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Posted Date: 7 December 2023

doi: 10.20944/preprints202312.0448.v1

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Review

Intermittent Fasting: Does It Affect Sports Performance? A Systematic Review

Javier Conde-Pipó [1], Agustín Mora-Fernandez [1], Manuel Martinez-Bebia [2], Nuria Gimenez-Blasi [3], Alejandro Lopez-Moro [1], José Antonio Latorre [2], Antonio Almendros-Ruiz [1], Bernardo Requena [4] and Miguel Mariscal-Arcas [1,5,*]

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Abstract: Intermittent fasting is one of the most popular types of diet at the moment because it is an effective nutritional strategy in terms of weight loss. The main objective of this review is to analyze the effects that intermittent fasting has on sports performance. We are going to focus on analyzing physical capacities: aerobic capacity, anaerobic capacity, strength and power, we are also going to analyze its effect on body composition. For this, a bibliographic search was carried out in several databases where 25 research articles were analyzed to clarify these objectives. This review was registered in PROSPERO with code ref. 407024, and an evaluation of the quality or risk of bias was performed. After this analysis, results were obtained regarding the improvement of body composition and the maintenance of muscle mass. Finally, it can be concluded that fasting provides benefits in terms of body composition without reducing physical performance, maintenance of lean mass and improvements in maximum power. But despite this, it is necessary to carry out new studies focusing on the sports field since the samples have been very varied.

Keywords: intermittent fasting; sport nutrition; sport performance; exercise

1. Introduction

Different recent reviews and high-level sports nutrition bodies highlight the role that nutrition plays today in the sports performance of athletes in each of the different sports disciplines [1,2].

However, in recent years different dietary patterns and protocols have emerged that have tried to amplify or reduce the adaptations derived from physical exercise to try to achieve an improvement in the athlete's sports performance [3].

Within these strategies, intermittent fasting has been acquiring special renewed interest due to its supposed effects on health and improvement of body composition in patients with different pathologies of great predominance nowadays [4,5]. This dietary protocol focuses on timed fasting/eating periods with different time intervals [4,6].

Despite this recent popularity, currently its effects on performance do not seem to be clarified, having special importance in the physical and cognitive performance of those athletes who frequently perform this type of dietary patterns or temporary caloric restrictions as it happens with Islamic athletes during the religious practice of Ramadan [6–8].

Therefore, the main objective of the present review will be to investigate whether intermittent fasting intervenes in performance in professional athletes, evaluating the effects of this dietary

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protocol on aerobic and anaerobic capacity, strength and power and body composition (fat mass, muscle mass, weight).

2. Materials and Methods

This work is a systematized literature review based on scientific evidence documenting the effects of intermittent fasting in athletes and/or people who perform physical activity and its benefits on sports performance. This review was registered in PROSPERO with code ref. 407024, and an evaluation of the quality or risk of bias was performed by MM-B. For the literature review the following databases were used; MEDLINE through PubMed search engine, Web Of Science and Scopus. The keywords used were: "intermittent fasting" or "intermittent fasting", "sport" or "sport", "performance" or "performance" and "exercise" or "exercise" where 4,402 articles were obtained using as Boolean connectors "or" between the words in different languages and "and" between the different ones ("intermittent fasting" OR "intermittent fasting" AND "sport" OR "sport" AND "performance" OR "performance" AND "exercise" OR "exercise"). The exclusion criteria that have been established are the following: dates established between 2013 and the present, free full texts, studies conducted in adult human athletes, languages of the articles in English and/or Spanish.

As for the inclusion criteria of the articles, it has been considered that intermittent fasting is mainly linked to sports practice and that this obtains a result in terms of performance or physical capacities.

Therefore, when filtering articles from 2013 to today, being in humans and adults and limiting the languages to Spanish and English 114 articles were found. After eliminating duplicates, we obtained 92 papers, once the title was read, 34 were selected and 58 were eliminated because the title was not related to the topic of the systematic review. After reading the abstract and observing the bibliography, 12 articles were eliminated, but 3 were added from the bibliography obtained for a complete reading. This whole procedure is followed according to PRISMA standards [9] by means of which a flow chart is made (Figure 1).

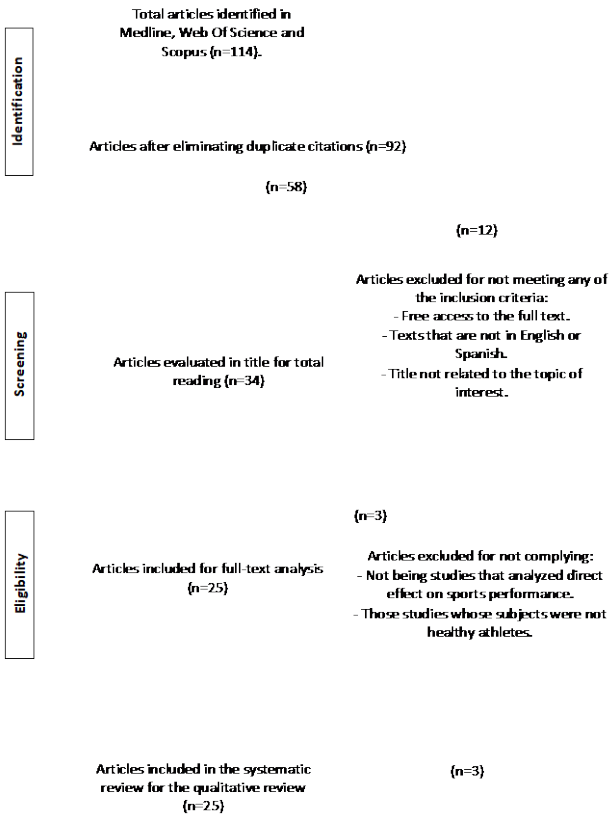

Figure 1. Flow chart for the selection of articles included in the systematic review.

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3. Results

Within the bibliography of this review, we found that the majority highlighted that the subjects were athletes [10,11,17,21–25,31–34]. Another did not specify if they were athletes [30], but due to their intervention it was included, while the rest indicated that the subjects were physically active [14,18,26–28].

Most of them showed time-restricted feeding (TRF) with a 16-hour fasting window and 8-hour feeding window [10,11,14,16–18,21,23,25,26,33]. Other studies analyzed 14/8 fasting during the Ramadan period [12,21,32], while another article analyzed overnight fasting [24].

In addition to this, it should be noted that two studies used more variables in their studies, such as the intake of supplementation in addition to the fasting follow-up, namely hydroxy methyl butyrate (HMB) and two types of whey protein, whey protein concentrate (WPC) and hydrolyzed whey protein (WPH) [26,29]. Another article sought to compare the difference between protein-loaded and carbohydrate-loaded fasting [34]. For the most part, a control group with no fasting and an experimental group performing fasting are identified [18].

Based on performance, specifically aerobic performance, 8 articles were included that used different tests (Table 1), among them: 20 minutes cycling test [29], 10 km test [17], repeated sprints test [24,28], treadmill test [25], test at 45% of maximum power [10].

Table 1. Results of IF on aerobic capacity.

Nº	Reference and date	Impact Index	Type of study	Study Size	Duration of fasting	Objective of the study	Parameters analyzed	Conclusions
1.	Moro T, et al. 2020 (10)	5.159 (IF) 22/88 (Q1)	Experimental	16 young cyclists	Intermittent Fasting TRF (16/8)	IF in 4 weeks of high-level resistance training	Body composition, resting metabolism and performance tests	Does not affect performance
2.	Kang J, et al. 2021 (16)	3.571 (IF) 57/109 (Q3)	Review	23 randomized studies	TRF Fasting	Effects on metabolic and anthropometric parameters.	Strength, power, aerobic capacity	Does not reduce aerobic capacity.
3.	Tovar AP, et al. 2021 (17)	6.706 (IF) 15/90 (Q1)	Experimental	15 male runners	Intermittent Fasting TRF 16/8.	Effects on the performance of endurance runners.	Body composition, stress test and 10 km test.	Minimal effect on performance
4.	Aird TP, et al. 2018 (22)	3.631 (IF) 11/83 (Q1)	Meta-analysis	46 studies	NT	To determine the effects of IF on aerobic and anaerobic exercise performance.	Aerobic capacity	Aerobic exercise performance does not differ when following IF vs. other nutrition
5.	Terada T, et al.	1.432 (IF)	Experimental	20 participants	Overnight fasting	Effects on subjects in sprint	Aerobic capacity	Improved sprint fasting vs.

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	2019 (24)	67/85 (Q4)				training and aerobic capacity.		carbohydrate abundance
6.	Brady AJ, et al. 2021 (25)	6.289 (IF) 9/88 (Q1)	Experimental	17 participants	Fasting TRF (16/8)	Effect of 8 weeks of TRF in conjunction with training.	Body composition, aerobic capacity and biomarkers.	No alteration in endurance running performance indices.
7.	Naharudin, et al. 2018 (28)	2.376 (IF) 29/83 (Q2)	Experimental	20 participants	Intermittent fasting	Effect of IF on high intensity exercise, Wingate test and HIIT cycling test.	Wingate test,	Attenuated performance at the start of practice.
8.	Aird TP, et al. 2021 (29)	5.900 (IF) 36/146 (Q1)	Experimental	28 male participants	Intermittent fasting	Compare performance and metabolic adaptations of short-term SIT with fasting and with WPH or WPC supplementation.	Body composition, aerobic exercise.	No significant results

Regarding anaerobic performance, 6 articles (Table 2) used different tests to evaluate different parameters of the sample such as stress tests [10,17], Wingate test [14,28,29], submaximal exercise [34], repeated sprints test [28] and interval training [34].

Table 2. Results of IF on anaerobic capacity.

Nº	Reference and date	Impact Index	Type of study	Study Size	Duration of fasting	Objective of the study	Parameters analyzed	Conclusions
1.	Moro T, et al. 2020 (10)	5.159 (IF) 22/88 (Q1)	Experimental	16 young cyclists	Intermittent Fasting TRF (16/8)	IF in 4 weeks of high-level resistance training	Body composition, resting metabolism and performance test.	No effect on performance
2.	Correia JM, et al. 2021 (14)	4.614 (IF) 100/279 (Q2)	Experimental	12 healthy males	Fasting TRF 16/8	Short- and long-term effects in trained young people.	Body composition and Wingate test.	No significant results in terms of performance

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								improvement. Improved sprint fasting vs. carbohydrate abundance.
3.	Terada T, et al. 2019 (24)	1.432 (IF) 67/85 (Q4)	Experimental	20 participants	Overnight fasting	Effects on subjects in sprint training and aerobic capacity.	Aerobic capacity	
4.	Naharudin, et al. 2018 (28)	2.376 (IF) 29/83 (Q2)	Experimental	20 participants	Intermittent fasting	Effect of IF in high intensity exercise, Wingate test and HIIT cycling test.	Wingate test, Body composition, aerobic exercise.	Attenuated performance at the start of practice.
5.	Aird TP, et al. 2021 (29)	5.900 (IF) 36/146 (Q1)	Experimental	28 male participants	Intermittent fasting	Compare performance and metabolic adaptations of short-term SIT with fasting and with WPH or WPC supplementation.	Aerobic and anaerobic performance.	No significant results
6.	Rothschild JA, et al. 2021 (34)	6.706 (IF) 15/90 (Q1)	Experimental	17 trained cyclists and triathletes	Intermittent fasting	Effects versus a protein-rich and a carbohydrate-rich meal on cycling performance.	Submaximal exercise, high intensity exercise.	No difference versus CHO in HIIT. Like PRO, uncompromised performance in shorter duration and higher intensity sessions.

Table 3 indexes the 8 included studies that evaluated muscular strength through maximal strength and endurance strength tests, and power through peak power (PPO), average power (W) [11,16,23,26–28,32,33].

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Table 3. Results of IF on muscular strength and power.

Nº	Reference and date	Impact Index	Type of study	Study Size	Duration of fasting	Objective of the study	Parameters analyzed	Conclusions
1.	Moro T, et al. 2016 (11)	3.786 (IF) 30/128 (Q1)	Experimental	34 participants	TRF (16/8)	Effects during endurance training in healthy males.	Body composition, strength and biomarkers	Improvement of biomarkers related to health, fat loss and maintenance of muscle mass.
2.	Kang J, et al. 2021 (16)	3.571 (IF) 57/109 (Q3)	Review	23 randomized studies	TRF Fasting	Effects on metabolic and anthropometric parameters.	Strength, power, aerobic capacity	Improvements in body composition and no alteration in muscle mass synthesis.
3.	Tinsley GM, et al. 2017 (23)	2.576 (IF) 22/81 (Q2)	Experimental	18 participants	TRF Fasting	To examine changes in body composition and strength in strength training in males.	Strength and body composition	Variation in fat mass loss versus diet, but not in muscle mass gain.
4.	Tinsley GM, et al. 2019 (26)	6.766 (IF) 6/89 (Q1)	Experimental	Healthy women aged 18-30 years	TRF Fasting	TRF + HMB in strength training vs TRF without HMB.	Body composition and muscle performance	TRF did not slow adaptations in hypertrophy and performance vs. other diets
5.	Martínez-Rodríguez A, et al. 2021 (27)	4.614 (IF) 100/279 (Q2)	Experimental	14 active women	Intermittent fasting	Effects of HIIT training and muscular and anaerobic performance.	Body composition, grip strength, jumping, Wingate cycling test	Decreased fat mass and increased jumping performance.
6.	Naharudin, et al. 2018 (28)	2.376 (IF) 29/83 (Q2)	Experimental	20 participants	Intermittent fasting	Effect of IF in high intensity exercise, Wingate	Wingate test, Body compositio	Attenuated performance at the beginning of practice.

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						test and HIIT cycling test.	n, aerobic exercise.	
7.	Abaïdia AE, et al. 2020 (32)	11.140 (IF) 2/88 (Q1)	Meta-analysis	11 studies	Fasting 14/10 (Ramadan)	Effects of 1 month of Ramadan on physical performance.	Aerobic performance, maximal power, strength, jump height, sprints.	No decrease in performance if nutrition is correct.
8.	Correia JM, et al. 2020 (33)	5.719 (IF) 17/88 (Q1)	Experimental	Individuals between 18 - 39 years old.	Intermittent fasting	Effects on sports performance.	Muscular strength, aerobic capacity, anaerobic capacity and body composition.	Positive results in fat mass reduction, without significant results in terms of strength.

Finally, Table 4 included the 15 studies that evaluated any body composition variable such as body fat mass, lean mass, and anthropometric folds [10–13,15,17–20,23,25–27,30–33].

Table 4. Results of IF on body composition and health.

Nº	**Reference and date**	**Impact Index**	**Type of study**	**Study Size**	**Duration of fasting**	**Objective of the study**	**Parameters analyzed**	**Conclusions**
1.	Moro T, et al. 2020 (10)	5.159 (IF) 22/88 (Q1)	Experimental	16 young cyclists	Intermittent Fasting TRF (16/8)	IF in 4 weeks of high-level endurance training.	Body composition, resting metabolism and performance testing	Improved body composition and inflammatory markers.
2.	Moro T, et al. 2016 (11)	3.786 (IF) 30/128 (Q1)	Experimental	34 participants	TRF (16/8)	Effects during endurance training in healthy males.	Body composition, strength and biomarkers	Improved health, fat loss and maintenance of muscle mass.
3.	Hosseini S, et al. 2015 (12)	NT	Experimental	50 healthy subjects	Ramadan	Effects of Ramadan and physical activity on biochemical	Body weight, fat percentage, biomarkers,	Reductions in anthropometric parameters, lower cholesterol.

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						parameters.		
4.	Laza V. 2020 (13)	NT	Magazine article	NT	TRF Fasting	Effects on the performance and health of athletes.	Biomarkers, body composition.	Decreased blood glucose, body fat, cholesterol, testosterone levels and improved insulin sensitivity, increased hepcidin levels, improved immune system and maintenance of muscle mass.
5.	Zouhal H, et al. 2020 (15)	NT	Review	71 studies	ICR, ADF and TRF Fasts	Identifying the effects of IF together with physical exercise.	Body composition, metabolic adaptations, sports performance.	Decreased circulating insulin levels and improved glucagon levels. Reduction of body fat
6.	Tovar AP, et al. 2021 (17)	6.706 (IF) 15/90 (Q1)	Experimental	15 male runners	Intermittent Fasting TRF 16/8.	Effects on the performance of endurance runners.	Body composition, stress test and 10 km test.	Improvements in fat mass reduction and muscle mass maintenance.
7.	Isenmann E, et al. 2021 (18)	6.706 (IF) 15/90 (Q1)	Experimental	35 subjects	TRF 16/8	Effects on body composition and adherence.	Weight, fat mass, BMI.	Improvements in weight, body composition, BMI and hip and waist circumference.
8.	Haupt S, et al. 2021 (19)	6.064 (IF) 75/297 (Q2)	Review	NT	TRF 16/8	Summarize fasting information on metabolic and hormonal		Improvements in blood pressure and insulin sensitivity and body composition.

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						responses.		Increased lipid utilization
9.	El-Outa A, et al. 2022 (20)	0.678 (SJR) (Q2)	Experimental	80 participants	TRF 16/8	Assess VO2max in addition to other parameters.	VO2max, weight, body composition, biomarkers	Reductions in glucose levels, LDL, HDL and body weight. No significance in VO2max
10.	Tinsley GM, et al. 2017 (23)	2.576 (IF) 22/81 (Q2)	Experimental	18 participants	Fasting TRF	Examine changes in body composition and strength in strength training in males.	Strength and body composition	Variation in fat mass loss vs. diet, but not in muscle mass gain
11.	Brady AJ, et al. 2021 (25)	6.289 (IF) 9/88 (Q1)	Experimental	17 participants	Fasting TRF (16/8)	Effect of 8 weeks of TRF together with training.	Body composition, aerobic capacity and biomarkers	Decrease in fat mass
12.	Martínez-Rodríguez A, et al. 2021 (27)	4.614 (IF) 100/279 (Q2)	Experimental	14 active women	Intermittent fasting	Effect of HIIT training and muscular and anaerobic performance.	Body composition, gripper strength, jumping, Wingate cycling test	Decrease in fat mass
13.	Naharuddin, et al. 2018 (28)	2.376 (IF) 29/83 (Q2)	Experimental	20 participants	Intermittent fasting	Effect of IF on high intensity exercise, Wingate test and HIIT cycling test.	Wingate test, body composition, aerobic exercise.	Attenuated performance at the beginning of practice.
14.	Hammouda O, et al. 2013 (31)	3.534 (IF) 8/55 (Q1)	Experimental	15 soccer players.	Fasting 14/10 (Ramadan)	Effects of Ramadan on lipoprotein	Body composition, biomarkers	Reductions in fat mass and LDL without affecting muscle mass

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						fluctuation during exercise.		and increase in HDL (significant reduction in YO-YO test).
15.	Correia JM, et al. 2020 (33)	5.719 (IF) 17/88 (Q1)	Experimental	Individuals between 18 - 39 years old.	Intermittent fasting	Effects on sports performance.	Muscle strength, aerobic capacity, anaerobic capacity and body composition.	Positive results in fat mass decrease, no significant results in strength.

4. Discussion

To begin with, we must consider that there is a wide variety of studies chosen in the review in terms of the difference of sports in the sample, the differences in gender and age and the different interventions.

Firstly, we can affirm that intermittent fasting (any type) affects the improvement of body composition [10,11,16–18,21,23,26–28]. With this, we can concretize that it intervenes positively in performance, since a reduction in body weight would be considered beneficial [10,17,27].

Intermittent fasting could be considered as an adequate nutritional strategy to reduce fat mass and body fat percentage to an adequate number for the athlete (between 6 - 12% in men and between 12 - 18% in women) and maintaining lean mass or muscle mass [1,2,8,12]. Martinez-Rodriguez et al. (2021) [27] in their study with 14 active women who combined TRF with high intensity training (HIIT) compared to HIIT with normal diet, observed a significant decrease in fat in the fasting group. It should be noted that the food log showed a non-voluntary caloric restriction of 10-20% per week. Hosseini et al. (2015); in their study with 50 healthy subjects combining a fasting intervention together with the performance of physical activity [12] observed a decrease in body mass index and body fat percentage.

It should be clarified that the effectiveness of the fasting protocols included in this review is closely linked to the time of application and to the type of population. Fasting is more effective in the medium and long term than in the short term [14,27].

In turn, we should consider that in some studies [18,23,25–27] caloric restriction is combined with the follow-up of intermittent fasting. This aspect highlights conclusions obtained from recent studies where no superiority of different dietary protocols is observed, including intermittent fasting, if an adequate caloric deficit and a correct adherence to the dietary plan is reached [35,36]. Therefore, the effect of caloric restriction is a very important element to consider in relation to the reduction of fat mass.

Despite this, studies such as the of Isenmann et al. study show a greater adherence to the diet in those subjects who followed a nutritional plan with intermittent fasting compared to a diet without restrictions [18]. This aspect could be interesting onsidering the important role of a higher adherence for the adequacy of a long-term fat loss and the need for individualization of the same [37].

Considering health in conjunction with intermittent fasting, Perez-Montilla et al. (2022) in their review points out that fasting controls body weight, improves insulin sensitivity, reduces systemic inflation and strengthens the immune system [21]. Thus, it can be linked to injury prevention and recovery. Several reviews mention benefits of IF in improving metabolic health and insulin sensitivity [13], as well as in regulating glucose and certain lipid metabolism [19]. Certain metabolic processes in adipose tissue are mediated by endogenous clocks in our body such as adiponectin, the levels of this hormone can be altered by changes in sleep/wake or feeding/fasting cycles [19]. The TRF type of fasting appears to be an effective strategy to improve the levels of this hormone. Moro et al. (2016) in

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their randomized clinical trial, 34 men habituated to resistance training [11] found an increase in adiponectin levels and a decrease in leptin levels. The same author in another study with 16 cyclists [10] observed a trend of higher increase in adiponectin levels in the TRF group (+33%) compared to (+8%) in the normal diet group. Low levels of adiponectin have been associated with obesity, oxidative stress [11] and insulin resistance, whereas higher levels are associated with improved insulin sensitivity in adipose tissue [19].

This improvement in the treatment of different diseases has also been contrasted by other trials [38,39]. However, recent reviews show the need for long-term studies evaluating this type of intervention versus isocaloric restriction in humans to know whether the results may be different from those observed after similar weight loss achieved through modest continuous energy restriction [40–42].

Respect to the levels of certain inflammatory markers some studies hypothesize that fasting may activate cellular mechanisms that enhance immune function [4]. In a group of elite cyclists, interleukin (IL-6) appeared to decrease in the TRF group with an upward trend in the normal diet group [10]. Also, in this same study he observed a decrease in the neutrophil-lymphocyte ratio (NLR) in both groups, but it was significant relative to baseline values only in the TRF group. NLR is a biomarker of systemic inflammation that correlates with blood C-reactive protein levels, which were found to be decreased during Ramadan fasting in two studies of soccer players [31].

Finally, in terms of performance, we found both positive and negative aspects. It seems that during Ramadan (14/10), negative effects appear in terms of performance, which may be due to other aspects such as rest and hydration. Greater negative effects can be observed in elite athletes, but in amateur athletes there is not much difference [21,32,33]. On the other hand, in the TRF modality (16/8), there do not seem to be differences in the performance of physical capacities: aerobic [10,16,17,22,25,29], anaerobic [17,22,28,29,33], strength and power [11,14,16,21,23,26,29,33,34]. The results of this review thus show that, in terms of capacities, fasting does not have a negative impact on sports performance and could be considered an adequate type of diet for sports practice.

Recent reviews have also highlighted these varied findings, stressing the need for more research in this regard given the wide heterogeneity of protocols and measurable variables [33,43].

Nevertheless, the possible effect of this type of interventions on the athlete's body composition and therefore, its possible link with the athlete's performance should be considered [16,29].

Finally, the possible limitations observed during the elaboration of the work are presented, and due to these, it is not possible to obtain accurate conclusions.

The review has had little variety of interventions, which does not allow us to identify a specific action protocol. The samples, tests, measurements, objectives, and variables of the different studies have also been a limitation. Some of them did not count calories during the interventions and because of this we cannot obtain a reliable conclusion about the results obtained, or in the case of the variables, not all the studies measured the same ones, so we cannot draw reliable conclusions in their entirety. Many of the articles look for short term effects, when it has been concluded that long- and medium-term effects are more effective. Most of the studies conclude that a follow-up of future interventions is necessary to continue monitoring the effects of fasting, so there seems to be a lack of evidence in the studies.

5. Conclusions

After carrying out this systematic review of the studies and literature on how intermittent fasting affects athletes and sports performance, the questions and objectives posed at the beginning of the study can be answered. Referring to the main objective, the scientific evidence indicates that intermittent fasting does not negatively affect sports performance and does affect the improvement of body composition. Therefore, it may be an appropriate strategy for sports or athletes seeking a control of lean mass and a decrease in fat mass, which can have a positive transfer in terms of performance, since by reducing their weight and specifically their fat mass they will be able to perform better in certain situations in which power capacity is used.

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The performance of the aerobic capacity would be benefited since the improvement of the corporal composition can help to the improvement of the resistance; this fact ends in an improvement of the power being related directly with the corporal weight. As far as strength is concerned, it is not compromised by intermittent fasting and remains at the same level. Intermittent fasting would be related to an increase or improvement of health and the immune system; this is also related to performance as it improves the ability to prevent injuries and their recovery. Further studies would be needed to be more certain about the effects of intermittent fasting on sports performance. The heterogeneous samples make it difficult to have a definitive conclusion, but the data are favorable, and it could be recommended to follow intermittent fasting without reducing performance in athletes.

In the case of Ramadan is different, it can be considered as a type of intermittent fasting/TRF in which the fasting period varies between 12 and 18 hours depending on the season and location, unlike the other types of TRF is not allowed the intake of any type of liquid and the fasting time lasts from sunrise to sunset. This causes disturbance in the sleep-wake and rest-activity cycles. Due to changes in sleeping and eating hours physiological and psychological disturbances can be caused. There is evidence showing that fasting during Ramadan affects a decrease in performance in the Yo-Yo test that measures VO2 max [14].

Author Contributions: The study was designed by MM-B, BR and MM-A; data were collected and analyzed by JC-P, AA-R, BR and MM-A; data interpretation and manuscript preparation were undertaken by AM-F, JAL, NG-B, AL-M and MM-A. Evaluation of the quality or risk of bias was performed by MM-B and JC-P. All authors have read and agreed to the published version of the manuscript.

Funding: The funding sponsors had no role in the design of the study; the collection, analyses, or interpretation of the data; the writing of the manuscript; or the decision to publish the results. This study was funded by the High Council for Sports (CSD), Spanish Ministry of Culture and Sport, through the NESA NETWORK "Spanish Network of Sports Care at Altitude (RADA)" Ref. 19/UPB/23. This research was supported by an FPU grant from the Spanish Ministry of Universities to Alejandro Lopez-Moro (FPU20/00210).

Data Availability Statement: There are restrictions on the availability of data for this trial due to the signed consent agreements around data sharing, which only allow access to external researchers for studies following the project's purposes. Requestors wishing to access the trial data used in this study can make a re-quest to mariscal@ugr.es.

Acknowledgments: The authors thank to FSI Football Science Institute for their support.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Thomas DT, Erdman KA, Burke LM. Position of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine: Nutrition and Athletic Performance. J Acad Nutr Diet. 2016 Mar;116(3):501-528.
2. Vitale K, Getzin A. Nutrition and Supplement Update for the Endurance Athlete: Review and Recommendations. Nutrients. 2019 Jun 7;11(6):1289.
3. Jeukendrup AE. Periodized Nutrition for Athletes. Sports Med. 2017 Mar;47(Suppl 1):51-63.
4. Dong TA, Sandesara PB, Dhindsa DS, Mehta A, Arneson LC, Dollar AL, Taub PR, Sperling LS. Intermittent Fasting: A Heart Healthy Dietary Pattern? Am J Med. 2020 Aug;133(8):901-907.
5. Welton S, Minty R, O'Driscoll T, Willms H, Poirier D, Madden S, Kelly L. Intermittent fasting and weight loss: Systematic review. Can Fam Physician. 2020 Feb;66(2):117-125.
6. Welton S, Minty R, O'Driscoll T, Willms H, Poirier D, Madden S, Kelly L. Intermittent fasting and weight loss: Systematic review. Can Fam Physician. 2020 Feb;66(2):117-125.
7. Cherif A, Roelands B, Meeusen R, Chamari K. Effects of Intermittent Fasting, Caloric Restriction, and Ramadan Intermittent Fasting on Cognitive Performance at Rest and During Exercise in Adults. Sports Med. 2016 Jan;46(1):35-47.
8. Ahmed I, Maughan RJ, Iqbal Z, Ali K, Naji O, Awan S, Tumi AM, Chamari K. Competing in the Ramadan fasted state: for spirituality, health and performance. Br J Sports Med. 2022 Mar 15:bjsports-2021-105230.
9. Page MJ, Moher D, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, Shamseer L, Tetzlaff JM, Akl EA, Brennan SE, Chou R, Glanville J, Grimshaw JM, Hróbjartsson A, Lalu MM, Li T, Loder EW, Mayo-Wilson E, McDonald S, McGuinness LA, Stewart LA, Thomas J, Tricco AC, Welch VA, Whiting P, McKenzie JE.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 7 December 2023 doi:10.20944/preprints202312.0448.v1

PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. BMJ. 2021 Mar 29;372:n160.
10. Moro T, Tinsley G, Longo G, Grigoletto D, Bianco A, Ferraris C, Guglielmetti M, Veneto A, Tagliabue A, Marcolin G, Paoli A. Time-restricted eating effects on performance, immune function, and body composition in elite cyclists: a randomized controlled trial. J Int Soc Sports Nutr. 2020 Dec 11;17(1):65.
11. Moro T, Tinsley G, Bianco A, Marcolin G, Pacelli QF, Battaglia G, Palma A, Gentil P, Neri M, Paoli A. Effects of eight weeks of time-restricted feeding (16/8) on basal metabolism, maximal strength, body composition, inflammation, and cardiovascular risk factors in resistance-trained males. J Transl Med. 2016 Oct 13;14(1):290.
12. Hosseini S, Hejazi K. Evaluation of Changes in Blood Hematological and Biochemical Parameters in Response to Islamic Fasting and Regular Physical Activity in Male and Female Subjects. Journal of Fasting & Health. 2015;3(3):118-25.
13. Laza V. Intermittent fasting in athletes: PROs and CONs. Health, Sports & Rehabilitation Medicine. 2020;21(1):52-8.
14. Correia JM, Santos I, Pezarat-Correia P, Minderico C, Schoenfeld BJ, Mendonca GV. Effects of Time-Restricted Feeding on Supramaximal Exercise Performance and Body Composition: A Randomized and Counterbalanced Crossover Study in Healthy Men. Int J Environ Res Public Health. 2021 Jul 6;18(14):7227.
15. Zouhal H, Saeidi A, Salhi A, Li H, Essop MF, Laher I, Rhibi F, Amani-Shalamzari S, Ben Abderrahman A. Exercise Training and Fasting: Current Insights. Open Access J Sports Med. 2020 Jan 21;11:1-28.
16. Kang J, Ratamess NA, Faigenbaum AD, Bush JA, Beller N, Vargas A, Fardman B, Andriopoulos T. Effect of Time-Restricted Feeding on Anthropometric, Metabolic, and Fitness Parameters: A Systematic Review. J Am Nutr Assoc. 2022 Nov-Dec;41(8):810-825.
17. Tovar AP, Richardson CE, Keim NL, Van Loan MD, Davis BA, Casazza GA. Four Weeks of 16/8 Time Restrictive Feeding in Endurance Trained Male Runners Decreases Fat Mass, without Affecting Exercise Performance. Nutrients. 2021 Aug 25;13(9):2941.
18. Isenmann E, Dissemond J, Geisler S. The Effects of a Macronutrient-Based Diet and Time-Restricted Feeding (16:8) on Body Composition in Physically Active Individuals-A 14-Week Randomised Controlled Trial. Nutrients. 2021 Sep 6;13(9):3122.
19. Haupt S, Eckstein ML, Wolf A, Zimmer RT, Wachsmuth NB, Moser O. Eat, Train, Sleep-Retreat? Hormonal Interactions of Intermittent Fasting, Exercise and Circadian Rhythm. Biomolecules. 2021 Mar 30;11(4):516.
20. El-Outa A, Ghandour L, Hamade H, Borgi C, Fares EJ, Gherbal T, Mufarrij A. Intermittent fasting & performance: The iFast clinical trial protocol. Contemp Clin Trials Commun. 2021 Apr 15;25:100766.
21. Perez-Montilla JJ, Cuevas-Cervera M, Gonzalez-Muñoz A, Garcia-Rios MC, Navarro-Ledesma S. Efficacy of Nutritional Strategies on the Improvement of the Performance and Health of the Athlete: A Systematic Review. Int J Environ Res Public Health. 2022 Apr 1;19(7):4240.
22. Aird TP, Davies RW, Carson BP. Effects of fasted vs fed-state exercise on performance and post-exercise metabolism: A systematic review and meta-analysis. Scand J Med Sci Sports. 2018 May;28(5):1476-1493.
23. Tinsley GM, Forsse JS, Butler NK, Paoli A, Bane AA, La Bounty PM, Morgan GB, Grandjean PW. Time-restricted feeding in young men performing resistance training: A randomized controlled trial. Eur J Sport Sci. 2017 Mar;17(2):200-207.
24. Terada T, Toghi Eshghi SR, Liubaoerjijin Y, Kennedy M, Myette-Côté É, Fletcher K, Boulé NG. Overnight fasting compromises exercise intensity and volume during sprint interval training but improves high-intensity aerobic endurance. J Sports Med Phys Fitness. 2019 Mar;59(3):357-365.
25. Brady AJ, Langton HM, Mulligan M, Egan B. Effects of 8 wk of 16:8 Time-restricted Eating in Male Middle- and Long-Distance Runners. Med Sci Sports Exerc. 2021 Mar 1;53(3):633-642.
26. Tinsley GM, Moore ML, Graybeal AJ, Paoli A, Kim Y, Gonzales JU, Harry JR, VanDusseldorp TA, Kennedy DN, Cruz MR. Time-restricted feeding plus resistance training in active females: a randomized trial. Am J Clin Nutr. 2019 Sep 1;110(3):628-640.
27. Martínez-Rodríguez A, Rubio-Arias JA, García-De Frutos JM, Vicente-Martínez M, Gunnarsson TP. Effect of High-Intensity Interval Training and Intermittent Fasting on Body Composition and Physical Performance in Active Women. Int J Environ Res Public Health. 2021 Jun 14;18(12):6431.
28. Naharudin MNB, Yusof A. The effect of 10 days of intermittent fasting on Wingate anaerobic power and prolonged high-intensity time-to-exhaustion cycling performance. Eur J Sport Sci. 2018 Jun;18(5):667-676.
29. Aird TP, Farquharson AJ, Bermingham KM, O'Sulllivan A, Drew JE, Carson BP. Divergent serum metabolomic, skeletal muscle signaling, transcriptomic, and performance adaptations to fasted versus whey protein-fed sprint interval training. Am J Physiol Endocrinol Metab. 2021 Dec 1;321(6):E802-E820.
30. Cherif A, Meeusen R, Farooq A, Briki W, Fenneni MA, Chamari K, Roelands B. Repeated Sprints in Fasted State Impair Reaction Time Performance. J Am Coll Nutr. 2017 Mar-Apr;36(3):210-217.
31. Hammouda O, Chtourou H, Aloui A, Chahed H, Kallel C, Miled A, Chamari K, Chaouachi A, Souissi N. Concomitant effects of Ramadan fasting and time-of-day on apolipoprotein AI, B, Lp-a and homocysteine responses during aerobic exercise in Tunisian soccer players. PLoS One. 2013 Nov 11;8(11):e79873.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 7 December 2023 doi:10.20944/preprints202312.0448.v1

32. Abaïdia AE, Daab W, Bouzid MA. Effects of Ramadan Fasting on Physical Performance: A Systematic Review with Meta-analysis. Sports Med. 2020 May;50(5):1009-1026.
33. Correia JM, Santos I, Pezarat-Correia P, Minderico C, Mendonca GV. Effects of Intermittent Fasting on Specific Exercise Performance Outcomes: A Systematic Review Including Meta-Analysis. Nutrients. 2020 May 12;12(5):1390.
34. Rothschild JA, Kilding AE, Broome SC, Stewart T, Cronin JB, Plews DJ. Pre-Exercise Carbohydrate or Protein Ingestion Influences Substrate Oxidation but Not Performance or Hunger Compared with Cycling in the Fasted State. Nutrients. 2021 Apr 14;13(4):1291.
35. Fanti M, Mishra A, Longo VD, Brandhorst S. Time-Restricted Eating, Intermittent Fasting, and Fasting-Mimicking Diets in Weight Loss. Curr Obes Rep. 2021 Jun;10(2):70-80.
36. Freire R. Scientific evidence of diets for weight loss: Different macronutrient composition, intermittent fasting, and popular diets. Nutrition. 2020 Jan;69:110549.
37. Thom G, Lean M. Is There an Optimal Diet for Weight Management and Metabolic Health? Gastroenterology. 2017 May;152(7):1739-1751.
38. Albosta M, Bakke J. Intermittent fasting: is there a role in the treatment of diabetes? A review of the literature and guide for primary care physicians. Clin Diabetes Endocrinol. 2021 Feb 3;7(1):3.
39. Varady KA, Cienfuegos S, Ezpeleta M, Gabel K. Cardiometabolic Benefits of Intermittent Fasting. Annu Rev Nutr. 2021 Oct 11;41:333-361.
40. Antoni R, Johnston KL, Collins AL, Robertson MD. Effects of intermittent fasting on glucose and lipid metabolism. Proc Nutr Soc. 2017 Aug;76(3):361-368.
41. Patikorn C, Roubal K, Veettil SK, Chandran V, Pham T, Lee YY, Giovannucci EL, Varady KA, Chaiyakunapruk N. Intermittent Fasting and Obesity-Related Health Outcomes: An Umbrella Review of Meta-analyses of Randomized Clinical Trials. JAMA Netw Open. 2021 Dec 1;4(12):e2139558.
42. Mattson MP, Longo VD, Harvie M. Impact of intermittent fasting on health and disease processes. Ageing Res Rev. 2017 Oct;39:46-58.
43. Levy E, Chu T. Intermittent Fasting and Its Effects on Athletic Performance: A Review. Curr Sports Med Rep. 2019 Jul;18(7):266-269.

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