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Impact of Ramadan Fasting on Sports Performance

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Abstract

This study systematically reviews and analyzes the impact of Ramadan fasting on athletes' anaerobic performance, aerobic endurance, and strength variations. As a unique form of intermittent fasting with religious and cultural significance, Ramadan fasting requires abstaining from food and drink from sunrise to sunset for an entire month. The study explores the physiological adaptations during fasting, such as changes in energy metabolism, hydration status, and recovery processes, as well as psychological factors like motivation, focus, and perceived exertion that may influence athletic performance. The results indicate that while the effects of Ramadan fasting on anaerobic and aerobic performance are limited, certain performance metrics (e.g., endurance and strength) may improve with proper training and nutrition management. The study emphasizes the importance of maintaining consistent training, optimizing hydration and energy intake during non-fasting hours, and ensuring adequate sleep and recovery. This work provides valuable insights for athletes, coaches, and sports scientists, supporting the development of individualized training and nutrition strategies to help athletes maintain competitive performance while respecting religious and cultural practices. It also offers directions for future research into the long-term effects of Ramadan fasting on athletic performance and the development of evidence-based guidelines.

Keywords: Ramadan fasting; aerobic exercise; anaerobic exercise; endurance exercise

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Introduction

Ramadan fasting is a specific form of intermittent fasting characterized by alternating periods of fasting and eating, where individuals abstain from food and drink from sunrise to sunset for an entire month. This practice is deeply rooted in religious and cultural traditions, observed by Muslims worldwide as a time of spiritual reflection and self-discipline. Intermittent fasting, in a broader sense, encompasses various approaches, including alternate-day fasting, time-restricted eating, and periodic fasting, each with its own unique structure and guidelines. For example, alternate-day fasting involves alternating between days of normal eating and days of significant calorie restriction, while time-restricted eating limits food intake to a specific window of time each day, such as 8 hours, followed by 16 hours of fasting. Periodic fasting, on the other hand, involves extended fasting periods, such as 24-hour fasts, conducted once or twice a week.These fasting models, including Ramadan fasting, serve as short-term dietary strategies aimed at improving health by adjusting meal frequency and timing(Hoddy,2015). They have been associated with various potential benefits, such as enhanced metabolic health, improved weight management, and better regulation of blood sugar levels. Additionally, intermittent fasting may promote cellular repair processes, such as autophagy, and reduce inflammation, contributing to overall well-being. While Ramadan fasting is primarily observed for religious purposes, it shares common physiological mechanisms with other forms of intermittent fasting, making it a valuable area of study for understanding the broader impacts of fasting on health and performance. By exploring these fasting models, researchers and practitioners can gain insights into how dietary interventions can be tailored to support both physical and mental health(Ding,2023).

Information and methodology

systematic review

Utilized to conduct a thorough analysis of existing research on the impact of Ramadan fasting on athletic performance. The primary aims of this study are:To assess the effects of Ramadan fasting on aerobic performance,anaerobic exercise, endurance exercise, and muscular strength;To summarize and compare the findings of different studies in order to identify consistencies and discrepancies;To identify key factors influencing athletic performance, such as nutritional intake, training intensity, training schedule, and individual adaptability(Hua,2023).

Results

Mechanisms of Energy Metabolism During Ramadan Fasting

Aerobic Energy Metabolism

The energy conversion mechanism in aerobic exercise describes how the human body efficiently converts food energy into the energy needed to support physical activity under aerobic metabolic conditions. This process involves three key stages: glycogen metabolism, fat metabolism, and protein metabolism.

Glycogen Metabolism: In aerobic exercise, the body's glycogen stores, mainly located in the liver and muscles, are mobilized and broken down into glucose. This glucose undergoes glycolysis to produce pyruvate, releasing small amounts of adenosine triphosphate (ATP), providing initial energy. The pyruvate is then transported into the tricarboxylic acid (TCA) cycle, a complex biochemical process occurring in the mitochondria, ultimately producing a large amount of ATP, which serves as the primary energy source for muscle activity (Hargreaves,2015).

Fat Metabolism: Fat serves as another crucial energy source in aerobic exercise. During physical activity,Fat is metabolized into free fatty acids and glycerol.These free fatty acids are transported

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to the mitochondria, where they undergo β-oxidation, converting into acetyl-CoA. This acetyl-CoA then enters the tricarboxylic acid (TCA) cycle, leading to the production of a significant amount of ATP.thereby supporting sustained aerobic exercise demands (Spriet,2014).

Protein Metabolism: During prolonged, low-intensity aerobic exercise, when glycogen and fat supplies are insufficient, the body may utilize protein as an energy source. In this process, proteins are broken down into amino acids, some of which can be converted into metabolic intermediates that participate in the TCA cycle, ultimately generating ATP. Although protein can provide energy, it is not the primary energy source, as relying on protein metabolism may lead to muscle tissue breakdown, potentially resulting in negative physiological effects.The synergistic function of these three stages ensures a continuous and efficient supply of energy during aerobic exercise, enabling the body to sustain high energy output while minimizing energy loss.

Anaerobic Energy Metabolism

The energy production mechanism in anaerobic exercise differs significantly from that in aerobic exercise. This is primarily because, under anaerobic metabolic conditions, muscle cells cannot obtain sufficient oxygen to support ATP synthesis.

Phosphocreatine System (ATP-PCr System): Phosphocreatine (PCr) is a high-energy phosphate compound stored in muscle cells, capable of rapidly breaking down to provide immediate energy.During this process, PCr transfers its phosphate group to ADP, quickly resynthesizing ATP. Since this process does not require oxygen, it provides the necessary energy for high-intensity, short-duration activities such as sprinting and weightlifting, making it a critical energy source for explosive movements(Fox,1965).

Lactic Acid System: Under anaerobic conditions, muscle glycogen is broken down into glucose, which then undergoes glycolysis to produce ATP. However, due to insufficient oxygen supply, lactate accumulates as a byproduct in the muscles, leading to muscle acidification. This can impair muscle function and limit continued physical activity.The buildup of lactate is a major contributor to muscle fatigue and a crucial factor limiting the duration of anaerobic exercise (Hua,2023).

Synergistic Action of ATP-PCr and Lactic Acid Systems: During high-intensity exercise, the phosphocreatine system and the lactic acid system often work in coordination. The ATP-PCr system provides an immediate energy supply, while the lactic acid system offers energy for a slightly longer duration. This dual mechanism enables athletes to engage in short bursts of intense physical activity. The efficient cooperation of these energy systems forms the biochemical basis for sustaining high-intensity, short-duration exercise.

Research on Ramadan Fasting

Recent research continues to provide new insights into the impact of Ramadan fasting on athletic performance, particularly in understanding how fasting influences physical fitness, exercise capacity, and metabolic adaptations. The following summarizes key findings from recent studies, highlighting the physiological and performance-related effects of fasting:

Soeters et al. recently published a comprehensive review examining the relationship between lipid and glucose metabolism during short-term fasting. The study revealed that within the first 24 hours of food deprivation, significant metabolic changes occur. Specifically, a decrease in plasma insulin concentration, an increase in sympathetic nervous system activity, and elevated growth hormone levels collectively enhance whole-body lipolysis and fat oxidation. These changes lead to a reduced reliance on carbohydrates and an increased dependence on fatty acids as the primary energy source. Plasma fatty acid concentrations were found to rise notably during the initial fasting phase, particularly within 14 hours after the last meal. This shift in substrate utilization underscores the body's ability to adapt to fasting by optimizing fat metabolism for energy production (Tinsley,2015).In a related study, Klein et al. conducted a detailed investigation into the whole-body lipid and glucose metabolism of young adult males with normal body weight during fasting intervals of 12, 18, 24, 30, 42, 54, and 72 hours. The results demonstrated that between 12 and 24 hours of fasting, the rate and concentration of plasma glycerol increased most significantly, accounting for 50% to 60% of the total glycerol increase observed over 72 hours. During this period, fat oxidation increased by approximately 50%, while glucose oxidation decreased by about 50%, further supporting the concept of a substrate utilization shift. Additionally, the study found that plasma insulin levels declined significantly during fasting, while glucagon levels increased. Interestingly, epinephrine and cortisol concentratio(Tinsley,2015).Lawrence investigated Ramadan fasting as a way to study how time-restricted eating influences aerobic performance in top runners. The findings showed that even with a decrease in nutritional intake during fasting, the athletes' aerobic performance was mostly unchanged. This indicates that after a period of adjustment, athletes can sustain their aerobic capacity despite limited nutrition. However, additional research has suggested that fasting could affect endurance performance, especially during extended and high-intensity activities, where lower nutrient intake might result in greater fatigue (Spriet,2014).

In summary, these studies highlight how short-term fasting leads to significant shifts in the body's energy utilization, especially during Ramadan fasting. By increasing fatty acid usage and reducing carbohydrate dependence, the body adjusts its primary energy sources. These metabolic changes may have profound implications for athletes engaged in prolonged and high-intensity training, although aerobic capacity may remain stable after adaptation.

Impact of Ramadan Fasting on Sports Performance

Impact of Ramadan Fasting on Sports Performance

The influence of Ramadan fasting on aerobic performance appears to be minimal, with some studies suggesting potential benefits under specific conditions. Ali and colleagues conducted a study to explore whether Ramadan fasting could enhance long-distance running performance in elite athletes. The research involved fifteen well-trained male long-distance runners who observed Ramadan. Each participant visited the human performance laboratory on two occasions—once before Ramadan and once during the final week of Ramadan. During each visit, the athletes underwent a graded exercise test on a treadmill, during which key physiological and performance metrics were measured, including VO_2 (maximal oxygen uptake), heart rate, time to exhaustion, perceived exertion (RPE), and running speed. Additionally, the study collected detailed data on anthropometric measurements, dietary intake, sleep patterns, and exercise routines to provide a comprehensive understanding of the athletes' overall condition during the fasting period.The findings of the study revealed that fasting conditions led to notable improvements in time to exhaustion and running speed compared to non-fasting conditions. These improvements suggested that Ramadan fasting might have a positive impact on endurance performance in elite long-distance runners. However, the study also found that these enhancements were not associated with significant changes in peak VO_2 , oxygen consumption, or RPE. This indicates that the observed improvements in performance were likely not due to changes in aerobic capacity or cardiovascular efficiency but rather to other factors, such as potential adaptations in substrate utilization, psychological resilience, or pacing strategies during fasting.The study's results highlight the complexity of the relationship between Ramadan fasting and athletic performance(Spriet.2014). While the fasting period did not negatively affect aerobic performance, the improvements in time to exhaustion and running speed suggest that elite athletes may adapt effectively to the physiological and metabolic demands of fasting. The absence of significant changes in VO_2 and RPE further underscores the idea that the observed

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performance enhancements may be influenced by non-physiological factors, such as mental focus, motivation, or altered energy management strategies during fasting.These findings have important implications for athletes and coaches, particularly those working with endurance athletes who observe Ramadan. The study suggests that with proper management of training, nutrition, and recovery, elite athletes can maintain or even improve their performance during Ramadan. It also emphasizes the need for individualized approaches to training and competition scheduling to account for the unique challenges and opportunities presented by fasting. Overall, the research contributes to a growing body of evidence that Ramadan fasting, when managed appropriately, does not hinder athletic performance and may, in some cases, offer performance benefits for certain athletes.esearchers Chtourou and Güvenç examined the effects of Ramadan fasting on aerobic performance in athletes of similar age and health levels as the current study participants. Their study reported that peak running speed increased at the end of Ramadan compared to pre-Ramadan levels. However, some published studies on the effects of Ramadan fasting have reported negative impacts on endurance performance when exercise tests were conducted within the first two weeks of fasting(Al-Nawaiseh,2021).

Scholar Alpay GüvençA study was conducted involving sixteen amateur football league players, comprising five defenders, seven midfielders, and four forwards. These athletes had an average age of 17.4 years, a mean height of 175.4 cm, an average weight of 69.6 kg, and an average training experience of 5.1 years. The research took place in Turkey between August and October and was divided into four distinct phases: the last four days before Ramadan (Pre-RF), the first weekend of Ramadan (Beg-RF), the final four days of Ramadan (End-RF), and two weeks post-Ramadan (After-RF). Throughout Ramadan, all participants voluntarily observed a full fast from sunrise to sunset, abstaining from food and drink during daylight hours.The primary objective of the study was to evaluate the effects of Ramadan fasting (RF) on body composition, aerobic performance, lactate (LA) levels, heart rate (HR), and ratings of perceived exertion (RPE) in young football players who maintained their regular training routines. Despite limited existing data on the impact of RF on physical performance, this study was the first to focus specifically on young amateur athletes. The findings revealed that as long as a consistent training regimen, adequate sleep duration, daily energy intake, and fluid balance were maintained, Ramadan fasting did not adversely affect aerobic performance or body composition in these athletes. While submaximal RPE responses to aerobic exercise increased during Ramadan, objective measures of exercise intensity, such as LA and HR, remained unchanged or even declined by the end of the fasting period.In addition to the changes in submaximal LA and HR responses, the study observed notable improvements in peak running distance, peak running time, peak running speed, and running speed at the anaerobic threshold by the end of Ramadan. These improvements suggest that young football players can adapt effectively to the physiological demands of fasting without compromising their aerobic performance. The study's findings underscore the importance of maintaining regular training schedules, fluid balance, daily energy intake, and sleep duration during Ramadan to ensure optimal performance outcomes. Although subjective perceptions of exertion during submaximal-intensity exercise increased, objective measures of aerobic performance remained stable or showed improvement by the end of the fasting period, indicating that the athletes' physical capabilities were not negatively impacted.Throughout Ramadan, all players continued their regular training sessions after breaking their fast in the evening(Güvenç,2011). The continuation of structured training regimens likely played a significant role in enhancing aerobic capacity and mitigating any potential negative effects of fasting. From a practical standpoint, maintaining normal training routines and scheduling training sessions post-fast may serve as an effective strategy for fasting athletes and their coaches to optimize performance while adhering to Ramadan fasting practices(Pritchard,1993). This approach ensures that athletes can meet the physical demands of their sport while respecting their religious obligations.The study's results provide valuable insights for coaches, athletes, and sports scientists, highlighting the importance of tailored training and recovery strategies during Ramadan. By maintaining consistent training, nutrition, and hydration practices, young football players can sustain or even improve their aerobic performance during the fasting period. These findings contribute to a growing body of evidence that Ramadan fasting, when managed appropriately, does not hinder athletic performance and may, in some cases, offer opportunities for physiological adaptation and performance enhancement (Güvenç,2011).

These findings indicate that the impact of Ramadan fasting on aerobic performance is multifaceted and varies depending on individual and contextual factors.However, with appropriate training adjustments and sufficient nutrition and hydration, athletes can effectively adapt to the challenges of Ramadan fasting and, in some cases, even improve performance. For fasting athletes and their coaches, continuing regular training programs and adjusting training times post-Iftar may be an effective strategy.

Impact of Ramadan Fasting on Anaerobic Performance

Karli et al. conducted a detailed study to investigate the effects of Ramadan fasting on anaerobic power capacity and lactate clearance rate in elite strength athletes following high-intensity anaerobic exercise. The study involved ten male elite strength athletes, comprising two wrestlers, seven sprinters, and one thrower, aged between 20 and 24 years, with an average age of 22.30 ± 1.25 years. The research was structured into three distinct phases: three days before Ramadan (Pre-RF), the last three days of Ramadan (End-RF), and the final three days of the fourth week after Ramadan (Post-RF). To assess anaerobic power and capacity, the Wingate Anaerobic Test (WAnT) was administered at each of these stages. Additionally, capillary blood samples were collected at rest, immediately after the WAnT, and throughout the recovery period to analyze lactate levels and record heart rate (Karli,2004).

The findings from the repeated measures analysis of variance indicated no significant changes in the participants' body weight, body mass index, lean body mass, body fat percentage, daily sleep duration, or daily caloric intake during Ramadan. Overall hydration levels remained relatively stable throughout the fasting period; however, urine density at End-RF was significantly higher compared to Post-RF. Measurements of peak heart rate (HR) and lactate (LA) levels at Pre-RF, End-RF, and Post-RF suggested that the cardiovascular and metabolic stress induced by the Wingate Anaerobic Test (WAnT) was not impacted by Ramadan fasting. Furthermore, Ramadan fasting had no adverse effects on the athletes' power capacity or lactate clearance rate following high-intensity anaerobic exercise. The study's main findings suggest that if strength athletes maintain regular strength training, food intake, fluid balance, and sleep duration during Ramadan, fasting does not negatively impact body composition, anaerobic power, or performance capacity. Additionally, high-intensity exercise and post-exercise lactate metabolism remained unaffected during Ramadan(Karli,2004). These results highlight the importance of maintaining proper training and lifestyle habits for sustaining athletic performance.

In a related study, Chaouachi, Anis, and colleagues examined the impact of Ramadan Intermittent Fasting (RIF) on maintaining aerobic and anaerobic performance in elite judokas undergoing regular training. The study included 15 elite judo athletes who participated in physical tests at four different time points: before Ramadan (T1), at the beginning of Ramadan (T2), at the end of Ramadan (T3), and three weeks after Ramadan. These tests assessed various performance metrics, including the squat jump (SJ), countermovement jump (CMJ), 30-second repeated jumps, 30-meter sprint, multi-stage fitness tests, and fatigue levels. The results indicated that RIF did not have a negative impact on the overall aerobic and anaerobic performance of athletes engaged in

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intensive physical training. Throughout Ramadan, elite judokas maintained their performance in maximal aerobic and anaerobic tests. However, a decline in the 30-second repeated jump test results and an increase in perceived fatigue were observed at the end of Ramadan. These findings suggest that while RIF may lead to short-term effects on specific performance metrics, elite judokas can sustain their athletic capabilities during Ramadan with proper training and recovery strategies(Chaouachi,2014).

Both studies underscore the resilience of elite athletes to the physiological demands of Ramadan fasting, provided they adhere to consistent training regimens and maintain balanced nutrition and hydration. The results emphasize the importance of tailored training and recovery protocols to mitigate any potential short-term declines in performance, ensuring that athletes can continue to perform at their peak even during periods of intermittent fasting(Chaouachi,2014).

In conclusion, both studies suggest that when appropriate training and lifestyle habits are maintained, Ramadan fasting does not necessarily have a negative impact on elite athletes' performance. Whether in strength-based or endurance sports, athletes can sustain or even improve certain aspects of their performance during Ramadan.

Effects of Ramadan Fasting on Endurance Performance

BouguerraA study was conducted to assess the effects of Ramadan fasting on runners training at different times of the day (9:00 AM, 2:00 PM, and 10:00 PM) concerning maximal aerobic velocity (MAV), time to exhaustion (tlim100), and 3000-meter run performance. The study was structured into three phases: pre-Ramadan, during Ramadan, and post-Ramadan, with participants divided into three groups based on training time—AG group (afternoon training), MG group (evening training), and EG group (morning training).The results indicated that MAV and maximal oxygen uptake (VO_2 max) in the AG and MG groups were significantly higher than in the EG group before, during, and after Ramadan. Notably, compared to the AG group, the EG and MG groups experienced a significant increase in 3000-meter run completion time ($p < 0.01$) and a significant reduction in time to exhaustion (tlim100, $p < 0.001$) before and after Ramadan. These findings suggest that training in the afternoon may be more advantageous for improving aerobic capacity while fasting during Ramadan. Additionally, runners training in the afternoon exhibited higher MAV, VO_2 max, and overall performance across all test phases. Compared to those training in the morning or evening, they also demonstrated greater improvements in tlim100 and distance limit (dlim100)(Bouguerra,2017).

No significant differences in biochemical responses were observed in the afternoon training group across the three test periods.Although research indicates that VO_2 max does not significantly change during Ramadan fasting, heart rate decreases, and moderate-intensity aerobic exercise performance remains largely unaffected(Bouguerra,2017).Additionally, studies have shown that young male soccer players exhibited significantly improved endurance performance within two weeks after Ramadan, likely due to their consistent training during the fasting period. Some studies also report that elite long-distance runners improved their time to exhaustion and maximal running speed during Ramadan, while their VO_2 max and body composition remained unchanged. This may be attributed to athletes adapting better to unfavorable environmental conditions and adjusting their training load to mitigate dehydration risks, thereby maintaining high-quality training levels.Another study found that at the end of Ramadan, young soccer players' maximum sprint distance and speed improved, with no negative impact on their aerobic capacity or body composition. Therefore, maintaining appropriate training volume, adequate sleep, and sufficient hydration and nutrition during Ramadan fasting can effectively prevent or mitigate its potential negative effects on aerobic exercise performance (Al-Nawaiseh,2021).

The impact of Ramadan fasting on aerobic endurance performance is closely related to the timing of exercise. For instance, a study on 20 middle- and long-distance runners who trained at different times (9:00 AM, 2:00 PM, and 10:00 PM) during Ramadan found that afternoon training resulted in better aerobic endurance performance due to higher muscle temperature, which facilitated better utilization of free fatty acids. Conversely, another study observed that 10 adolescent soccer players performed better in aerobic and anaerobic exercises at 7:00 AM compared to 5:00 PM during Ramadan. This suggests that Ramadan fasting does not negatively impact morning exercise performance, likely because athletes are well-rested, have recovered to their optimal physiological state, and have adequate carbohydrate stores in the morning, whereas afternoon performance may decline due to fatigue, hunger, and sleep deprivation(Hua,2023).

Overall, Ramadan fasting may have some adverse effects on aerobic endurance performance, primarily due to dehydration, reduced muscle glycogen stores, fatigue, and sleep disturbances. Additionally, decreased melatonin and cortisol secretion and increased IL-6 levels may further influence performance (Bouguerra,2017). However, by maintaining consistent training and selecting optimal exercise timing during Ramadan, athletes can effectively mitigate these negative effects, sustain, or even enhance their endurance performance. This strategy not only helps athletes adapt to the physiological changes during Ramadan fasting but also optimizes their overall performance.

Effects of Ramadan Fasting on Strength Changes

Rebaï conducted a comprehensive study to investigate the effects of Ramadan Intermittent Fasting (RIF) on short-term maximal performance, specifically examining the outcomes of maintaining or reducing resistance training volume during this period. The research involved 20 young male football players, with an average age of 18.4 ± 0.8 years, an average weight of 72.4 ± 4.1 kg, and an average height of 183.4 ± 4.6 cm. These participants were randomly assigned to one of two groups: a normal training group (G1), which maintained their regular training regimen throughout the study, and a tapering training group (G2), which implemented a gradual reduction in training volume during the RIF period. The study was designed to assess the impact of these training strategies on muscle strength and power over four key time points: one month before the start of RIF (T0), one week before RIF began (T1), two weeks into the fasting period (T2), and at the end of RIF (T3).To evaluate the participants' performance, the study focused on two primary metrics: muscle strength, measured through maximal voluntary contraction (MVC), and muscle power, assessed using squat jump (SJ) and countermovement jump (CMJ) tests. Between T1 and T2, all participants followed a standardized full-body resistance training program, which included 8 repetitions across 4 sets, with 4-minute rest intervals between sets to ensure adequate recovery. This phase was critical for establishing a baseline of strength and power improvements. However, during the RIF period, the two groups diverged in their training approaches. G1 continued with their original training program without any modifications, while G2 adopted a tapering strategy, reducing their training volume to 3 sets per session, representing a 22% decrease in overall training load.The results of the study revealed that both groups experienced significant improvements in muscle strength and power from the baseline (T0) to each subsequent testing phase (T1, T2, and T3). However, the data highlighted a notable difference between the two groups. G2, which reduced its training volume during RIF, demonstrated significantly greater enhancements in both strength and power between T1 to T2 and T1 to T3 compared to G1, with these differences reaching statistical significance ($p < 0.05$). By the time of the second testing phase (T2), G2's performance had surpassed that of G1, with the difference being statistically significant at $p < 0.01$. Furthermore, when analyzing the overall performance changes from the baseline (T0) to T2 and T3, G2 exhibited significantly higher improvements than G1, with these differences also achieving statistical significance (p <

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0.05).These findings suggest that a strategically implemented reduction in training volume, as seen in G2's tapering approach, can lead to superior gains in strength and power during periods of intermittent fasting, such as Ramadan. The study underscores the potential benefits of adjusting training loads to align with physiological and metabolic changes induced by fasting, highlighting the importance of periodization and individualized training strategies for optimizing athletic performance. Additionally, the results provide valuable insights for coaches and athletes who may need to adapt their training programs during religious or other fasting periods to maintain or even enhance performance outcomes(Rebaï,2013).

From the initial testing phase (T0) to the first follow-up (T1), all participants engaged in a structured full-body resistance training program, which consisted of performing 8 repetitions across 4 sets, with a 4-minute rest interval between each set to ensure adequate recovery. This regimen was designed to optimize strength and power gains over the training period. Following T1, during the reduced intensity phase (RIF), the participants were divided into two groups: Group 1 (G1) continued with their original training program without any modifications, maintaining the same intensity and volume. In contrast, Group 2 (G2) implemented a gradual reduction in their training volume, decreasing to 3 sets per session, which represented a 22% reduction in overall training load.The results indicated that both groups experienced significant improvements in strength and power from the baseline (T0) to the first follow-up (T1), and these gains were sustained and further increased from T0 to the second follow-up (T2) and from T0 to the third follow-up (T3). However, the data revealed that G2, which had reduced their training volume during the RIF, demonstrated a significantly greater improvement in both strength and power metrics between T1 to T2 and T1 to T3 compared to G1, with statistical significance set at $p < 0.05$.By the time of the second follow-up (T2), the performance of G2 was notably superior to that of G1, with the difference being statistically significant at $p < 0.01$. Furthermore, when examining the performance changes from the baseline (T0) to T2 and T3, G2 showed statistically significantly higher improvements than G1, with the differences again reaching statistical significance at $p < 0.05$. These findings suggest that a strategically implemented reduction in training volume, as seen in G2, can lead to enhanced strength and power outcomes compared to maintaining a constant training load, highlighting the potential benefits of periodization and load management in resistance training programs.

These results suggest that gradually reducing training volume during RIF may significantly enhance muscle strength and power for young football players. The study also confirmed that during the pre-RIF training phase, both groups experienced significant improvements in muscle strength and power. However, during RIF, reducing training volume further improved muscle performance, particularly in the first two weeks of fasting. In contrast, maintaining high training volume resulted in stable or slightly reduced muscle strength and power, as seen in the counter-movement jump performance at T3(Rebaï,2013).

These findings highlight the importance of adjusting training volume to optimize athletic performance, especially during fasting periods such as Ramadan. For young football players, gradually reducing training volume during Ramadan may be more beneficial for enhancing overall muscle strength and performance. Additionally, even with high training volumes, muscle strength and power may remain stable or slightly decline, particularly at the end of Ramadan, emphasizing the critical role of training adjustments in optimizing performance during this period.

Discussion

Analysis of publications, authors and institutions

In conclusion, during Ramadan fasting, athletes may experience energy deficits due to prolonged fasting, particularly a reduction in muscle glycogen stores. This can negatively impact endurance exercises that require sustained energy output, such as running and cycling. Anaerobic exercises, such as weightlifting and sprinting, rely on rapid energy release. During Ramadan, the restrictions on food and fluid intake may affect muscle explosiveness and the ability to sustain high-intensity efforts.

Regarding strength, the inability to replenish energy and nutrients immediately, especially inadequate protein intake, may influence muscle power output and explosiveness. As for endurance, muscle fatigue may accumulate more rapidly due to decreased energy utilization efficiency. The body's inability to obtain energy from food in real-time limits glycogen replenishment, which is crucial for prolonged endurance exercises such as long-distance running or cycling. The reduction in glycogen stores may lead to a decline in athletic performance.

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Author Contributions

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