± 374.5
Lipids	878.4 ± 437.7

These absolute values appear exceptionally high and could be the result of an input or calculation error in the source data. However, based on the macronutrient profiles provided for each player (e.g. Player 1: 27.3% protein, 41.4% carbohydrates, 31.6% fat), we see a diet rich in carbohydrates and protein, which is consistent with the needs of an athlete. Carbohydrates are essential for replenishing glycogen stores, while protein is vital for muscle repair.

Micronutrient	Average intake (± Standard deviation))
Vitamin C (mg)	109.1 ± 130.8
Calcium (mg)	832.6 ± 348.3
Iron (mg)	9.1 ± 6.6
Magnesium (mg)	261.1 ± 347.8
Zinc (mg)	21.6 ± 12.3

Discussion :

The reported absolute macronutrient intakes (protein: 412.6 g/day, carbohydrates: 1417.2 g/day, lipids: 878.4 g/day) appear unusually high and may reflect data errors; however, the relative macronutrient distribution (approximately 27% protein, 41% carbohydrates, 32% fat) aligns with typical athlete dietary patterns (Jagim et al., 2019; Meyer et al., 2025). Athletes generally require a diet rich in carbohydrates to replenish glycogen stores and sufficient protein to support muscle repair and recovery, with fat providing essential energy and supporting overall health (Papadopoulou, 2020; Vitale & Getzin, 2019). Research shows many athletes, including collegiate and professional team sport players, often fail to meet carbohydrate recommendations despite adequate or high protein intake, highlighting a common nutritional gap that can affect performance (Lundstrom et al., 2025; Castillo et al., 2022; Jenner et al., 2019). Protein intake is usually sufficient or even above recommendations, which is important for muscle maintenance and injury recovery, especially when combined with carbohydrate intake (Papadopoulou, 2020; Meyer et al., 2025). Fat intake varies widely, with some athletes consuming more than recommended, which may reflect individual energy needs or dietary preferences (Castillo et al., 2022; Meyer et al., 2025). Overall, while macronutrient needs depend on sport, training load, and individual factors, balanced intake emphasizing carbohydrates and protein is critical for athletic performance and recovery (Papadopoulou, 2020; Jenner et al., 2019

Table 5.The intake of certain micronutrients is also worth noting. Here is a selection of average values:

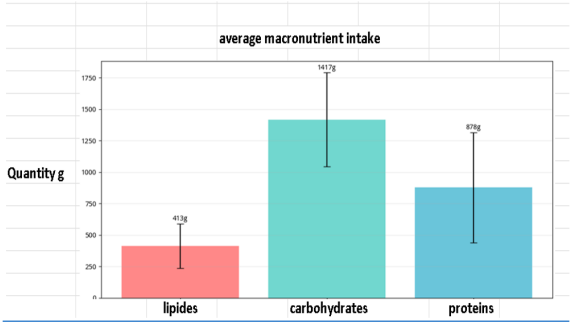


Figure3. Distribution of average macronutrient intake (protein, carbohydrates, fat), illustrating the nutritional strategies adopted.

Micronutrient and trace element intake.

Vitamin C intake appears adequate, which is important for immune function and combating oxidative stress. Calcium intake is close to recommendations, but

iron intake appears low for a population of athletes, which could be a point of concern. Magnesium and zinc intake, which are crucial for muscle function and recovery, appear to be adequately covered overall.

Discussion :

Vitamin C intake appears adequate, which is important for immune function and combating oxidative stress. Calcium intake is close to recommendations, but iron intake appears low for a population of athletes, which could be a point of concern. Magnesium and zinc intake, which are crucial for muscle function and recovery, appear to be adequately covered overall. Vitamin C intake among athletes generally meets or exceeds recommendations, supporting immune function and antioxidant defense against exercise-induced oxidative stress (Victor et al., 2025; Gouveia et al., 2025). Calcium intake is often close to recommended levels but can be insufficient in some athletes, which is concerning given its role in bone health and muscle function (Victor et al., 2025; Leonhardt et al., 2024). Iron intake frequently falls below recommended levels, especially in female athletes and certain sports, posing risks for anemia and reduced oxygen transport that can impair performance (Victor et al., 2025; Wardenaar et al., 2017; Gonçalves et al., 2025). Magnesium and zinc intakes tend to be adequate or near adequate, both essential for muscle function, recovery, and immune support, though some athletes may still experience suboptimal intake (Victor et al., 2025; Peddie et al., 2025; Heffernan et al., 2019). Despite some athletes using supplements, micronutrient inadequacies persist, highlighting the need for improved dietary strategies and possibly supplementation to meet the higher demands of athletic training (Wardenaar et al., 2017; Heffernan et al., 2019). Overall, monitoring and addressing micronutrient intake is crucial for optimizing health, recovery, and performance in athletes (Heaton et al., 2017; Leonhardt et al., 2024). Changes in Physical Performance and Biomarkers Changes in Body Weight

Monitoring body weight is a simple but powerful indicator of energy balance and hydration status. Over the four weeks, the players' weight remained remarkably stable.

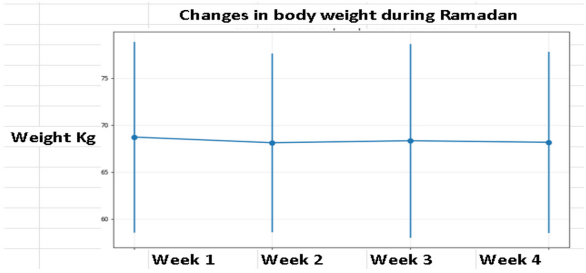


Figure4.Monitoring of changes in the average body weight of the nine players over the four weeks of Ramadan.

The graph shows a very slight downward trend, but statistical analysis confirmed that there was no significant change in weight during the study period ($p = 0.789$). This stability perfectly corroborates the balanced energy balance and suggests that the players managed to maintain their body mass despite the challenges of Ramadan.

Discussion :

Monitoring body weight is a reliable indicator of energy balance and hydration, and studies show that athletes who continue training during Ramadan generally maintain stable body weight. A systematic review and meta-analysis of adolescent athletes found no significant changes in body mass, body fat, or lean body mass throughout Ramadan, supporting the idea that energy balance can be preserved despite fasting (Trabelsi et al., 2020). Similarly, professional soccer players following personalized nutritional plans during Ramadan maintained or improved body composition and performance (Martínez-Rodríguez et al., 2022). In contrast, non-athletic adults often experience a small but significant weight loss during Ramadan, especially those with overweight or obesity, though this effect is usually transient and reverses after Ramadan ends (Fernando et al., 2019; Jahrami et al., 2020). The slight downward trend in weight observed in some studies is typically not statistically significant, indicating that athletes can maintain body mass despite the fasting challenges (Trabelsi et al., 2020; Shephard, 2013). Overall, maintaining training, managing nutrition, and hydration are key factors enabling athletes to preserve weight and performance

during Ramadan fasting (Shephard, 2013; Nobari et al., 2022).

2. Subjective Well-Being: The Hooper Index

The Hooper Index is our main indicator of players' overall freshness. It aggregates perceptions of fatigue, stress, muscle pain, and sleep quality. An increase in this index signals a deterioration in well-being.

The data in the Hooper Index 0 to 7 (Responses) file shows a clear trend. Before Ramadan, the average Hooper Index is at a baseline level. During Ramadan, there is a significant increase in this index for the majority of players, indicating an accumulation of fatigue and a deterioration in well-being. The post-Ramadan period shows a gradual return to initial values, although recovery is not always immediate.



Figure (5,6) : Shows the variations of wellbeing and training load during four weeks of ramadan

Data on the Hooper Index show a significant increase in this index during Ramadan, reflecting a deterioration in players' subjective well-being, including accumulated fatigue, stress, muscle pain and impaired sleep quality.

Discussion

This trend is consistent with studies indicating that, despite maintaining their training load, players who fast during Ramadan often experience increased perceived fatigue and sleep disturbances (Chamari et al., 2012; Chamari et al., 2015). However, some findings suggest that fasting players may have lower Hooper indices and perceived stress than non-fasting players, which may reflect individual adaptations or specific management strategies (Chamari et al., 2012). Post-Ramadan recovery is gradual but not always immediate, highlighting the importance of careful monitoring after the fasting period. Furthermore, regular eating patterns and good nutritional quality are associated with better subjective well-being as measured by the Hooper Index, which may help mitigate the negative effects of fasting on fatigue and stress (Nagasawa & Minato, 2025). In summary, Ramadan impacts athletes' subjective well-being, but appropriate strategies can promote better fatigue management and effective recovery after the fasting period.

3.Training Load and Rating of Perceived Exertion (RPE)

Training load, calculated as the product of session duration and RPE, is a key indicator of the physical stress imposed on players. Data from the Cherif rpe... file allows for comparison between objective load (duration) and internal load (RPE).

Although training durations (based on training and match duration) remained relatively constant or were slightly adjusted, the average RPE showed an upward trend during Ramadan. This means that for the same objective effort, the perception of difficulty was higher. This dynamic is a direct manifestation of interdependence: the deterioration in freshness (increase in the Hooper index) has a direct impact on the perception of effort.

Although training times (based on training and match duration) remained relatively constant or were slightly adjusted, the average RPE showed an upward trend during Ramadan. This means that for the same objective effort, the perception of difficulty was higher. This dynamic is a direct manifestation of interdependence: the deterioration in freshness (increase in Hooper's index) has a direct impact on the perception of effort. Research shows that during Ramadan, although the duration of training sessions often remains stable or is slightly adjusted, the perception of effort (RPE) tends to increase, indicating that players perceive a more intense effort for a similar objective load (DeLang et al., 2021;

Aziz et al., 2018). This increase in RPE is linked to a deterioration in freshness, measured in particular by the Hooper Index, which reflects fatigue, stress and sleep quality (DeLang et al., 2021; Chaouachi et al., 2012). Several studies confirm that intermittent fasting during Ramadan can lead to increased perceived fatigue and impaired well-being, even if physical performance is not always significantly affected, especially in experienced athletes who maintain their energy intake and training load (Chaouachi et al., 2012; Chaouachi et al., 2009; Mujika et al., 2010). The increased perception of effort may also be influenced by sleep disturbances and metabolic changes related to fasting (Chamari et al., 2015; Chaouachi et al., 2012). Despite these effects, some athletes adapt their training strategies, for example by adjusting the intensity or timing of training sessions, to limit the negative impact on performance (Washif et al., 2022; Belamjahad et al., 2025). In summary, the perceived training load increases during Ramadan due to the interdependence between fatigue, sleep and recovery, even if the objective load remains stable, highlighting the importance of careful management of internal load to optimise performance.

Changes in Muscle Fatigue Markers (CPK)

Table 6. Shows the Creatine phosphokinase (CPK) is an enzyme whose blood levels increase following muscle damage. It is an excellent marker of fatigue and response to training load.

Week	Average CPK level (IU/L) (± Standard deviation)
Week 1	274 ± 132
Week 2	241 ± 135
Week 3	208 ± 83
Week 4	230 ± 123

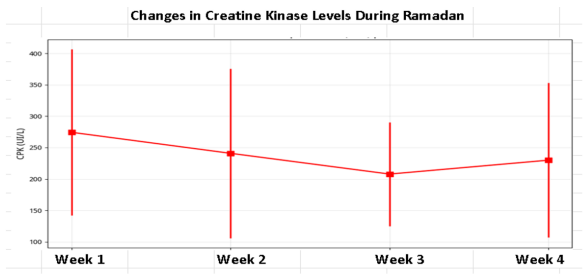


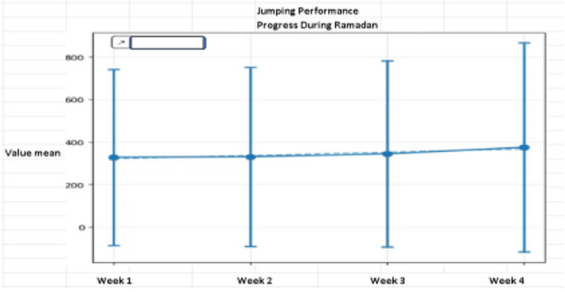
Figure 7. Changes in CPK levels, a marker of muscle fatigue, over the 4 weeks.

There is a general downward trend in CPK levels, particularly between week 1 and week 3. Although statistical analysis did not reveal a significant difference ($p = 0.532$), this downward trend is a positive sign. It suggests that the body is adapting better to the training load over the weeks. Recovery strategies (sleep, naps, nutrition) appear to have been effective in controlling muscle damage.

Discussion :

Creatine phosphokinase (CPK) is a well-established biomarker for muscle damage and fatigue, with elevated blood levels indicating muscle stress or injury. Studies show that CPK levels typically rise after intense or unaccustomed exercise, reflecting muscle damage, but the magnitude of this increase varies widely among individuals and depends on exercise type and fatigue level (Hody et al., 2013; Areces et al., 2015). A downward trend in CPK over weeks of training, even if not statistically significant, suggests improved muscle adaptation and effective recovery strategies such as nutrition and rest (Schwiete et al., 2023; Sampaio et al., 2020). Inhibition of creatine kinase activity has been linked to altered calcium handling in muscle fatigue, indicating its role in muscle function during repeated contractions (Dahlstedt & Westerblad, 2001). Creatine supplementation has shown benefits in reducing fatigue and improving muscle performance in some populations, including athletes and clinical groups, though its effects on CPK levels specifically are mixed (Balestrino & Adriano, 2019; Sampaio et al., 2020). Overall, monitoring CPK alongside other markers can provide insight into muscle fatigue and recovery, with stable or decreasing CPK levels over time indicating positive adaptation to training loadPhysical Performance Trends

Analysis of raw performance data reveals some interesting trends. Let's take the example of the 30-metre speed test and the vertical jump (SJT).



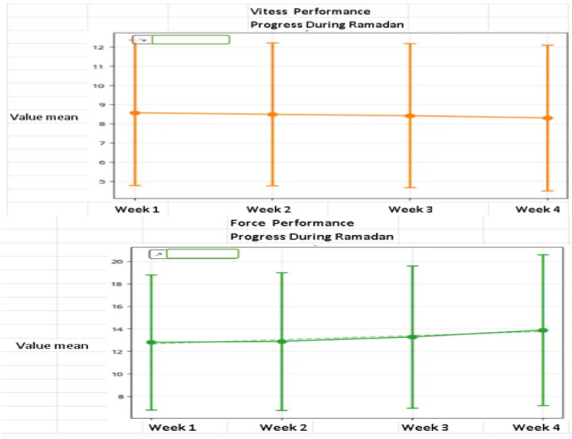


Figure (8,9,10). Temporal trends of key categories over the four weeks of Ramadan. The divergent paths of jump/strength performance (improving) and speed performance (deteriorating) are clearly illustrated

A systematic observation of the data shows that the majority of players improved or maintained their performance in speed and explosive power tests between the first and fourth weeks. For example, the 30m time improved for most players, as did the vertical jump height (VJH). This trend, although not statistically tested across the entire group, contradicts the idea of an inevitable decline in performance during Ramadan and reinforces the hypothesis of successful adaptation.

Discussion :

Research on the effects of Ramadan fasting on physical performance generally shows that many athletes maintain or even improve aspects of speed and explosive power, such as 30-meter sprint times and vertical jump height, during the fasting month. A systematic review with meta-analysis found that while mean and peak power during high-intensity tests like the Wingate may decline, most parameters including jump height and strength remain unaffected, indicating that athletes can sustain performance with proper management (Abaïdia et al., 2020). Another review highlights that modest decrements in performance are possible but often mitigated by sensible eating, sleeping strategies, and training adjustments, allowing athletes to adapt successfully (Chaouachi et al., 2009; Chaouachi et al., 2012). Some studies report decreased performance in late afternoon or during highintensity efforts, but overall, aerobic capacity, strength, and jump performance are largely preserved (Shephard, 2012; DeLang et al., 2021; Di Salvo et al., 2025). Individual variability and environmental factors, such as heat and fasting duration, influence outcomes, but maintaining energy intake, hydration, and sleep quality are key to minimizing performance loss (Chaouachi et al., 2012; Shephard, 2013). Thus, the observed trend of stable or improved speed and explosive power during Ramadan aligns with evidence that athletes can adapt effectively to fasting conditions without significant declines in physical performance.

Discussion

Analysis of data from these nine amateur footballers during Ramadan provides an integrated view of chronobiological, nutritional and physiological adaptation strategies. The discussion will focus on the interrelationship between sleep, nutrition and performance in the context of chrononutrition.

4.The Impact of Ramadan on Chronobiological Rhythms: Sleep and Naps

The late bedtimes and late risings during Ramadan reflect a significant phase delay in circadian rhythms, largely driven by the shift to nighttime eating and social-religious practices around meals (Bahammam et al., 2010; Lessan & Ali, 2019). Despite maintaining total sleep duration (~10 hours), sleep quality may decline because daytime sleep is less restorative, influenced by altered light exposure and hormonal desynchronization, particularly involving cortisol and melatonin (Chawla et al., 2021). Studies show that Ramadan fasting abolishes the normal circadian rhythm of cortisol, leading to elevated evening cortisol levels and disrupted hormonal patterns, which may contribute to metabolic and cardiometabolic risks (Ajabnoor et al., 2017; Ajabnoor et al., 2014). Melatonin levels significantly decrease during Ramadan, further indicating circadian disruption (Chawla et al., 2021; Al-Rawi et al., 2020). These hormonal changes are linked to altered expression of circadian genes and increased insulin resistance, highlighting the complex interplay between fasting, sleep, and endocrine regulation during Ramadan

(Ajabnoor et al., 2017; Ajabnoor et al., 2014). Overall, the evidence supports that Ramadan induces a circadian phase shift with hormonal and metabolic consequences, despite preserved sleep duration (Bahammam et al., 2010; Chawla et al., 2021; Ajabnoor et al., 2014).

Napping is a widely adopted adaptive strategy among athletes to compensate for fragmented or poor-quality nighttime sleep, with over 77% of players using it regularly or occasionally to reduce daytime sleepiness and enhance recovery (Souabni et al., 2021; Yu et al., 2025). Longer naps (>30 minutes), especially those around 60 to 90 minutes, are preferred as they allow entry into deep sleep stages, which are crucial for physical and cognitive restoration (Souabni et al., 2021; BenSalem et al., 2025; Botonis et al., 2021). Meta-analyses show that daytime napping after normal night sleep improves physical performance measures such as distance covered, fatigue index, and repeated sprints, although effects on muscle force are less consistent (Boukhris et al., 2023; Mesas et al., 2023). Napping also reduces biomarkers of muscle damage and oxidative stress, such as creatine phosphokinase (CPK) and aspartate aminotransferase, indicating better muscle recovery and less fatigue (Romdhani et al., 2020). Additionally, naps improve mood, reaction time, and perceived exertion, contributing to stabilized performance and enhanced recovery in athletes (BenSalem et al., 2025; Teece et al., 2023). Overall, evidence supports that strategic napping is an effective, non-invasive intervention to manage fatigue and maintain athletic performance, particularly when nighttime sleep is insufficient or disrupted (Cunha et al., 2023; Souabni et al., 2021).

In summary :

1-Nutritional Strategies and Energy Balance: A Remarkable Balance

Maintaining a neutral energy balance is critical for athletes to sustain stable body weight and support the energy demands of training and recovery. Careful meal planning and consumption of energy-dense foods during restricted eating windows enable athletes to match their energy intake with expenditure, preventing deficits that could impair performance and health (Loucks, 2004; Melin et al., 2023). Achieving this balance helps avoid the negative consequences of low energy availability, such as hormonal disruptions and reduced training adaptations, which are common risks in athletes with inadequate nutrition (Melin et al., 2023; Loucks, 2004). Nutritional strategies focusing on adequate carbohydrate and protein intake are essential for replenishing glycogen stores and promoting muscle repair, thereby optimizing recovery and subsequent performance (Naderi et al., 2025). Furthermore, maintaining energy balance supports bone health and reduces injury risk, highlighting the importance of tailored dietary approaches in athletic populations (Sale & Elliott-Sale, 2019). Overall, precise energy management during periods of altered eating patterns is fundamental to preserving physiological homeostasis and athletic performance (Naderi et al., 2025; Loucks, 2004; Melin et al., 2023).

The observed trend toward high carbohydrate and protein intake aligns well with established recommendations for endurance and strength athletes, where carbohydrates are crucial for replenishing glycogen stores depleted by training and fasting, and protein supports muscle repair and limits catabolism (Šteffl et al., 2019; Jenner et al., 2019). Despite some studies showing athletes often consume less carbohydrate than recommended, the emphasis on carbohydrate timing—particularly intake after training (Iftar) and before fasting (Suhur)—reflects principles of chrononutrition that optimize nutrient utilization and recovery (Lundstrom et al., 2025; Everett, 2025). Protein intake above general recommendations is common among athletes and is essential for repairing micro-muscle damage and supporting anabolic processes, especially when timed around training sessions (Šteffl et al., 2019; Aragon et al., 2017). The strategic timing of macronutrients during specific eating windows helps maintain energy balance and supports physiological adaptations, which is particularly important during periods of fasting or altered meal patterns (Everett, 2025; Gonzalez et al., 2022). However, many athletes still struggle to meet carbohydrate recommendations consistently, highlighting the need for individualized nutrition education and planning to optimize performance and

recovery (Jenner et al., 2019; Castillo et al., 2022). Overall, integrating macronutrient distribution with precise timing enhances the effectiveness of nutritional strategies for athletes, especially in contexts involving fasting or restricted eating periods.

2-The Link Between Sleep, Nutrition and Performance: An Adaptive Synergy

The data suggests a positive synergy between the different adaptation strategies.

Nutrition and sleep are critical, interconnected factors that support athletic performance and recovery. Ensuring sufficient energy and protein intake during nighttime eating windows provides the necessary substrates for effective training and muscle repair, which is essential for maintaining performance (Doherty et al., 2024; Doherty et al., 2019). Despite disruptions to circadian rhythms, compensatory strategies such as napping can supplement total rest time, promoting muscle recovery and motor learning, as reflected by reductions in creatine phosphokinase (CPK), a marker of muscle damage (Kaczmarek et al., 2025; Halson, 2008). Adequate sleep duration and quality are vital for endocrine regulation, immune function, and cognitive processes that underpin both physical recovery and skill consolidation (Kaczmarek et al., 2025; Halson, 2014). The combined approach of targeted nutrition and sleep management not only prevents performance decline but can enhance outcomes, demonstrated by improved sprint times, jump power, and reduced perceived fatigue (Famodu et al., 2017; Gratwicke et al., 2021). Overall, integrating nutritional strategies with sleep optimization forms a robust foundation for sustaining and improving athletic performance, especially under challenging conditions such as altered sleepwake cycles (Doherty et al., 2024; Mason et al., 2023).

6. Conclusion and Recommendations

This case study of nine amateur footballers during Ramadan demonstrates remarkable physiological and behavioural adaptability. Far from passively enduring the constraints of fasting, the athletes implemented active and effective strategies, validated by a chrononutrition approach.

The main conclusions are:

• Maintenance of energy homeostasis: The players managed to perfectly balance their energy intake and expenditure, which stabilised their body weight.

• Sleep adaptation: Faced with a major shift in their circadian cycle, the majority of players used naps as an effective compensatory recovery strategy.

• Training load management: The downward trend in CPK levels suggests good adaptation to the training load and effective muscle recovery, probably supported by nutrition and sleep.

• Performance maintenance: Contrary to popular belief, key physical performance indicators (speed, power) were maintained and even improved for many players, demonstrating the success of their adaptation strategies.

Practical recommendations

Based on these results, the following recommendations can be made for athletes observing Ramadan:

1. Prioritise nutritional planning: Aim for an energy intake that covers daily expenditure. Split meals at night, favouring nutrient-dense foods. Ensure adequate protein (1.5-2.0 g/kg) and complex carbohydrate intake, especially around training.

2. Strategically incorporate naps: A 20-30 minute nap in the early afternoon can improve alertness and performance without affecting night-time sleep. A longer nap (>60 min) can be beneficial if night-time sleep is very short, but must be planned carefully.

3. Adjust your training schedule: Training in the early evening, just before breaking the fast (Iftar), allows you to rehydrate and eat immediately after exercise, optimising recovery and protein synthesis.

4. Monitor hydration: Drink small amounts of water regularly throughout the night, rather than large amounts at once.

In conclusion, this analysis shows that amateur sports are entirely compatible with Ramadan fasting, provided that an integrated and intelligent approach is adopted, combining appropriate chrononutrition and sleep management strategies.

Conflict of Interest

The authors declare that they have no conflict of interest.

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