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Summary / Sumario

COVID-19: looking to the future

COVID-19: una mirada al futuro

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Due to its great virulence and ease of transmission, the COVID-19 pandemic has affected the health of many of the people who have contracted the illness, and despite drastic measures being taken to slow the spread by preventing many everyday activities, the number of positive cases and deaths continue to grow. This health crisis - with its unprecedented evolution - has generated lifestyle changes among society on an international scale, reducing the quality of life we enjoyed just a year ago.

We know that this highly contagious and potentially lethal virus is mainly transmitted through respiratory droplets, aerosols and contact, requiring close human contact for its spread. This justifies the measures that have been taken, and until mass vaccination has been deployed, physical distancing is a necessary regulation in place to slow or prevent the propagation of COVID-19.

Among the social and personal repercussions that this pandemic has caused until now, those suffered on a sporting level must be highlighted, revealing (I believe for the first time in the history of humanity) the huge influence that sport has on our lives.

COVID-19 has posed an obstacle to performing sport on an international level, as most organised sporting events have been cancelled or postponed; professional football, basketball, handball and rugby leagues have never suffered such a paralysis, nor have mass participation events such as athletics or youth sports, school or university championships. The sporting restrictions placed on the population - in particular on children and teenagers during the confinement - have resulted in a short and long-term reduction in their physical and mental health, with repercussions still on-going. However, all these decisions, taken on a sporting level to protect the health of athletes and people involved in sport, have been necessary. In the past few months, sports have begun to return, though most events are taking place without spectators, with social distancing measures and with many precautions.

The crisis and economic instability that professional sport is undergoing is also unprecedented. The lack of audiences at competitions has meant that funding has plummeted drastically, leaving club, team and association funds at bare minimum, which is also taking its toll on athletes. These restrictions have forced some professional teams to close completely, encompassing the entire sporting sphere, including technicians, support staff, and sports medicine professionals.

The consequences of this pandemic have just begun to develop, and the most probable outcome is that many will not return to how they were; we cannot imagine what will happen in the near future as everything is still changing.

People linked to the healthcare of athletes (doctors, physiotherapists, podiatrists, psychologists, etc.), just like other healthcare professionals, have had to adapt to the situation we are living in to perform all activities safely. Sports consultancies and medical centres must adhere strictly to the regulations, including the use of face masks, gloves, personal protective equipment that must comply with the UNE-EN 14126:2004 standard, and even remodel working spaces.

Sports Medicine and Sciences professionals are facing an uncertain future, requiring on-going research. We have abundant consensus and protocol documents about many aspects linked to practising safe sport, regarding how athletes should be reincorporated into performing physical exercise and competition sport (Guide to Reincorporation into Sporting Practice in Competition Sport, Guidelines for performing medical examinations on athletes that have suffered an illness, SEMED, CGCOM) after confinement. There are some related studies to the possible side effects associated with the use of face masks, during intensive training, which appear to indicate that a slight increase in CO2 takes place during exhalation (when the N95 mask is used), though despite these repercussions being minimal, more research is required.

We do not know how this pandemic will affect the future of the Sports Medicine Specialisation. Our responsibilities include ensuring safe training sessions and competitions: physical distancing measures, the use of face masks, the use of biomarkers and other diagnostic strategies.

New doors are also opened on a scientific level. Although many research studies have been performed in record time linked to the repercussions of COVID-19 on sports, much more research is required. Evidence about the most effective measures that should be taken is limited, and recommendations require more research. What is evident, is that the pandemic has uncovered the faults and weaknesses in the healthcare system.

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Athletes of all levels that have suffered from COVID-19 to any degree of affectation, must undergo a sporting aptitude medical examination before returning to training, aimed at detecting any emerging post-COVID-19 findings, with particular attention paid to the respiratory and cardiovascular system. An ECG and echocardiogram are recommended, as well as an exertion test, heart MRI scan or heart bio-marker measurements, if required. Depending on the results, a physical exercise programme may be prescribed, aimed at improving cardio-respiratory function.

There is not enough data regarding the degree of affectation of professional athletes that have suffered from COVID-19. Some studies have found up to 10% change in pulmonary function tests at 5-6 months follow up (in patients that required oxygen during acute treatment), and cardiovascular changes have also been discovered, but we do not yet know the long-term after-effects, or if athletes that have undergone the illness have a deterioration in physical, pulmonary, cardiovascular, muscular-skeletal, or nervous system function, or in other vital organs, or reduced quality of life.

Existing data regarding the recovery time needed by an athlete who has suffered pulmonary complications to fully regain respiratory capacity, is insufficient. The same occurs with cardiovascular problems.

In turn, there are many knowledge voids, such as how people should return to sport, and especially, high-performance sport in a safe way, after suffering from the illness. As such, we are still not completely sure if athletes that have been affected by COVID-19 recover their full sporting performance, or if some of this is lost. Nor is there data about whether an early return to intensive sport can hold a greater risk of cardio-respiratory complications, but it is clear that athletes should not train until their symptoms disappear. They should start with low-intensity exercises and make gradual increases under medical surveillance.

How long must we continue taking the careful measures we have adopted to prevent infections? How much longer must personal protection equipment be used? It is possible that these regulations will be in place for a long time.

From this point on, sporting-medical examination protocols will probably have to be changed, and we will have to look for cardiovascular and respiratory repercussions or other side-effects of the COVID-19.

Sport contributes to economic and social development and is a great tool for building bridges between generations and communities. This healthcare crisis has enabled us to gauge a deeper understanding of how physical exercise and sports help us maintain healthy bodies and minds. This could be an opportunity to increase participation in sporting activities, and to reduce the high level of sedentary behaviour that already existed before the pandemic, but which has now increased even further.

The search for the causes of the rapid spread of COVID-19 has led us to reflect upon whether the current model and use of our cities has influenced this in some way, with large agglomerations of people when travelling, on the streets and squares, or in recreational and leisure areas. This negative experience we are undergoing must lead us to create healthier and safer cities, avoiding overcrowding, promoting improved sporting infrastructures, the use of cycle paths, parks and play areas for children (which should be designed to activity, not sitting waiting for someone to move them), pedestrian networks, pathways, etc. In short, we must encourage healthy and safe physical exercise, with outdoor activities aimed at more vulnerable people, ensuring the health and quality of life of the population and increasing healthcare efficiency.

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Original article

The effects of aerobic exercise in water on perceived pain and heart rate variability in women with fibromyalgia

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Summary

Fibromyalgia is a disease characterized by conical pain associated with autonomic dysregulation of the sufferer, without many treatment alternatives. The objective of this study was to find out the relationship between physical exercise in an aquatic environment, pain perception and cardiovascular autonomic control in adult women suffering from fibromyalgia. The sample consisted of 15 women diagnosed with fibromyalgia who participated in 24 40-minute exercise sessions in a water environment. Anthropometric measures, heart rate variability (HRV) and pain perception (PCS) were evaluated in four experimental times (t1, baseline; t2, session 8; t3, session 16; t4, session 24). In addition, the perception of pain was evaluated in each session through VAS. The results show that the perception of pain through VAS decreased when comparing all the means evaluated before and after each session (p <0.05). In the PCS application, a lower Total Pain and Rumination was obtained when comparing t1 with t4. HRV values showed that SDNN and RMSSD were higher after the session, when t4 was compared with t1 (p <0.05). The mean heart rate decreased at the end of the sessions, showing a better adaptation to exercise. The relationship between pain and cardiac measurements was given by a positive correlation in the pain domains recorded before the sessions and the RMSSD and SDNN values. In conclusion, the practice of physical exercise in an aquatic environment would indicate a lower perception of pain and a better cardiac autonomic response in women with fibromyalgia.

Key words:
Fibromyalgia. Pain. Autonomous Nervous System. Exercise.

Efectos del ejercicio aeróbico en agua sobre el dolor percibido y la variabilidad cardiaca en mujeres con fibromialgia

Resumen

La fibromialgia es una enfermedad caracterizada por presentar un dolor cónico asociada a una desregulación autonómica de quien la padece, sin muchas alternativas de tratamiento. Este estudio tuvo como objetivo, conocer la relación existente entre el ejercicio físico en medio acuático, la percepción del dolor y el control autonómico cardiovascular en mujeres adultas que padecen fibromialgia. La muestra se compuso por 15 mujeres diagnosticadas con fibromialgia quienes participaron en 24 sesiones de ejercicio en medio acuático de 40 minutos. Se evaluaron medidas antropométricas, variabilidad de frecuencia cardiaca (VFC) y percepción de dolor (PCS) en cuatro tiempos experimentales (t1, basal; t2, sesión 8; t3, sesión 16; t4, sesión 24). Además, se evaluó la percepción al dolor en cada sesión a través de EVA. Los resultados muestran, que la percepción del dolor a través de EVA disminuyó al comparar todas las medias evaluadas antes y después de cada sesión (p<0.05). En la aplicación de PCS, un menor Dolor Total y Rumiación se obtuvo al comparar t1 con t4. Los valores de VFC mostraron que SDNN y RMSSD fueron mayores después de la sesión, cuando se comparó t4 con t1 (p<0.05). La frecuencia cardiaca media disminuyó al finalizar las sesiones, mostrando una mejor adaptación al ejercicio. La relación entre dolor y medidas cardiacas, estuvo dada por una correlación positiva en los dominios de dolor registrados antes de las sesiones y los valores de RMSSD y SDNN. En conclusión, la práctica de ejercicio físico en medio acuático, indicaría una menor percepción de dolor y una mejor respuesta autonómica cardiaca en mujeres con fibromialgia.

Palabras clave:
Fibromialgia. Dolor. Sistema Nervioso Autónomo. Ejercicio.

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Introduction

Fibromyalgia (FM) is a disabling disease, recognised by the World Health Organisation with code M79.7 of the International Classification of Diseases (ICD -10 CM)[1]. Few studies have been conducted in Latin America to investigate its prevalence. However, in 2005, the Clinical Hospital of the University of Chile estimated that 5.4% of the population suffered from this disease while, at a global level, it is estimated that it affects 5% of the western population and predominantly women[2–5]. Studies have reported that, in Chile, there is an accelerated increase in its diagnosis over the last few decades, which is consistent with other studies that report a similar rise worldwide[2,6].

This disease is characterised by giving rise to chronic pain, fatigue, poor physical functioning, sleep alterations and depression, among other symptoms, leading to a predisposition to develop other diseases such as hypertension, overweight, diabetes[1,6]. These disorders affect the perception of pain and its nervous regulation, to become a cyclical health problem that will increase over time[3,7–13].

One of the key factors in understanding this disease is its direct relationship with the dysregulation of the autonomic nervous system[14]. One of the principal theories on the etiology of the pain associated with this disease specifically indicates that the causal agent is the central dysregulation of the degree of activity of the sympathetic and parasympathetic nervous systems[3,15–18], in other words, a dysautonomia or autonomic dysfunction. This dysregulation is characterised by the hyperactivity of the sympathetic nervous system and the hypoactivity of the parasympathetic nervous system[5,17]. The increased sympathetic activity, characteristic of FM, generates a cyclic condition of stress that has a direct impact on FM sufferers[19], a process that would explain the reduced pain tolerance threshold shown by these individuals. Additionally, these cerebral changes affect other organs such as the heart. Therefore, the measurement of the heart frequency variability (HFV) could serve as an indicator of the sympathetic activity level and, therefore, as a possible indicator of this disease[20], allowing for a more objective evaluation supported by a physiological parameter.

Based on the symptomatology of this disease, aerobic exercise has been studied as a variable that could reduce the perception of pain, reduce fatigue, improve the physical condition, thereby improving the quality of life of individuals[21]. Although many types of exercise stand as viable alternatives to improve the quality of life, for FM there is still no clear relationship between the effects of exercise and autonomic regulation.

Given that the studies are inconclusive on the subject, it is difficult to estimate with certainty, which is the best methodology to promote autonomic changes based on the physical activity performed. In 2004, Gavi, et al., reported that muscle strengthening exercises could reduce the symptoms and improve the quality of life of individuals, yet with no changes to autonomic modulation in fibromyalgia[22]. In contrast, in 2015 Sañudo et al., reported that there were indeed autonomic changes following six months of exercise, directly influencing changes in the levels of anxiety and depression of the subjects[23]. In order to identify these autonomic changes, a validated methodology is the measurement of heart rate variability, which reflects the changes occurring in the heart. These changes are represented by time-domain and frequency-domain measurements, making it possible to estimate the influence of the nervous system on the heart. The consequences of pain include the limitation of physical activity, contributing to the fact that many individuals with FM are overweight[24], associated with reduced heart rate variability and increased sympathetic activity in the heart[25]. All these works evaluate the many factors that could have an impact on each fibromyalgia sufferer, particularly with regard to the autonomic component, affecting the heart. Therefore, the study of pain variables and autonomic control could provide fresh evidence that would serve to better understand the influence of exercise in the treatment of this disease.

The objective of this study was to describe and relate the changes caused by physical exercise in an aquatic environment with regard to the perception of pain and autonomic cardiovascular control through heart rate variability in adult women suffering from fibromyalgia. Although there are currently a number of alternatives for the non-medical treatment.of fibromyalgia, there is little evidence of quantifiable scientific parameters that serve as a reference for the treatment of the disease. Therefore, any new study will prove useful in the pursuit of a better quality of life for these patients.

Materials and method

Participants

25 volunteers selected by non-random accidental sampling took part in this descriptive-correlational study. The inclusion criteria were: female in gender; aged from 30 to 60 years; diagnosed with fibromyalgia by a physiatrist; and receiving no drug treatment that would affect the heart variables or pain-sensitive pathways during the intervention. The study excluded women who were pregnant, with a heart disease, or those whose health was incompatible with the aquatic environment. The study also excluded those participants who did not meet the minimum requirement of 80% attendance at the water exercise sessions. After applying these criteria, the study sample was reduced to 15 participants, who met all the requirements.

The study was conducted in accordance with the Declaration of Helsinki of 1975, revised in 2008, on the ethical principles for medical research involving human subjects. It also complies with the ethical standards of the committee responsible for medical research involving human subjects of the University of Magallanes. All the women were given general information in personal interviews, in which they were able to resolve all concerns. They subsequently signed the informed consent, prior to taking part in this study.

Instruments

Body composition

Bioimpedance served to evaluate the body composition measurements, using the BC-558 Ironman Segmental Body Composition Monitor

(Tanita Ironman, Arlington Heights, IL 60005 USA) to obtain the following data: weight (Kg.), total muscle mass (Kg.), bone mass (Kg.), total body fat (%) and basal metabolic rate (Kcal.).

Pain parameters

In order to analyse the Pain Parameters for each participant, two instruments were used to assess pain perception: Visual Analogue Scale (VAS) and Pain Catastrophizing Scale (PCS)[26].

The Visual Analogue Scale for pain consists of a 10 cm long line of cartoon faces showing different pain intensities. The values range from 0, equivalent to "no pain" and 10 "unbearable pain" (Figure 1).

The Pain Catastrophizing Scale measures how catastrophizing thoughts impact on the experience and perception of pain. This scale includes three areas of multidimensional catastrophizing: Rumination; a feeling of constant concern, *"I can't stop thinking about how much it hurts"* ; Magnification, an exaggeration of the unpleasantness of the pain, *"I worry that something serious may happen"* ; and Helplessness, a loss of hope in achieving something, *"There is nothing I can do to reduce the intensity of the pain".* Furthermore, this scale gives a Total Pain score that can range from 0 to 52 points. The survey comprises 13 items with 5-point scales where 0 is never and 4 is all the time. The highest scores indicate higher catastrophizing levels.

Cardiovascular parameters

To analyse these parameters, Heart Rate Variability (HRV) was measured with the Polar Team2 monitor (Polar®, Finland).

The time-domain parameters considered for the analysis were the Root mean square of successive RR interval differences (RMSSD expressed in ms.) that reflect the parasympathetic influence[27] and the standard deviation of NN intervals (SDNN), which are considered to reflect the total variability, that is the sympathetic and parasympathetic contribution of the autonomic nervous system[28,29] on the heart. Finally, all the data obtained were digitised using the free Kubios HRV® software[30].

Perceived effort

To guide constant work in relation to the exertion of each participant in the course of the study, the 10-point Borg Scale[31] was used. This scale has been designed and is recommended for measuring the intensity of physical exertion involving cardiovascular work during patient rehabilitation. A maximum score of 4 was considered, in order to establish a low-intensity aerobic exercise for participants[31,32].

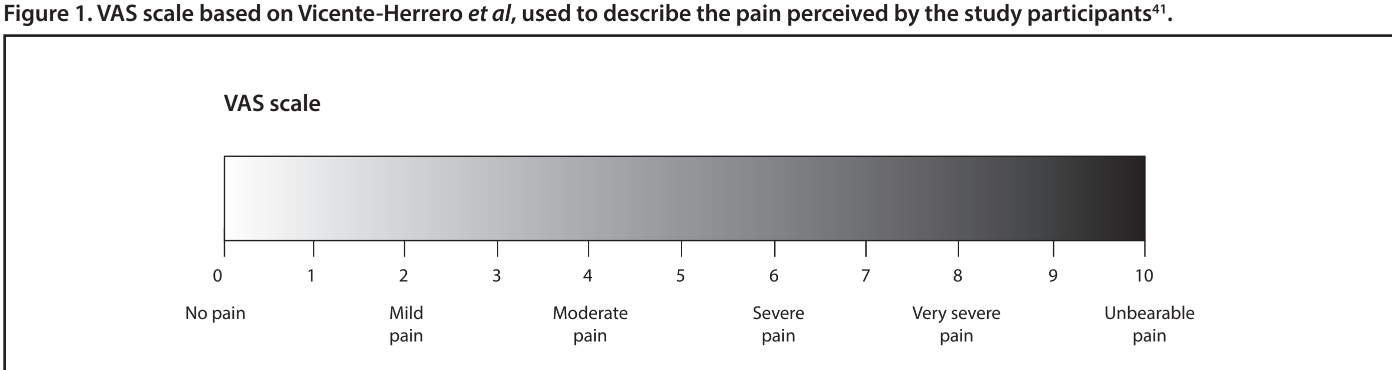
Procedure

Each participant, after voluntarily signing the informed consent, was included in the study. For the assessments, participants were requested not to consume tea, coffee or herbal stimulants and not to have taken medicines or drugs in the 12 hours prior to the assessment. Over a 12-week period, each woman took part in two 40-minute weekly sessions of individual and group exercises in an aquatic environment at a constant temperature of 36 ºC. The sessions were structured as follows: joint mobility and warm-up; work on upper limbs with material that increased water resistance; lower limb exercises with no added weight, giving priority to moving in the water and raising the heart rate yet always maintaining an aerobic estimation of the activity; cooling down exercises in the water. Each exercise was adapted to each patient based on her daily condition, guided by the Borg perceived exertion scale, considering a score of 4 for each low intensity aerobic activity (the total score of the scale considered for this study was 0 to 10).

The assessment of the body parameters and PCS was conducted at 4 different times: t1 or baseline, performed prior to the start of the physical exercise sessions in an aquatic environment; t2, made prior to the 8th training session in an aquatic environment; t3, made prior to the 16th training session in an aquatic environment; t4 made prior to the 24th training session in an aquatic environment. In order to assess each of these parameter, the study followed the internal protocols for each assessment instrument. In order to assess perceived pain, the VAS instrument was administered to participants. This instrument was applied at two different times: the first, 5 minutes before the start of the session and then the second was applied 5 minutes after the end of the exercise, during the 24 sessions.

The HRV assessment was performed twice, at each of the assessment times (t1, t2, t3 and t4). The first was conducted after the administration of the questionnaires and prior to the water aerobic

Figure 1. VAS scale based on Vicente-Herrero *et al*, used to describe the pain perceived by the study participants[41].



session, while the second was conducted at the end of the physical activity session. In the case of t1 (baseline) the assessment was also repeated twice, allowing 40 minutes between each measurement. For the assessment of this parameter, a chest band holding the Polar device was used. The participant was requested to put on this band with the device and then to sit comfortably, with both feet resting on the floor. She was told that she must remain in that position for around 5 minutes in order to reach an at-rest condition. Once the at-rest condition had been reached, the HRV data were then taken for a time of not less than 10 minutes, during which the participants had to stay calm, without talking and without doing anything that could alter their heart rate. In parallel, a visual assessment was made of the participants' breathing rate for greater precision. This was found to be above 12 cycles per minute. The tachograms generated by the Kubios program were visually inspected in order to exclude defects from artefacts and ectopic beats, not exceeding 3% of the data recorded.

Annex 1 outlines the protocol for the collection of the data used in this study.

All the data obtained were digitised in a Microsoft Office Excel 2016 spreadsheet. In order to maintain the privacy of the participants, the data were numbered, in other words an alphanumeric value was assigned to the identity of each subject. This ensured that only the investigator responsible would be able to correlate the results obtained with the identity of the participant.

Statistical analysis

For the statistical analysis, the database was exported to the *Statistical Package for the Social Sciences®* (IBM SPSS) software, version 24. In order to observe the difference between the four assessment times, a paired sample t test was performed for PCS and the Wilcoxon Test for VAS and HRV parameters. The Spearman correlation coefficient was used to determine the relationships between the PCS and HRV variables while descriptive tests were also conducted on the data compiled . All the analyses were made considering a statistically significant value of p<0.05.

Results

In this study the average age of the participants was 47 years (± 8 years). Their anthropometric measurements are shown in Table 1.

The results of the body composition, observed in Table 2, indicate that 12 of the 15 women were either overweight or obese (BMI > 25).

With regard to the perceived pain assessment using VAS, the statistically significant differences are given by greater values at the start than at the end, with positive ranges (Z = -11.265; *p*= 0.001), as observed in Figure 2.

With regard to the rating of pain using the PCS instrument, an analysis was made of the 4 domains assessed. The statistical results show significant differences, as can be seen in Table 3.

With regard to the PCS scores at t4, the scores for Total Pain show a significant difference with *p*=0.048, with gl=14 with regard to t4, while similar statistical characteristics are given for the Rumination score

Table 1 Anthropometric measurements and body composition of the women included in the sample assessed.

	t1 (n=15)	t2 (n=15)	t3 (n=15)	t4 (n=15)
Weight (Kg)	76.5 ± 14.1	76.3 ± 14.4	76.5 ± 13.7	75.5 ± 16.7
BMI	29.1± 4.01	29.8 ± 4.32	29.9 ± 4.42	29.5 ± 4.63
Total muscle mass (Kg)	44 ± 4.66	44 ± 4.64	44.4 ± 4.49	43.2 ± 4.55
Total body fat (%)	38.5 ± 7.22	38.3 ± 7.24	38 ± 7.95	38.3 ± 8.18
Bone mass (Kg)	2.35 ± 0.24	2.35 ± 0.22	2.36 ± 0.21	2.31 ± 0.23
Basal metabolic rate (Kcal)	1418 ± 154	1414 ± 151	1425 ± 143	1391 ± 160

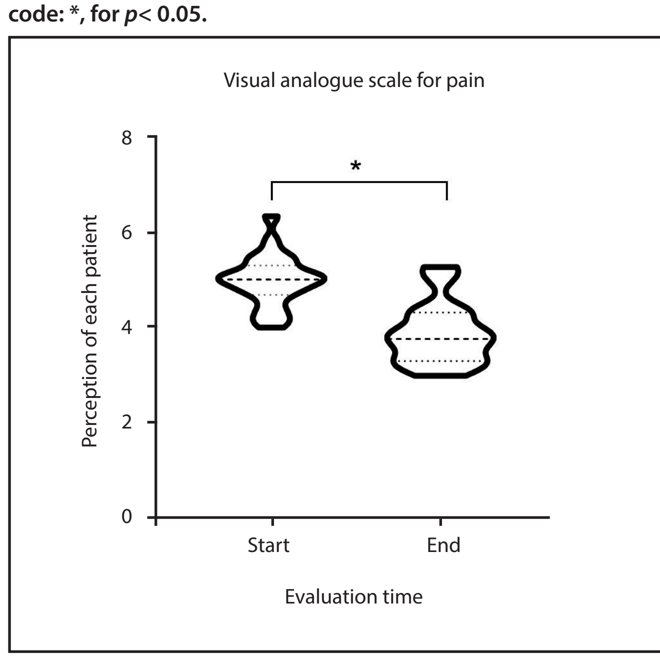
This table shows the ± mean standard deviation from the anthropometric measurements and body composition assessed through the Tanita BC-558 Ironman.

Table 2. Sample classification based on BMI.

Assessment	BMI Range	Prevalence
Healthy	18.5 - 24.9	3
Overweight	25.0 - 29.9	5
Obese	30.0 – 39.9	7

This table created by the authors, shows the distribution of the study participants based on their BMI, following the parameters of the WHO33. Moderate obesity (class I) and severe obesity (class II) are grouped together as a single parameter.

Figure 2. Values for the mean score for the daily VAS record at the start at end of all the exercise sessions in an aquatic environment. The significant differences are described through the following code: *, for *p*< 0.05.



showing *p*=0.049 with the same degree of freedom, as the same study times are compared.

The results of the cardiovascular measurements for the different assessment times are given in table 4. It can be seen that significant differences mainly arise when comparing t1 and t3 with the fourth assessment time (t4). Furthermore, it is possible to observe a progressive reduction in the mean heart rate (HR) of the participants, as the assessments progress, both at the start and end of the intervention. Although this reduction is not significant, it can be explained by an improvement in the physiological adaptation to exercise.

By relating the PCS and VFC variables, it was possible to observe that at t2 there was a moderate positive correlation between the RMSSD at the start and Magnification ($r_{(s)}$= 0.591, R^2= 0.34 *p*= 0.020), and RMSSD with Helplessness ($r_{(s)}$= 0.514, R^2= 0.26 *p*= 0.050). Analysing t3, moderate positive correlations were observed between the start measurements for Rumination with SDNN ($r_{(s)}$= 0.533, *p*= 0.041) and Rumination with RMSSD ($r_{(s)}$= 0.522, *p*= 0.046). While for t4 a moderate positive correlation was observed for the start values of SDNN with Total Pain ($r_{(s)}$= 0.599, *p*= 0.018) and SDNN with Helplessness ($r_{(s)}$= 0.558, *p*= 0.031), while RMSSD did so with Magnification ($r_{(s)}$= 0.516, p= 0.049).

When comparing the set of HRV start and end values, no significant differences were obtained between the SDNN values (Z= -1.406; *p*=0.16), however the RMSSD values did show a significant difference (Z= -2.506; *p*=0.012), showing that the output ranges were greater than the input ranges. The mean heart rate also showed a significant difference between both periods (Z = -4.461; *p*= 0.012), indicating that the output ranges were lower than the input ranges.

Table 3. Scores for the Pain Catastrophizing Scale (PCS).

	t1 (n=15)	t2 (n=15)	t3 (n=15)	t4 (n=15)
Total pain	25.7± 13.91	18.7 ± 13.4	19.1 ± 11.8	15.7 ± 13.1
Rumination	9.13± 5.29	6.20 ± 4.52	7.13 ± 4.76	5.47 ± 4.76
Magnification	5.67± 3.64	4.13 ± 3.62	3.60 ± 2.77	3.60 ± 3.18
Helplessness	10.9± 6.10	8.40 ± 5.73	8.40 ± 5.15	6.67 ± 5.59

This table shows the ± mean standard deviation for each PCS catastrophizing area considered in this study: Rumination; Magnification; Helplessness; Total Pain. The significance is given by values of p<0,05 and it is structured according to the following nomenclature: *in relation to t1.

Table 4. Measurements of the heart rate variability for the different experimental times.

	t1 (n=15)	t2 (n=15)	t3 (n=15)	t4 (n=15)
SDNN (ms)				
Input	16.9± 8.69	15.1 ± 8.28	16.5 ± 7.18	22.8 ± 11.7
Output	14.0± 7.18	16.2 ± 7.89	13.6 ± 4.55	22.9 ± 11.7[ae]
RMSSD (ms)				
Input	13.5± 6.62	11.9 ± 7.25	13.3 ± 6.92	19.9 ± 14.5a
Output	12.3± 4.68	10.8 ± 5.30	9.65 ± 3.32	18.9 ± 11.9[ae]
Mean HR (BPM)				
Input	89.2± 12.5	81.6 ± 13.9	84.1 ± 11.2	82.7 ± 8.64
Output	99.9± 30.3	94.9 ± 26.3	93.0 ± 14.2	81.3 ± 9.56[ae]

This table shows the ± mean standard deviation for the HRV values considered in this study. SDNN corresponds to the standard deviation of NN intervals shown in milliseconds (ms), RMSSD corresponds to the root mean square of successive RR interval differences expressed in milliseconds (ms), mean HR, corresponds to the mean heart rate of patients, expressed in beats per minute (BPM). The significance is given by values of p<0,05 and it is structured according to the following nomenclature: a in relation to t1; e in relation to t3.

Discussion

Fibromyalgia (FM) predisposes the patient to develop different diseases that mainly affect the perception of pain and its nervous regulation, causing a cyclic health problem that constantly affects the quality of life of individuals[2,3,13]. Evidence for non-medical treatments of FM point to different therapies that primarily seek to reduce the perception of pain in patients, covering activities such as cognitive-behavioural therapy, acupuncture, mindfulness, massage, hydrotherapy, among others[12,33,34]. Scientific evidence shows that low-intensity physical exercise and, in particular, exercise performed in an aquatic environment, gives the best results in the management of symptomatology[9,13,35]. However, chronic pain is one of the key factors limiting the performance of physical exercise in patients, showing a trend to be overweight and obese with BMI values of more than 25, a characteristic that was also observed in the participants of this study [8,10,11].

The VAS results observed, show a reduction in the perception of pain when comparing the before and after data of the exercise session. These results are similar to those found in other studies in an aquatic environment where it was observed that, through bio-dance, it was possible to reduce the feeling of pain following the exercise sessions[35], as well as through physical rehabilitation therapy in water[8].

When using the PCS to assess the pain, it was interesting to observe a trend towards a reduction in the perception of pain as the exercise sessions progressed, in each domain covered by the test. t4 shows a significant reduction in the feeling of constant concern about pain, as well as in the overall perception of pain, in relation to the baseline time (t1). Although not statistically significant, the domains of Magnification and Helplessness also show a decreasing trend as the exercise sessions progress. These results would indicate that therapy based on physical activity in an aquatic environment would be appropriate for these patients and could have a positive influence on the perception of pain and contribute to the patients' quality of life. However, one limitation of this study was to discern whether the wellbeing achieved through exercise could be affected by the social wellbeing inherent in this type of activity. We therefore consider that future studies should include an assessment of the impact of social environment on physical activity, given that it could also be an influencing factor in the participants' perception of pain.

With regard to the autonomic regulation (SDNN), the values were seen to be lower than those found in a population of similar characteristics, but without fibromyalgia[36]. However, exercise tends to improve the values as the sessions in the aquatic environment progress, particularly with regard to the heart rate response after completing the session. The progressive increase in the autonomic response was also observed in the parasympathetic response of the patients. The RMSSD values are also lower than for a population without the associated disease[36], although there was a significant increase in relation to the baseline values as the sessions progressed, both before and after the exercise session. Similar effects on autonomic modulation were not observed in patients with fibromyalgia and subjected to strength training[37], presumably due to the intensity of the exercise used, while treatments through hydrotherapies have been shown to be the most effective in the nonlinear improvement of HRV in these patients[38]. We hypothesized that the changes perceived could be due to a better adaptation to low-intensity physical exercise that is adjusted to the physiological possibilities of the patient, allowing the patients to progress in line with their own possibilities[39]. Our evidence shows that, when comparing the different measurements for the mean HR at the start, no great changes can be seen, contrary to what was observed with the mean HR at the end. This demonstrated that, with the same effort, which may have been extremely tiring at the beginning, at the end of the intervention it was not so tiring. Therefore, these values imply that exercise would not only permit a reduction in the possibility of suffering FM-related diseases but would also improve the autonomic and cardiovascular regulation of the exercisers.

When relating the values for heart rate and pain, relationships were found between the experimental exercise times but not at the baseline time. The parasympathetic response represented by RMSSD was positively related to PCS pain domains at t2, t3 and t4, always at the start of the session. Similar values were obtained by positively relating the SDNN values for autonomic regulation at the start of t3 and t4 with the PCS pain domains. Based on the fact that PCS measures the perception of pain during the entire day and that the HRV figures only represent the time of measurement, it could be interpreted that a greater pain domain, predominant in the daily perception of a patient with FM, permits a greater autonomic response to exercise. We consider that this relationship is given for two reasons. Firstly, exercise permits a greater autonomic response to feelings of pain, that is, the individual has a greater response to what he/she perceives as pain and, therefore, a greater tolerance. Secondly, the practice of group activities has additional benefits to those obtained when exercising alone, due to the fact that the socialisation process helps in recovery, by increasing motivation and, consequently, adherence to the physical activity, as shown by other studies[34,40].

Each of these findings describes the changes that could affect FM sufferers and their response to perceived pain and autonomic heart rate regulation. The results obtained allow us to be confident that heart rate variability could be an objective parameter for monitoring the progress of palliative therapies for patients with fibromyalgia and it could be included as a representative assessment of the autonomic heart rate modulation for this disease. Although we are aware that further studies need to be made, the finding of fresh evidence on the nervous and physiological mechanisms associated with this disease makes it possible to have more alternatives for its diagnosis and, consequently, new strategies for the treatment of the symptomatology of FM, which is extremely important in terms of relieving the constant pain experienced by those diagnosed with FM.

The strengths of the study include: a) the importance of characterising patients with fibromyalgia; b) the assessment of therapies that are currently being conducted in an aquatic environment, as part of the treatment of this disease; c) the type of measuring instruments applied, considering validated questionnaires and objective measurements that could be used in other therapy contexts with patients with fibromyalgia. The main limitations were: a) continuity and strict attendance of each of the sessions; b) the number of participants, which could affect the results. Nevertheless, this study reports new information on little-studied variables that could affect the treatment of patients with fibromyalgia.

Conclusions

This study would indicate that the practice of aerobic exercise through a program of 24 sessions in an aquatic environment would be associated with a reduction in the perceived pain and a greater autonomic regulation, in women diagnosed with fibromyalgia.

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Conflict of interests

The authors have no conflict of interest at all.

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Original article

Comparison of performance-related responses to an endurance running training between untrained men and women

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Summary

Introduction: The adherence on endurance running events is increasing exponentially around the World in both previously untrained men and women, thus the incorporation of more appropriate and individualized training approaches are required. It is not known if male and female untrained runners differ in the responses to endurance running training on performance-related variables.
Objective: We aimed to compare performance-related responses to an endurance running training program between untrained men and women.
Material and method: Sixteen participants (8 men and 8 women) were paired in the baseline by age, body mass index, and percentage in which time to complete 5 km (t_{5km}) represented from the average of best 50 runners t_{5km} in the greatest regional race for each gender. They completed an 11-week training protocol alternating high-intensity interval training and moderate-intensity continuous running, three times per week, in a running track. In the week 1 and 11 of the protocol (baseline and post-training weeks), peak running velocity at treadmill (V_{peak}), time limit (t_{lim}) at 100% V_{peak}, t_{5km}, and the index rMSSD of heart rate variability (HRV) were measured for cardiac autonomic function. Baseline gender-differences were accounted in the analysis.
Results: Male and female significantly improved V_{peak} (9.4 ± 1.7% and 7.2 ± 1.7%, respectively) and t_{5km} (-13.0 ± 1.8% for both), and no gender-related differences for the adaptations in these two variables were observed. The t_{lim} at 100% V_{peak} and rMSSD did not change across the training period in both groups. Percentage of change for men was "moderately" higher than for women for rMSSD (33.4 ± 40.7% vs. 13.9 ± 21.4%), although statistically non-significant.
Conclusion: Men and women responses to training were similar with regards to their running performance and cardiac autonomic function. With regards to practical application, V_{peak} and its t_{lim} can be applied in exercise settings for the prescription of moderate- to high-intensity running training with similar benefits regardless of the biological gender.

Key words:
Athletic performance. Exercise. Running. Gender.

Comparación de respuestas relacionadas con el rendimiento a un entrenamiento de carrera de resistencia entre hombres y mujeres no entrenados

Resumen

Introducción: La adherencia a los eventos de carreras de resistencia está aumentando exponencialmente en el mundo entre hombres y mujeres no entrenados, y por eso es necesaria la incorporación de un entrenamiento individualizado y apropiado. No se sabe si los hombres y mujeres desentrenados en carrera difieren en las respuestas al entrenamiento de carrera de resistencia en relación a las variables relacionadas con el rendimiento.
Objetivo: Nuestro objetivo fue comparar las respuestas del rendimiento durante un programa de entrenamiento de carrera de resistencia entre hombres y mujeres no entrenados.
Material y método: Dieciséis participantes (8 hombres y 8 mujeres) fueron emparejados en la línea de base por edad, índice de masa corporal y porcentaje del tiempo para completar los 5 km (t_{5km}) representados por el promedio de los t_{5km} de los 50 mejores corredores obtenidos en las mejores carreras regionales (para cada género). Los participantes completaron un protocolo de entrenamiento de 11 semanas alternando entrenamiento de intervalos de alta intensidad con entrenamiento continuo de intensidad moderada, tres veces por semana, en una pista de atletismo. En las semanas 1 y 11 del protocolo (línea de base y semana posterior al entrenamiento), se midieron la velocidad máxima de carrera en la cinta (V_{peak}), el tiempo límite (t_{lim}) en V_{peak}, t_{5km} y el índice rMSSD de la variabilidad de la frecuencia cardíaca (VFC) para la función cardíaca autónoma. En los análisis se consideraron las diferencias entre géneros en la línea de base.
Resultados: Hombres y mujeres mejoraron significativamente la V_{peak} (9,4 ± 1,7% y 7,2 ± 1,7%, respectivamente) y el t_{5km} (-13,0 ± 1,8% para ambos), y se observaron diferencias relacionadas con el género para las adaptaciones en estas dos variables. El t_{lim} en V_{peak} y el rMSSD no han cambiado durante el período de entrenamiento en ambos grupos. El porcentaje de cambio en los hombres fue moderadamente superior al de las mujeres para la rMSSD (33,4 ± 40,7% vs. 13,9 ± 21,4%), aunque no fue significantemente diferente.
Conclusión: Las respuestas de hombres y mujeres al entrenamiento fueron similares considerando el rendimiento de carrera y la función cardíaca autónoma. En relación con la aplicación práctica, V_{peak} y su respectivo t_{lim} se pueden aplicar en programaciones de ejercicio para prescribir intensidades de entrenamiento de carrera con intensidades moderadas a altas y con beneficios similares, independientemente del género.

Palabras clave:
Desempeño atlético. Ejercicio. Carrera. Géneros.

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Introduction

Running is one of the most common types of endurance exercise and the popularity of this activity has increased exponentially in the last few decades[1,2], which can be seen by the number of finishers in the 20 largest road races in the world that doubled in an 11-year period (from ≈ 866.000 to 1.600.000 finishers)[3]. Both men and women have increased their adherence to endurance running events in recreational level with participation numbers never seen before[4,5]. The higher rates of adherence are followed by significant improvements in performance, as the average finishing time of the top 100 and 1000 men and women in traditional 10-km road running races has previously shown to significantly decrease annually[4].

The improvements in running performance are likely related to greater engagement in endurance training routines as well as the incorporation of more appropriate and individualized training approaches that increase the magnitude of benefits (*e.g.*, high-intensity interval trainings and their potential variation and strength muscular training)[6-10]. This training approach is capable of increasing markers of aerobic fitness (*e.g.*, $\dot{V}O_{2max}$)[11], which are expected to reduce risk of all-cause mortality and cardiovascular mortality[12]. Different running training programs have been developed[13-16] and they usually combine moderate-intensity continuous training (MICT) and high-intensity interval training (HIIT)" More interestingly, these training regimens have been proven effective not only for the highly athletic population, but also in untrained and moderately-trained ones[6,13,17].

HIIT seems to contribute to improve aerobic energy metabolism and promote neuromuscular, cardiovascular and respiratory changes[8] that will benefit physiological markers, such as cardiac autonomic function and aerobic power[18], as well as endurance performance[17]. However, women may present physiological disadvantages when compared to men, such as lower systolic volume and cardiac mass, lower lungs, and are more prone to arterial desaturation when performing high-intensity exercise[19,20]. Additionally, women present smaller muscle cross-sectional area[21] and lower glycolysis rates in type I muscle fibers[22], which result in lower blood lactate concentrations during sprint exercise[23]. On the other hand, women showed higher aerobic participation in sprint exercise than men[8].

Together, these evidences suggest that men and women may metabolically and muscularly differ in their responses to sprint/HIIT[8,22], and these differences could play a role on physiological markers of aerobic fitness (*e.g.,* $\dot{V}O_{2max}$). However, a few studies with untrained sedentary populations showed that men and women improved $\dot{V}O_{2max}$ similarly after aerobic training with HIIT incorporated[11,24]. Despite these interesting findings, to the best of our knowledge, differences between male and female in the responses to endurance running training on performance-related variables (*e.g.,* time trials, the maximal velocity at incremental running test) are poorly understood[8]. Investigations on this topic are further required in a protocol combining HIIT with MICT, given these two strategies are very likely the most popular ones adopted in endurance exercise settings[25] and have been shown to be capable of improving 5-km running performance[26]. A comparison between men and women after this type of aerobic training could improve the individualization of training regimens[24].

Thus, this study aimed to compare performance-related responses ([V_{peak}], [t_{lim}], [t_{5km}] and [HRV]) to an endurance running training program between untrained men and women. The training sessions consisted of MICT and HIIT. We hypothesized that there are no differences in endurance running training changes on performance-related markers between males and females, considering that changes in $\dot{V}O_{2max}$ did not differ after aerobic training between genders[1,24].

Material and method

Participants

The study was based on a quasi-experimental pre-post test design. Firstly, the recruitment of participants was carried out by disseminating the study through electronic means and direct contact. Thus, sixteen untrained participants (8 male and 8 female) aged between 20 and 35 years participate in this study. The inclusion criteria were to be an untrained who had never engaged in systematic running training program with a coach and individualized running training prescription and be aged between 20 to 35 years old. With regards to the exclusion criteria, the individuals were excluded if they reported to use regular pharmacological agents or nutritional supplements; smoker, diabetic, hypertensive, asthmatic and/or present any cardiovascular disease; body mass index (BMI) ≥ 30 $kg \cdot m^{-2}$; and were engaged in other systematic exercise training. Prior to testing, all participants signed the informed consent form to participate in the study. All procedures and test protocols were explained individually for each participant, and were in accordance with the Declaration of Helsinki. The protocol was approved by the Local Human Research Ethics Committee (#623.581/2014; #409.162/2013) and appropriate standards for human experimentation have been followed.

Men and women were matched in the baseline for the following characteristics: age, BMI, and percentage in which time to complete 5 km (t_{5km}) represented from the average of best 50 runners t_{5km} in the greatest regional race for each gender.

Experimental design

This was an 11-week protocol with eight weeks of endurance running training (from week 2-5 and week 7-10) and three weeks of exercise testing (week 1 for baseline tests, week 6 to update exercise prescription and week 11 for post-training tests). The training program consisted of sessions with MICT and HIIT. Prior to assessments, it was performed a resting and maximal exercise electrocardiogram and echocardiogram by a cardiologist to follow local recommendations prior to engaging in high-intensity exercise training. Both men and women performed a continuous incremental test under laboratory conditions (temperature = 20–22 °C and relative humidity = 50–60%) on a motorized treadmill (Inbramed Super ATL®, Porto Alegre, Brazil) to determine V_{peak}. The second test consisted on a time limit (t_{lim}) at 100% V_{peak}, and the third trial was a 5-km running performance performed in outdoor running track. These evaluations were performed in a maximum period of seven days and separated from each other by 48 h to ensure the recovery of the participants[27]. Furthermore, cardiac autonomic function by HRV was evaluated pre- and post-training for all participants. Participants were instructed to attend the testing sessions well rested, nourished, hydrated and wearing comfortable clothing. Furthermore, they were also instructed to avoid eating 2 h before the tests, to abstain from caffeine and alcohol, and to refrain from strenuous exercise for 24 h before testing.

After baseline evaluations men and women performed the exact same standardized training protocol. Assessments and training protocol are described below.

Assessments

Cardiac autonomic function evaluated by heart rate variability (HRV)

The rate-to-rate (R-R) intervals were monitored for 5 minutes, starting in seated position (2-min) and then in standing position (3-min); only the 3 minutes in the standing position were considered in the analysis[28]. We chose this position to avoid possible saturation of HRV, expressed as unchanged or even decreased HRV despite increased cardiac vagal outflow, which is susceptible at low heart rate (HR) levels[29]. Moreover, this position seems to be more suitable to long-term changes on HRV *(i.e.*, 24 and 48 h), favoring HRV application in exercise training settings[27]. Participants were instructed to remain quiet, with eyes open, and to breathe spontaneously over the data acquisition period[30,31]. We used a HR monitor (Polar®, RS800cx, Kempele, Finland) previously validated for this purpose[32]. Ectopic, missed or aberrant values were identified and excluded[33]. R-R intervals data was downloaded the software (Polar Pro Trainer®) and expressed in milliseconds to be analyzed by Kubios® HRV analysis software (Department of Applied Physics, University of Eastern Finland, Kuopio, Finland). The R-R intervals were analyzed using the time-domain index square root of the mean of the squares of successive R-R intervals differences (rMSSD)[13,29,34].

Peak running velocity (Vpeak) at treadmill

The V_{peak} was measured at week 1 and week 11 of the protocol to assess training effects and at week 6 to update prescribed training intensities. After warming-up walking for 3 min at 6 km•h^{-1}, the protocol initiated with a treadmill velocity of 8 km•h^{-1}, followed by an increase of 1 km•h^{-1} at each successive 3-min stage until volitional exhaustion (*i.e.,* participant was unable to continue running)[35,36] and when the two the following criteria were met: (1) maximum HR (HR_{max}) ≥ 100% of endurance-trained age-predicted HR_{max} using the age-based "206 – 0.7 × age" equation[37] and (2) maximum RPE (RPE_{max}) ≥ 18 in the 6–20 Borg scale[38].The incline gradient was set at 1%[39]. Consistently across each trial, participants were verbally encouraged, to invest maximum effort.

Before testing, participants were familiarized with the 6–20 Borg scale[38], which was used to determine the rating of perceived exertion (RPE) during the last 15 seconds of each stage and at perceived exhaustion. The highest RPE value was considered the maximal RPE (RPE_{max}). HR was also measured at the last 15 seconds of each stage of the tests (Polar® RS800sd, Kempele, Finland) and HR_{max} was defined as the highest HR value recorded during the test.

The V_{peak} was defined as the velocity of the last complete stage added to the multiplication of the velocity increment by the completed fraction of the incomplete stage, calculated according to the equation[40]: $V_{peak} = V_{complete} + (Inc \times t/T)$, in which '$V_{complete}$' is the running velocity of the last complete stage, Inc the velocity increment (*i.e.*, 1 km•h^{-1}), 't' the number of seconds sustained during the incomplete stage, and 'T' the number of seconds required to complete a stage (*i.e.*, 180 s).

Time limit (t_{lim}) at V_{peak}

After a 15-min warm-up at 60% V_{peak}, the running velocity in the treadmill was increased (over 6 seconds) to the individual's V_{peak}[41]. The incline gradient was set at 1%[39] and participants were also encouraged to provide their maximal effort. The result obtained in the t_{lim} test was the test duration (min) without considering the warm-up. This variable was measured at week 1, 6 and 11 of the protocol to assess training effects and for the prescription of the duration of the series and intervals during HIIT sessions.

5-km running performance

It was completed as a field test to verify the time to complete a 5-km running performance (t_{5km}). This took place on a 400-m running track after 10 minutes of warm-up. The warm-up included 5-min jogging at a self-selected intensity and 5-min stretching.

Diary of symptoms related to pre-menstrual syndrome (PMS)

Women were instructed to provide information daily regarding emotional and physical symptoms related to PMS that were based on the criteria established by the American College of Obstetricians and Gynecologists[42]. Given that the diagnosis of PMS requires a long follow-up period to ensure the symptoms are consistently present (*e.g.*, at least three cycles in a row)[42], we classified women as presenting or not presenting symptoms related to PMS. In brief, when the subject presented a combination of at least one emotional symptom and one physical symptom in the five days prior to menstruation, that were not observed in the follicular period (from the sixth to the tenth day of the menstrual cycle), PMS was noted[42].

Endurance running training

Training sessions were performed on a 400-m running track during the afternoon and evening due to the availability of the participants on Mondays, Wednesdays, and Fridays. If for any reason they missed a training session, they were re-scheduled for another weekday (usually Tuesday or Thursday) in order to perform at least 90% of the training sessions (*i.e.,* at least 22 of the 24 training sessions prescribed). Participants were asked to do their training and subsequently testing at a similar time each day to avoid circadian cycle influence.

Training sessions consisted of MICT and HIIT. MICT and HIIT were both performed in the first (weeks 2 to 5) and last (weeks 7 to 10) training weeks. The MICT and HIIT were prescribed based on of V_{peak} and t_{lim} at 100% V_{peak} determined during pre-training (week 1) and the exercise intensity was readjusted at week 6 (Table 1)[11,24]. Training sessions were preceded by a 15 min warm-up, with 5 min of low self-selected intensity running, 5 min of stretching exercises, and 5 min of running at 60% V_{peak}. After each session, participants had 10-15 minutes of cool-down. In total, both groups of participants performed 24 training

Table 1. MICT and HIIT used during training sessions for both groups.

	1st four weeks of training
MICT	30 ± 2.5 minutes at 75 ± 4% of V_{peak}
HIIT	*X*[a] series at 100 ± 2% of V_{peak} with duration of 60% of t_{lim} and the same interval (1:1)
	2nd four weeks of training
MICT	40 ± 2.5 minutes at 75 ± 4% of V_{peak}
HIIT	*X*[a] series a 100 ± 2% of V_{peak} with duration of 60% of t_{lim} and the same interval (1:1)

[a] The number of series of each participant was adjusted for a duration of 30 ± 2.5 minutes (in the 1st four weeks of training) and 40 ± 2.5 minutes (in the 2nd four weeks of training).

HIIT: High intensity interval training; MICT: moderate-intensity continuous training.

sessions on non-consecutive days over a period of eight weeks (weeks 2-5 and weeks 7-10). They completed eight weeks of training with MICT and HIIT training every other day. All training sessions were monitored by session-RPE and training load was quantified by multiplying the whole RPE using the 10-point scale (CR-10) by its duration (min)[43].

Statistical analysis

The Statistical Package for the Social Sciences 17.0 software (SPSS Inc., United States) was used in the analysis. Data were presented as means ± standard deviations (SD). Normality was tested with the Shapiro–Wilk test. Group comparisons at baseline were performed *t* tests for independent samples according to normality test results. The training adaptations (i.e., Week 1 *vs*. Week 11) were assessed using paired *t*-test for each gender. Gender differences in the variation between week 1 *vs.* week 11 were tested with univariate ANOVA and ANCOVA (controlling by the baseline values when baseline between-group significant differences were observed). Statistical significance was set at $P < 0.05$. In addition, effect size (ES)[44] and confidence intervals (CI) were used to determine the magnitudes of differences between groups (Hedges' g) for training adaptations. The threshold values for ES were: < 0.2 (trivial), 0.2 to < 0.6 (small), 0.6 to < 1.2 (moderate), ≥ 1.2 (large)[45].

Results

Baseline comparison between men and women

With regards to the matching parameters for men *vs*. women, no differences were found to age (male: 26.6 ± 5.0 years; female: 26.3 ± 3.2 years; $P = 0.853$), BMI (male: 25.8 ± 3.0 kg•m^{-2}; female: 22.8 ± 4.8 kg•m^{-2}; $P = 0.157$) or percentage in which t_{5km} represented from the average of best 50 runners t_{5km} in the greatest regional race for each gender (male: 148.9 ± 27.7 %; female: 160.7 ± 24.9 %; $P = 0.385$).

Training loads measured by session-RPE were not different between groups for both MICT (male: 299 ± 113.4 AU; female: 280.8 ± 68.5 AU; $P = 0.703$) and HIIT (male: 345.6 ± 101.0 AU; female: 331.0 ± 73.0 AU; $P = 0.747$). The cardiac autonomic function (male rMSSD: 21.9 ± 6.2 ms; female rMSSD: 24.5 ± 10.3 ms; $P = 0.563$) and t_{lim} at V_{peak} (male: 6.3 ± 0.7 min; female: 5.2 ± 1.3 min; $P = 0.054$) were also not different between genders. However, the t_{5km} (male: 28.1 ± 3.0 min; female: 36.9 ± 5.7 min; $P = 0.002$) presented higher values in women while V_{peak} (male: 13.2 ± 0.9 km•h^{-1}; female: 36.9 ± 5.7 km•h^{-1}; $P = 0.001$) was higher for men.

Responses to endurance running training

Male and female significantly improved V_{peak} (male: 9.4 ± 1.7 %; female: 7.2 ± 1.7 %) and t_{5km} (men: -13.0 ± 1.8 %; female: -13.3 ± 1.8 %). No gender-related differences for the adaptations in these two variables were observed.

The t_{lim} at 100% V_{peak} and rMSSD did not change across the training period in either men and women. Percentage of change for men was "moderately" higher than for women for rMSSD, although not significantly different (confidence intervals crossing "0" for both ANOVA and ES). Mean and standard deviation as well as inferential analyses are presented in Table 2.

Symptoms related to pre-menstrual syndrome (PMS)

The results concerning the frequency of women who presented symptoms related to PMS, from the eight women assessed, three presented emotional and physical symptoms during pre-menstrual phase

Table 2. Peak running velocity (V_{peak}), time limit at peak running velocity (t_{lim} at 100% V_{peak}), time to complete the 5 km (t_{5km}), and square root of the mean of the squares of successive R-R intervals (rMSSD) differences pre and post endurance running training program in male and female.

Variable	Male (n = 8)		Variation (%, 1 × 11)	Female (n = 8)		Variation (%, 1 × 11)	Difference (95% CI) (Male *vs* Female)	ES (95% CI - clssification) (Male *vs* Female)
	Week 1	Week 11		Week 1	Week 11			
V_{peak} (km•h^{-1})	13.2 ± 0.9	14.3 ± 0.9*	9.4 ± 1.7#	10.6 ± 1.5	11.5 ± 1.5*	7.2 ± 1.7#	2.2 (-4.0; 8.3)	-0.03 (-0.89; 0.85 - trivial)
t_{lim} at 100% V_{peak} (min)	6.3 ± 0.7	6.7 ± 0.5	6.7 ± 17.6	5.2 ± 1.3	5.6 ± 1.6	10.7 ± 27.7	-4.1 (-28.9; 20.8)	-0.18 (-1.04; 0.77 - trivial)
t_{5km} (min)	28.1 ± 2.9	24.5 ± 2.4*	-13.0 ± 1.8#	36.9 ± 5.7	31.9 ± 5.4*	-13.3 ± 1.8#	0.3 (-6.2; 6.9)	-0.10 (-0.99; 1.35 - trivial)
rMSSD (ms)	21.9 ± 6.2	28.7 ± 11.0	33.4 ± 40.7	24.5 ± 10.3	27.0 ± 8.9	13.9 ± 21.4	19.6 (-15.9; 55.1)	0.63 (-0.85; 2.51 - moderate)

ES: effect size; rMSSD: square root of the mean of the squares of successive R-R intervals differences; t_{lim} at V_{peak}: time limit at peak running velocity in the treadmill; t_{5km}: time to complete 5 km; V_{peak}: peak running velocity.
*$P < 0.05$ Week 1 *vs*. Week 11.
#Variation (means and standard error) was corrected by the baseline values (covariate) for these variables.

in two different cycles. When the presence or not of PMS was applied in our analysis to control changes after the running training program, no influence in the results was observed ($P > 0.05$; unpublished data).

Discussion

The present study aimed to compare performance-related responses to an endurance running training program (*i.e.*, with MICT and HIIT sessions) between untrained men and women. The main finding was that the responses to endurance running training showed to be similar between men and women. Percentage of change for men was "moderately" higher than for women for rMSSD, although statistically non-significant (confidence intervals crossing "0" for both ANOVA and ES). The non-difference between genders confirms our hypothesis.

These results are similar to the ones observed by de Prada *et al.*[24] who showed that women and men improved similarly after a 16-week, 3 days/week, high-intensity interval training program in markers of aerobic fitness (*e.g.*, oxygen uptake efficiency slope, VO_2 at ventilatory threshold, VE/VCO_2 slope and $\dot{V}O_{2max}$). Metcalfe *et al.*[11] investigated the differences between sedentary men and women with regards to $\dot{V}O_{2max}$ changes after a 6-week reduced-exertion HIIT and found that both genders increased in similar magnitude this physiological variable.

While de Prada *et al.*[24] and Metcalfe *et al.*[11] focused on physiological markers of aerobic fitness, our outcomes are indices of running performance, such as V_{peak}, t_{lim} at 100% V_{peak} and t_{5km}. The V_{peak} is correlated with $\dot{V}O_{2max}$[46] and in fact was previously associated with the occurrence of $\dot{V}O_{2max}$[47]. In untrained and moderately-trained individuals, $\dot{V}O_{2max}$ is also a predictor of performance in endurance races (*e.g.*, from 3 km to ultramarathons)[46,47]. Nevertheless, V_{peak} would be a preferable predictor of performance in endurance events[35,36,46], as it accounts for the interaction between $\dot{V}O_{2max}$ and running economy[17].

The non-difference between genders could be because the HIIT planned was not intense enough to allow differences between women and men to be observed. Women have higher chances of presenting arterial desaturation when performing higher-intensity exercise[19], and sprint exercises (*i.e.,* higher than 100% V_{peak}) can exacerbate differences between men and women in acute physiological responses, such as lower glycolysis rates in type I muscle fibers[22] and lower blood lactate concentrations[23]. However, Astorino *et al*[48] did not find differences between genders in the responses to 2-3 weeks of sprint exercise training (*i.e.*, 4 bouts of Wingate test separated by 5-min of active recovery) on $\dot{V}O_{2max}$, fatigability, substrate oxidation, and voluntary force production of the knee flexors and extensors, so this factor should not be influencing our findings.

Another aspect that could lead to different responses between men and women is the baseline performance differences between genders. Men had better results in the t_{5km} and V_{peak} than women in this timepoint, which is expected if they are matched by their training levels (*i.e.*, similar performance when compared to highly-trained runners of their gender)[24]. This is due to their physiological advantage compared to women. For instance, men present higher systolic volume and cardiac mass, greater lungs, and higher absolute and relative $\dot{V}O_{2max}$[11,19,20]. As men have a higher capacity to generate muscle power during physical efforts, they could have greater aerobic fitness benefits[24]. However, this was not observed in the present study and the assessed variables presented no differential progression with the training program. Similar results were found in other populations, such as young and physically active[48], sedentary middle-aged[9], and older healthy but sedentary populations[49].

Our study did not find any significant gender-related differences in the rMSSD changes over the course of a running training program (confidence interval crossed "0" in the ANOVA and ES). However, the ES value (0.63) suggested a moderately greater improvement in men compared to women. The rMSSD is an HRV index related to cardiac autonomic function and changes in this variable represent adaptations in the parasympathetic activity[29]. Kiviniemi *et al.*[28] did not find any significant changes after 8 weeks of an aerobic training program in moderately active men and women for another parasympathetic index of HRV (SD1). However, the authors did not compared changes promoted by the training between men and women for SD1.

There are factors that could suggest some advantage for men compared to women in the changes in rMSSD, which may explain the greater ES we found in our study favorable to men (although not significant). For instance, the lower fitness level of women compared to men despite of the similar training status could have led women to a more exacerbated increase in sympathetic activity, particularly after high-intensity exercise[28]. This may attenuate women's long-term rMSSD response to aerobic exercise. Factors such as circulating hormone levels and higher odds of excessive heat stress after an acute session of exercise in women could have affected rMSSD responses to running training[50,51]. We did not perform the baseline and post-training assessment controlling by the phase of the menstrual cycle that women were; however, we monitored the presence or not of physical and emotional symptoms of pre-menstrual syndrome. With regards to the effect of menstrual cycle on aerobic variables, studies have reported no changes over the menstrual cycle on V_{peak}, $\dot{V}O_{2max}$ and other maximal and submaximal cardiorespiratory parameters[52-55]; however, other studies have found differences between luteal and follicular phases for these variables[56,57].

We have important strengths in the study, such as matching male and female participants by relative fitness level in the baseline, as well as age and BMI. We also accounted for the baseline differences between men and women and the impact on training adaptations[8,24]. Nonetheless, we also have limitations, such as the small sample size for each group, as this study represents secondary data analysis from larger projects. Even though, we calculated a *post hoc* achieved power using G*Power 3.1 (Düsseldorf, Germany), and we found that both men and women groups were powered ($1-\beta > 0.80$) to detect training adaptations in t_{5km} (i.e., main outcome). In an attempt of better controlling for type II error in other outcomes, we provided magnitude of change analysis through between-group ES.

We did not control the specific phase of menstrual cycle that women were assessed for the baseline and post-training time points, but literature suggests that Vpeak, $\dot{V}O_{2max}$, and performance in shorter endurance-related distances are not affected by the phase of menstrual cycle[52-55]. To minimize individual perceptual changes in physical and emotional symptoms during the pre-menstrual phase, we assessed these perceptions in two menstrual cycles in a row and noted no influence in our findings of those with symptoms of pre-menstrual syndrome.

Therefore, men and women responses to training were similar with regards to their running performance and cardiac autonomic function, with only a moderate ES for percentage changes in rMSSD for men compared to women. Regardless of the response to training, men presented higher endurance running performance than women did. V_{peak} and its t_{lim} can be applied in exercise settings for the prescription of moderate- to high-intensity running training with similar benefits independently of the gender.

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Conflict of interest

The authors do not declare a conflict of interest.

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Ferritin status impact on hepcidin response to endurance exercise in physically active women along different phases of the menstrual cycle

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Summary

Serum ferritin has been proposed as a predictor of hepcidin concentrations in response to exercise. However, this fact has not been studied in physically-active women. Therefore, the main objective of this study was to analyse the hepcidin response at different ferritin status before and after running exercise in physically active females. Fifteen eumenorrheic women performed a 40-min running protocol at 75% of VO_{2peak} speed in different menstrual cycle phases (early-follicular phase, mid-follicular phase and luteal phase). Blood samples were collected pre-exercise, 0h post-exercise and 3h post-exercise. For statistics, participants were divided into two groups according to their pre-exercise ferritin levels (<20 and ≥20 µg/L). Through menstrual cycle, hepcidin was lower in both early follicular phase (p=0.024; 64.81±22.48 ng/ml) and mid-follicular phase (p=0.007; 64.68±23.91 ng/ml) for <20 µg/L ferritin group, in comparison with ≥20 µg/L group (81.17±27.89 and 79.54±22.72 ng/ml, respectively). Hepcidin showed no differences between both ferritin groups in either pre-exercise, 0h post-exercise and 3h post-exercise. Additionally, no association between pre-exercise ferritin and hepcidin levels 3h post-exercise (r=-0.091; p=0.554) was found. Menstrual cycle phase appears to influence hepcidin levels depending on ferritin reserves. In particular, physically-active females with depleted ferritin reserves seems to present lower hepcidin levels during the early-follicular phase and mid-follicular phase. However, no association between ferritin and hepcidin levels was found in this study. Hence, ferritin levels alone may not be a good predictor of hepcidin response to exercise in this population. Multiple factors such as sexual hormones, training loads and menstrual bleeding must be taken into account.

Key words:
Iron. Anemia. Female. Athlete. Sex hormones.

Impacto de las reservas de ferritina sobre la respuesta de la hepcidina al ejercicio de resistencia en las mujeres físicamente activas a lo largo de las diferentes fases del ciclo menstrual

Resumen

La ferritina sérica parece ser un predictor de la respuesta de la hepcidina al ejercicio. Sin embargo, este hecho no ha sido estudiado en mujeres físicamente activas. El objetivo fue analizar la respuesta de la hepcidina en diferentes estados de la ferritina antes y después del ejercicio. Quince mujeres eumenorreicas realizaron un protocolo de carrera de 40 minutos al 75% de la velocidad VO_{2pico} en diferentes fases del ciclo menstrual (fase folicular temprana, fase folicular media y fase lútea). Se recogieron muestras de sangre antes del ejercicio y a las 0h y 3h después del ejercicio. Las participantes se dividieron en dos grupos según sus niveles de ferritina previos al ejercicio (<20 y ≥20 µg/L). La hepcidina fue más baja tanto en la fase folicular temprana (p=0,024; 64,81±22,48 ng/ml) como en las fase folicular media (p=0,007; 64,68±23,91 ng/ml) para el grupo de ferritina <20 µg/L en comparación con el grupo de ferritina ≥20 µg/L (81,17±27,89 y 79,54±22,72 ng/ml, respectivamente). La hepcidina no mostró diferencias entre ambos grupos de ferritina para ninguno de los momentos (antes del ejercicio ejercicio, 0h y 3h después del ejercicio). No se encontró ninguna asociación entre los niveles de ferritina previos al ejercicio y los niveles de hepcidina 3h posteriores al ejercicio (r=-0,091; p=0,554). El ciclo menstrual parece influir en los niveles de hepcidina dependiendo de las reservas de ferritina. En particular, las mujeres físicamente activas con reservas de ferritina agotadas parecen presentar niveles de hepcidina más bajos durante la fase folicular temprana y la fase folicular media. Sin embargo, no se encontró ninguna asociación entre la ferritina y la hepcidina. Por lo tanto, los niveles de ferritina por sí solos pueden no ser un buen predictor de la respuesta de la hepcidina al ejercicio en esta población. Se deben tener en cuenta múltiples factores como las hormonas sexuales, las cargas de entrenamiento y el sangrado menstrual.

Palabras clave:
Hierro. Anemia. Mujer. Atleta. Ciclo menstrual. Hormonas sexuales.

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Introduction

Poor iron status can affect health and athletic performance[1,2]. Daily iron needs are covered by dietary iron, iron stores as ferritin, and iron recycling by macrophages. These mechanisms are controlled by the peptide hormone hepcidin, which acts by internalizing and degrading ferroportin, the only known cellular exporter of iron. Increased expression of hepcidin reduces iron inflow to plasma, while decreased expression produces the opposite effect[3]. There are several stimuli that influence the synthesis of this hormone. Hepcidin expression is increased by intra and extra cellular iron concentrations and inflammation, mainly interleukin-6 (IL-6), while it is decreased by low iron intra and extra cellular concentrations, erythropoietic activity and hypoxic stimuli[4]. Exercise practice can modify aforementioned hepcidin regulators[5–9]. Specifically, running shows a powerful capacity to increase hepcidin expression due to IL-6 production, chiefly owing to the higher foot strike haemolysis befallen in this modality[10] and/or its production as a myokine in the muscle during aerobic exercise[11].

Moreover, gender has also influence over iron losses and stores due to menstrual menses[1,12]. Along with this, several studies have already suggested changes over hepcidin production by high concentrations of sex hormones; specifically, high oestrogen concentrations are supposed to downregulate hepcidin synthesis[13–16] and reduce ferroportin expression in cells membrane[17]. Interestingly, progesterone seems to produce an opposite effect[18]. Although these effects are still not clear, it is reasonable to hypothesize that menstrual cycle could influence the hepcidin response. For all of the above reasons, women and athletic population frequently suffer from iron deficiency (ID) and iron deficiency anaemia (IDA)[9].

Additionally, a positive correlation between ferritin and hepcidin levels has been described in the literature[19,20]. Based on this relation, some studies observed the hepcidin response to exercise depending on the previous ferritin status of the participants, obtaining that the higher the levels of ferritin were before exercise, the higher the levels of hepcidin were 3 hours post-exercise[21,22]. Only Peeling *et al.*[21] tested men and women´s response, but the results were presented as a whole, ignoring the possible influence of female sex hormones1[3–18]. It is unknown the hepcidin response to endurance exercise of the active females in different menstrual cycle phases, depending on their pre-exercise ferritin concentrations. This information could help many active women to avoid ID and IDA due to poor training and nutrition planning. Thus, the purpose of this study was to compare the hepcidin response to exercise attending to baseline ferritin levels in physically active eumenorrheic women.

Material and method

Participants

Fifteen endurance-trained females with eumenorrheic cycles (age=35.6±4.2 years; height=163.9±5.9 cm; body mass=58.12±5.2 kg; peak oxygen consumption (VO_{2peak})=50.5±3.7 ml/kg/min; body fat=24.2±7.0%; haemoglobin=13.1±0.9 g/dl; serum iron=73.9±37.1 µg/dl; serum ferritin=37.8±22.1 µg/L) were recruited for this study. They were females between 25 and 40 years old. Inclusion criteria required participants to meet: eumenorrheic menstrual cycle during the year previous to the study; training endurance sports between 5 and 12 hours per week; presented with no IDA; not presenting thyroid problems; not consuming currently medication or dietary supplements (e.g., iron supplementation, tricyclic antidepressants, α-blockers, β-blockers, etc.); non-smokers; non-pregnant or ovariectomy. Eumenorrheic cycle is defined as normally occurring menstrual cycles, from 24 to 35 days in length[23,24]. Research Ethics Committee of the Universidad Politécnica de Madrid approved the project, which is in accordance with the ethical standards of the Helsinki Declaration. In addition, each participant signed an informed consent form.

Experimental Overview

The current study is an observational and randomized controlled study. Participants visited the laboratory to perform initial testing (body composition and VO_{2peak} assessment). All the screening tests were performed during the early follicular phase (between days 2 and 5). Resting blood samples were obtained in early morning fasted state in order to verify that none of the participants showed signs of inflammation, IDA, thyroid problems or menstrual cycle dysfunction. For the last one, sexual hormones (progesterone, oestrogen, luteinizing and follicle-stimulating hormones and prolactin) were measured.

Body composition, as well as height and body mass were measured for all the participants. A stadiometer (SECA) was used for measuring height and a scale (range 0-150 kg, Beurer GmbH Germany) was used for body mass. For the body composition analysis, a Dual-Energy X-ray Absorptiometry (DEXA) scan was performed, which measured body fat mass (%), total body fat mass (kg) and free fat mass (kg), using a GE Lunar Prodigy apparatus (GE Healthcare, Madison, Wisconsin, USA).

For VO_{2peak} measurement, participants performed a maximal graded test consisting of 3 minutes warm up at 6 km/h followed by an incremental period in which the speed was set at 8 km/h and increased by 0.2 km/h every 12 seconds until participant´s exhaustion. 1% slope was set throughout all the test. A computerized treadmill (H/P/COSMOS 3PW 4.0, H/P/Cosmos Sports & Medical, Nussdorf-Traunstein, Germany) and a gas analyser Jaeger Oxycon Pro (Erich Jaeger, Viasys Healthcare, Germany) was used to determine their VO_{2peak} and maximal aerobic speed (vVO_{2peak}). VO_{2peak} was determined as the mean of the three highest breath-by-breath VO_2 measurements. vVO_{2peak} was recorded as the minimum speed required to elicit VO_{2peak}.

After initial measurements, participants attended the laboratory on three different occasions throughout the menstrual cycle to carry-out the experimental protocol. Different phases of the menstrual cycle were selected for this study in order to analyze different hormonal environments as literature suggest[25]: early follicular phase, low sex hormonal levels (days 2-5); mid-follicular phase, low progesterone but mid-high oestrogen levels (days 7-10; 8±1.09); and luteal phase, elevated progesterone and oestrogen levels (days 19-21). Nevertheless, mid-follicular phase was selected instead late follicular phase (peak oestrogen concentrations) in order to ensure testing before ovulation as no luteinizing hormone surge testing was used in this study[25]. The set value for individuals progesterone concentration for the luteal phase was 6.0 ng.mL-1, such as literature suggest to exclude deficient luteal phases[26].

Participants were asked to complete information about the length of their last four menstrual cycles (number of days from the cycle onset to the next one) to determine their average cycle length. Day 1 of the menstrual cycle was characterized by the onset of menstrual bleeding. These data were provided to a gynecologist, who confirmed menstrual cycles were eumenorrheic and calculated the days for the different menstrual phases. In addition, blood samples were collected for determination of female steroid hormones in each menstrual phase to confirm participants were performing the tests in the correct phase.

Ferritin Group Determination

Participants were divided into two groups according to their baseline ferritin levels before each exercise protocol performed in the different menstrual cycle phases conducted in the study. The cut-off point for the division of the groups was 20 µg/L. This decision was based on two criteria: 1º) at stage two of ID, this being the state prior to the IDA[27]; 2º) the clinical depletion of ferritin reserves was found at <22 µg/L[28]. Accordingly, the sample was divided into unexpended ferritin reserves group with ≥20 µg/L (FG≥20) and depleted ferritin reserves group with <20 µg/L (FG<20). The number of participants in each ferritin group were n=8 (early follicular and luteal phase) and n=7 (mid-follicular phase) for FG<20; n=7 (early follicular and luteal phase) and n=8 (mid-follicular phase) for FG≥20.

Experimental Protocol

Participants attended the laboratory at 07 am on the test day having had breakfast two hours earlier. Composition breakfast was controlled and supervised by a nutritionist in order to avoid pro-inflammatory food and carbohydrates as it may reduce the post-exercise hepcidin response following exercise[29]. Repeat testing for each participant was conducted at the same time of day to minimize the potential effect of diurnal fluctuations.

Prior to the test, venous blood samples were drawn to measure the serum concentrations of oestrogen and progesterone to verify menstrual cycle phase.

After this, a running aerobic endurance test was performed. This test consisted of 5 minutes of warm-up at 60% of vVO_{2peak} followed by 40 minutes at 75% of vVO_{2pea}k concluding with 5 minutes recovery at 30% of vVO_{2peak}. The same absolute velocity was used for each of the testing sessions. The testing protocol has been previously selected by other studies[30]. The speed that participants ran on the treadmill was 11.2±1.1 km/hour (mean±SD). Blood samples were collected before the start of exercise (Baseline), immediately post-exercise (Post-0h) and 3 h post-exercise (Post- 3h). Samples were subsequently analysed for serum hepcidin, IL-6, iron and ferritin.

Nutrition and physical activity

The participants completed a 24-hour dietary recall for the 24 hour period immediately prior to the first session, which was the replicated for the following testing sessions. Participants were asked to be adequately hydrated for each session, and to avoid caffeine and alcohol for 24 hours prior to testing. In addition, they were requested to refrain from any type of exercise for 24 hours prior to each testing session.

Blood samples analysis

All blood samples were obtained in a rested state by venipuncture using clot activator vacutainer tubes. Following inversion and clotting, the whole blood was centrifuged (Biosan LMC-3000 version V.5AD) for ten minutes at 3000 rpm and transferred into Eppendorf tubes and stored frozen at -80ºC until further analysis. Total 17β-estradiol and progesterone were measured via ADVIA Centaur® solid-phase competitive chemiluminescent enzymatic immunoassay (Siemens Healthineers, Germany). Coefficients of variation reported by the laboratory for sexual hormones were: 7.48% for estradiol, 14.11% for progesterone, 7.74% for FSH, 10.77% for LH, 5.65% for prolactin. And for iron parameters: 4.15% for iron, 4.92% for ferritin, 1.4% for transferrin, 5.9% for IL-6 and 4.55% for hepcidin.

Serum samples were analysed in a AU400 clinical analyser (Beckman Coulter Ltd) for Iron (OSR6186), Ferritin (OSR61203), using Beckman reactives; and in a Immulite 1000 (Siemens Healthineers) for Interleukin-6 (IL-6 Ref 6604071). Hepcidin was analysed using a microplate ELISA Kit (Elabscience Human Hepc25 Elisa kit. Catalog Nº. E-EL-H5497). Samples were assayed as duplicates. A Thermofisher Multiskan Ascent microplate reader connected to a computer was used to read ELISA microplate absorbance. The ascent software used controls microplate readings and ELISA microplate calibration data to calculate the final concentration of hepcidin in each sample.

Statistical analysis

All statistical analysis was conducted using the software package SPSS version 22 (IBM; Armonk, NY, USA) and the alpha level of significance was set at $p<0.05$. Data are expressed as means ± SD. All data were initially tested for normality with the Shapiro-Wilk test was used to determine data´s normal distribution. For data with a normal distribution (iron post_0h and iron post_3h) Independent t-test was used, while for data that were not normally distributed (the rest of them) the non-parametric Mann-Whitney test was performed. For the data with a normal distribution the Levene´s test was used to assess the equality of variances. Additionally, Pearson's correlation coefficients were calculated to assess any association between serum ferritin and hepcidin.

The effect size was used to examine the magnitude of change between ferritin groups. Their interpretation was based on the following criteria: <0.2 = trivial, 0.2 to 0.6 = small effect, >0.6 to 1.2 = moderate effect, >1.2 to 2.0 = large effect, and >2.0 = very large[31].

Results

Hormone levels (mean±SD) presented in each phase of the cycle fulfilled the expected fluctuations for a typical menstrual cycle. Oestrogen showed the lowest levels in the early follicular phase (39.4±18.4 pg/ml), increasing during the mid-follicular phase (82.7±51.3 pg/ml) and presenting its highest levels in the luteal phase (110.7±33.6 pg/ml).

Progesterone exhibited its highest concentrations in the luteal phase (10.43±5.58 ng/ml) in comparison with the low levels found in early follicular (0.91±0.79 ng/ml) and mid-follicular phases (0.53±0.31 ng/ml). The mean±SD for the testing days of the different phases were the following ones: day 3±0.85 for the early follicular, day 8±1.09 for the mid-follicular and day 21±1.87 for the luteal (Table 1).

The mean hepcidin levels across the menstrual cycle for each ferritin group are presented in Figure 1A, while baseline and post-exercise values are shown in Figure 1B. FG<20 presented lower hepcidin concentrations than FG≥20 during the early follicular (p=0.024, d=0.04) and mid-follicular phases (p=0.007, d=0.24).

IL-6 and iron concentrations in the different phases of the menstrual cycle are shown in Table 2 for each ferritin group. FG<20 plasma iron was lower in comparison with FG≥20 throughout all the menstrual cycle (early follicular, p<0.001, d=1.17; mid-follicular, p<0.001, d=0.75; luteal, p=0.002, d=1.79). Furthermore, baseline and post-exercise values are presented in Table 3. FG<20 showed lower iron concentrations than FG≥20 at Baseline (p<0.001, d=0.90), Post-0h (p<0.001, d=0.95) and Post-3h (p<0.001, d=0.85). IL-6 reported no significant differences between ferritin groups for menstrual cycle phases (early follicular, mid-follicular and luteal; p>0.05) or time (Baseline, Post-0h and Post-3h; p>0.05).

Correlation analysis did not reveal any association between baseline ferritin and hepcidin levels. We did not find any other association in each menstrual cycle phase for these two variables or between baseline ferritin and hepcidin at the different times of measurement (p>0.05). Figure 2 shows the association between Post-3h hepcidin response and Baseline serum ferritin levels in each menstrual cycle phase (r=-0.091; p=0.554).

Table 1. Ferritin, 17β-estradiol and progesterone of the participants in each menstrual cycle phase (Mean±SD).

		Early	Mid	Luteal
Ferritin µg/L	FG<20	13.4±5.73	11.09±5.26	18.19±17.36
	FG≥20	39.11±22.73	43.44±19.89	49.54±20.5
17β-estradiol pg/ml	FG<20	35.49±13.81	61.17±33.16	123.46±30.64
	FG≥20	43.87±22.94	101.61±58.79	96.2±32.84
Progesterone ng/ml	FG<20	0.66±0.21	0.71±0.25	9.19±5.76
	FG≥20	1.2±1.11	0.36±0.28	11.85±5.49

Early: Early follicular phase; Mid: Mid-follicular phase; Luteal: Luteal phase; FG<20: Depleted ferritin reserves group; FG≥20: Unexpended ferritin reserves group.

Table 2. Mean±SD serum IL-6 and iron of each FG<20 and FG≥20 during different menstrual cycle phases.

		Early	Mid	Luteal
IL-6 pg/ml	FG<20	3.95±3.73	2.81±1.28	6.21±7.52
	FG≥20	2.67±1.09	3.28±1.61	4.00±4.34
Iron µg/dl	FG<20	39.58±19.67	54.75±25.33	57.91±29.10
	FG≥20	80.40±33.92*	101.07±32.17*	103.43±46.49*

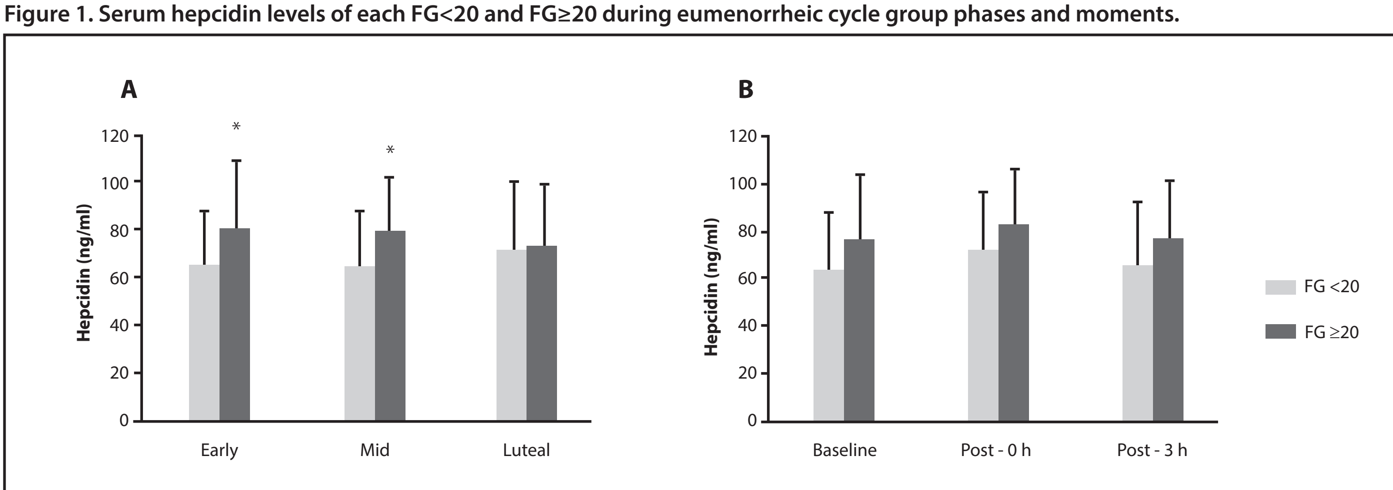
Early: Early follicular phase; Mid: Mid-follicular phase; Luteal: Luteal phase; IL-6: Interleukin-6; FG<20: Depleted ferritin reserves group; FG≥20: Unexpended ferritin reserves group. *Significantly different from FG<20.

Table 3. Mean±SD serum IL-6 and iron of the FG<20 and FG≥20 pre-exercise, post-exercise and 3 hours post-exercise.

		Baseline	Post-0h	Post-3h
IIL-6 pg/ml	FG<20	2.92±2.66	4.39±3.96	5.86±7.36
	FG≥20	2.10±0.33	3.33±1.29	4.51±4.24
Iron µg/dl	FG<20	47.46±25.16	49.51±24.46	53.75±28.24
	FG≥20	89.85±41.25*	99.06±41.16*	96.82±34.19*

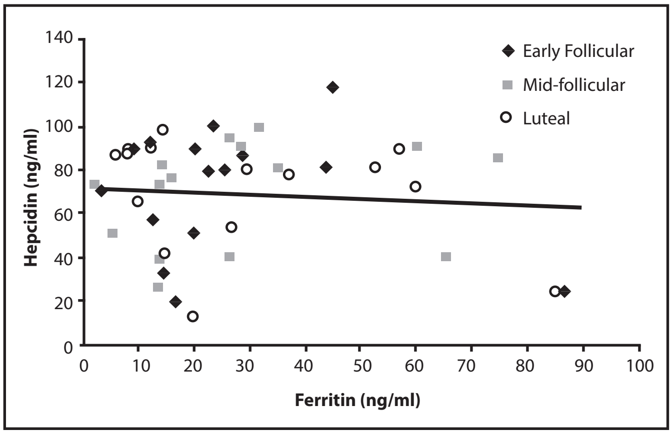
Post-0h: 0 hours post-exercise; Post-3h: 3 hours post-exercise; IL-6: Interleukin-6; FG<20: Depleted ferritin reserves group; FG≥20: Unexpended ferritin reserves group. *Significantly different from FG<20.

Figure 1. Serum hepcidin levels of each FG<20 and FG≥20 during eumenorrheic cycle group phases and moments.



Early follicular phase (Early); Mid-follicular phase (Mid); Luteal phase (Luteal); 0 hours post-exercise (Post-0h); 3 hours post-exercise (Post-3h) Depleted ferritin reserves group (FG<20); Unexpended ferritin reserves group (FG≥20). *Significantly different from FG<20. *Significantly different from FG<20. Early follicular phase (p=0.024); Mid-follicular phase (p=0.007).

Figure 2. Scatter plot and linear trend line of each individual's Post-3h hepcidin response in association with their baseline serum ferritin levels in each menstrual cycle phase (r=-0.091; *p*=0.554).



Discussion

The main finding of this study is that hepcidin concentrations showed differences between ferritin groups in the early follicular phase and in the mid-follicular phase. However, this fact did not occur in the luteal phase.

During early follicular and mid-follicular phases, participants with low ferritin levels showed lower hepcidin levels. This is supported by other studies, finding lower hepcidin concentrations when ferritin levels are low in men and women, disregarding menstrual cycle phase effect[21,22]. Nevertheless, this fact did not occur during the luteal phase where both groups showed similar hepcidin levels. Noting that previous literature did not take into account the influence of the menstrual cycle, a potential justification for the similarity between the two ferritin groups is the influence of sex hormones. Some authors[18] recently found that progesterone presence in animals could lead to an increase in hepcidin expression, as well as elevated hepcidin levels in women who received progesterone supplementation due to a fertility treatment. Therefore, progesterone concentrations may also influence on iron metabolism. Moreover, although our study did not statistically compare menstrual cycle phases, a higher IL-6 was observed at luteal phase.

So in this phase, the lower hepcidin levels theoretically expected in the FG<20 could be counteracted or affected by the presence of noticeably higher IL-6 and progesterone concentrations[18]. Conversely, it is unknown why there was no proportional increase in the FG≥20 group. Maybe the aforementioned mechanisms act by "blocking" the reduced hepcidin expression in an iron-deficient state (FG<20), but this is only a hypothesis that need to be explored in depth with further research.

Contrary to the results found throughout the menstrual cycle, ferritin groups showed no differences at any time, whereas other studies reported changes in hepcidin levels for different ferritin status[21,22]. Peeling *et al.*[22] tested elite male athletes in a 25-km running protocol at 75% of vVO_{2peak}. The mean duration of this protocol was approximately 120 minutes and produced 9.4±4.6 pg/ml of post-exercise IL-6. Our protocol was 40 minutes long, also at 75% of vVO_{2peak}. This produced lower levels of IL-6 (about 3.5-4.0 pg/ml), which could reduce hepcidin response and therefore mask the differences between ferritin groups. However, Peeling *et al.*[21] obtained similar IL-6 increments as our results at post-exercise with comparable protocols in duration and intensity, noting significant differences between ferritin groups in hepcidin levels at baseline and 3 hours post-exercise. Thus, IL-6 post-exercise response magnitude seems unlikely to mask hepcidin differences between ferritin groups.

In contrast to our study, the above mentioned studies[21,22] split the participants according to their ferritin levels with higher cut-off points than ours. "Being the lowest points 35 µg/L[21] and bottom 50th percentile of the participants, presenting a mean serum ferritin of 58±7.8 µg/L[22]. Our cut-off point was 20 µg/L and it is justified in *"Ferritin Group Determination"* methodology section, but with the current knowledge it is not possible to accurately establish the cut-off point where ferritin status is not blocking or reducing hepcidin response post-exercise. Due to the aforementioned, 20 µg/L of ferritin could be an inadequate point in order to confirm, in physically active women, the influence of ferritin status on post-exercise hepcidin levels[21,22]. In spite of this, endurance-trained females usually have low ferritin levels, as they are the population group most affected by iron deficiency[9].

In addition to this issue, Peeling *et al.*[21,22] found no differences in serum iron concentrations between ferritin groups. However, our results markedly showed lower serum iron in the FG<20 compared with the FG≥20. This result can be explained due to the differences in ferritin reserves between studies. Literature has previously suggested decreased serum iron levels in individuals with ferritin <30 µg/L[32], as it is the case of the FG<20 in our study. Therefore, in the case of physically active females, our results suggest a slightly lower cut-off point to evidence significant decrements in serum iron.

Curiously, no correlations were found between ferritin and hepcidin levels at baseline. Once again contradicting previous studies, which found positive correlations between ferritin and hepcidin in general population at baseline conditions[19,20]. As mentioned previously, endurance-trained females seem to have a poorer iron status[9], and ferritin levels are commonly low or deficient. This particular scenario for physically active women could differ from healthy women since ferritin means and ranges are wider in these studies (46, 18-140 µg/L[19] and 81.6, 8.7-368.6 µg/L[20]) compared with our study (37.8, 7.5-79.8 µg/L). Similarly, we did not obtain association between baseline ferritin and pre- and post-exercise hepcidin, although a positive association have been shown in studies with male participants[21,22]. Consequently, it is difficult to compare the results since they had higher and wider ferritin values and did not consider the possible influence of the menstrual cycle phase on this association.

Hence, considering menstrual cycle phases, physically active female could have a different ferritin/hepcidin association compared to physically active men and general population. This is not surprising knowing that endurance-trained eumenorrheic females are the population group most affected by different factors when regulating hepcidin, as they have been mentioned previously (Sangkhae and Nemeth 2017; Latunde-Dada 2013; Roecker *et al.* 2005; Sim *et al.* 2014; Peeling *et al.* 2008; Peeling *et al.* 2009; McClung 2012; Goldstein 2016; Pedersen and Febbraio 2008; Constantini, Dubnov, and Lebrun 2005; Lehtihet *et al*. 2016; Yang *et al.* 2012; Hou *et al.* 2012; Qian *et al*. 2015; Li *et al.* 2016; Bajbouj *et al.* 2018).

The main limitation of the present study was the small sample size recruited. Research with a larger sample could reinforce the new results found in our study. No ovulation test was carried out despite the verification of hormone levels in each phase, so it is not possible to guarantee the ovulation of participants. Furthermore, protocols with greater intensity, duration, or both could allow us to observe additional differences in blood parameters. These results suggest that further research is needed in order to clarify the ferritin/hepcidin relation in endurance-trained females due to their special conditions regarding iron metabolism.

Ferritin levels do not necessarily have to be a good predictor of hepcidin response to exercise in endurance-trained females. However, during the early follicular and mid-follicular phases the hepcidin response of those women with lower ferritin reserves was lower. Therefore, these phases appear to be favourable for assuming iron intake either by diet or by supplementation, being a good strategy to maximize iron absorption in individuals with low ferritin levels.

Menstrual cycle phase appears to influence hepcidin levels depending on ferritin reserves. In particular, physically active females with depleted ferritin reserves seems to present lower hepcidin levels during the early follicular and mid-follicular phases. Lastly, menstrual cycle and ferritin status should be considered together in future research since our results found different hepcidin levels in different hormonal environments.

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Conflict of interest

The authors do not declare a conflict of interest.

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Original article

Deep-water running training at moderate intensity and high intensity improves pain, disability, and quality of life in patients with chronic low back pain: a randomized clinical trial

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Summary

Objective: The present study aimed to verify the influence of training intensity in the aquatic environment on pain, disability, physical capacity, and quality of life in patients with chronic low back pain. Design/Setting: A randomized clinical trial. Subjects: Twenty-two patients with chronic low back pain of both sexes (13 women and 9 men) participated in the study.
Material and method: One group performed deep-water walking/running training at moderate intensity (MIT) and a second group performed deep-water walking/running training at high intensity (HIT). Pain, disability, peak oxygen uptake (VO_{2peak}), and quality of life were assessed before and after an intervention.
Results: Decreases in pain and disability were observed within both groups, without differences in these parameters between training groups. VO_{2peak} did not change in either group after the training intervention. The results of the HIT group showed more significant improvements in quality of life than that of the MIT group, highlighting the social domain, psychological domain, and general quality of life. Both groups presented significant improvements in the physical and environmental domains of quality of life.
Conclusions: Deep-water aerobic exercise training seems to be effective for improving pain symptoms and reducing the disability of people with chronic low back pain. These improvements seem to be independent of the intensity at which the training is performed. In addition, improving pain and disability does not directly reflect all areas of quality of life. In this case, the group that performed the intervention at high intensity achieved more significant improvements in quality of life.

Key words:
Exercise. Aerobic exercise. Exercise intensity. Aquatic exercise. Deep-water running. Back pain. Chronic pain. Low back pain. Health professions.

El entrenamiento de carrera de piscina profunda de intensidad moderada y alta intensidad mejora el dolor, la discapacidad y la calidad de vida en pacientes con dolor lumbar crónico: un ensayo clínico aleatorizado

Resumen

Objetivo: El presente estudio tuvo como objetivo verificar la influencia de la intensidad del entrenamiento en el ambiente acuático sobre el dolor, la discapacidad, la capacidad física y la calidad de vida en pacientes con dolor lumbar crónico. Diseño/entorno: un ensayo clínico aleatorizado. Sujetos: Veintidós pacientes con dolor lumbar crónico de ambos sexos (13 mujeres y 9 hombres) participaron en el estudio.
Material y método: Un grupo realizó entrenamiento de caminar/correr en aguas profundas a intensidad moderada (MIT) y un segundo grupo realizó entrenamiento de caminar/correr en aguas profundas a alta intensidad (HIT). El dolor, la discapacidad, el consumo máximo de oxígeno (VO_{2pico}) y la calidad de vida se evaluaron antes y después de una intervención.
Resultados: Se observaron disminuciones en el dolor y la discapacidad en ambos grupos, sin diferencias en estos parámetros entre los grupos de entrenamiento. VO_{2peak} no cambió en ninguno de los grupos después de la intervención de entrenamiento. Los resultados del grupo HIT mostraron mejoras más significativas en la calidad de vida que la del grupo MIT, destacando el dominio social, el dominio psicológico y la calidad de vida general. Ambos grupos presentaron mejoras significativas en los dominios físicos y ambientales de la calidad de vida.
Conclusiones: El entrenamiento de ejercicio aeróbico en aguas profundas parece ser efectivo para mejorar los síntomas del dolor y reducir la discapacidad de las personas con dolor lumbar crónico. Estas mejoras parecen ser independientes de la intensidad a la que se realiza el entrenamiento. Además, mejorar el dolor y la discapacidad no refleja directamente todas las áreas de calidad de vida. En este caso, el grupo que realizó la intervención a alta intensidad logró mejoras más significativas en la calidad de vida.

Palabras clave:
Ejercicio. Ejercicio aeróbico. Intensidad de ejercicio. Ejercicio acuático. Carrera en aguas profundas. Dolor de espalda. Dolor crónico. Dolor lumbar. Profesiones de la salud.

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Introduction

Currently, musculoskeletal pains are extremely frequent in the world´s population, mainly in middle-aged and working-aged adults. They negatively influence the quality of life of people, limiting their performance of daily activities[1]. In this context, low back pain affects about 12% of the world's population[2]. Chronic low back pain refers to pain in the vertebral region or lumbar paravertebral region; it is considered chronic when it lasts more than 12 weeks[3]. A considerable number of patients who develop chronic symptoms do not respond to conventional therapies[4] such as physiotherapy and medication. Thus, it is believed that regular mechanical activity, such as that produced by physical exercise, seems to be the most reasonable treatment for patients with chronic low back pain[3,5–7].

Among the indicated exercises, those performed in the aquatic environment stand out, since they have great influence on the sensorial system due to the ability of the hydrostatic pressure and water temperature to reduce the sensation of pain[8]. In addition, resting immersion, at thermoneutral temperature (33-35°C)[9], is closely linked to muscle relaxation and a sense of well-being[10]. Within this context, exercises in the aquatic environment seem to be an interesting alternative for people with chronic low back pain, because in addition to the benefits reported, aquatic exercises also have different biomechanical characteristics compared to that of the land environment. Deep-water running has no impact on the lower limbs and is also notable for causing spinal decompression compared to walking/running on a treadmill or in a shallow pool[11]. In addition, this modality allows one to achieve high aerobic intensities, which offer functional, strength, and resistance benefits[11,12] that are negatively correlated with the degree of disability and pain.

However, most studies in the literature discussing physical exercise interventions do not achieve a control and a progression of intensity throughout the intervention. In addition, no studies were found comparing the effect of different training intensities on pain and disability in patients with chronic low back pain[8,12,13]. In the aquatic environment, studies have been found that evaluate the effect of hydrotherapy alone or compared with traditional physiotherapy[8,13,14], but some studies evaluate a systematic training with intensity control in the aquatic environment[1,15,16]. In addition, some authors suggest that physical exercise at higher intensities may provoke an analgesic effect induced by hormonal changes, resulting from a greater release of cortisol and adrenaline[1,17].

Thus, the practice of regular exercise seems to provide important benefits in the treatment of chronic low back pain and the aquatic environment seems to be a safe environment for practice. However, there are still few studies in the literature regarding this topic, mainly regarding the intensity of the intervention. In this way, the present study aimed to verify the influence of training intensity in the aquatic environment on pain, disability, physical capacity, and quality of life in patients with chronic low back pain. According to the hypothesis of this study, it is believed that both moderate- and high-intensity training will provide important improvements in the evaluated outcomes. However, it is believed that the high-intensity training will maximize the benefits of the participants' physical capacity in a more significant way, which may be reflected in the other outcomes.

Material and method

Experimental design and problem approach

The study is characterized as a randomized clinical trial with two groups in parallel. One group (MIT) performed deep-water walking/running training at moderate intensity, and a second group (HIT) performed deep-water walking/running training at high intensity. A control group was not tested, since the effectiveness of the exercise interventions in the answers of interest are already well documented in the literature[1,3,5,7,15,16], leaving a gap in understanding which intensity provides the best benefits. All measurements were taken before the intervention period and 72 h after the last training session, with all assessments completed within a maximum period of one week after the end of the training. Each evaluation was always carried out by the same researcher, who was specifically trained for this evaluation, and was performed using the same equipment. In addition, the evaluators were blinded to the intervention groups to which the participants belonged. This study was designed following the recommendations of the Consolidated Standards of Reporting Trials (CONSORT)[18].

Subjects

Twenty-two physically active patients with chronic low back pain of both sexes (13 women and 9 men) participated in the study. For participation, those interested were required to present with a medical diagnosis of chronic low back pain, with or without irradiation to the lower limbs, for more than 12 weeks. It was not necessary to have previous experience with deep-water running. When included in the study, participants were instructed not to practice other modalities of physical exercise. There was no control over what type of physical activity was performed before the study, as well as, how long they were practicing.

The project was publicized in social networks and local newspapers. Participants were informed of the study objectives, the possibilities of discomfort, and the risks of procedures and interventions. After agreeing to participate in the study, they signed an informed consent form. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Research Ethics Committee of the Federal University of Rio Grande do Sul (registration nº: 39789014.6.0000.5347).

After all pre-intervention evaluations, the participants were randomized into the two intervention groups: deep-water walking/running at moderate intensity (MIT; n=11) and deep-water walking/running at high intensity (HIT; n=11). The randomization process was done by a researcher not involved in the evaluations, and the interventions of the study were determined by removing a paper from an opaque envelope in which there were numbers corresponding to each group.

Assessments

The evaluations were conducted in the Biodynamics Laboratory of Movement of the School of Physical Education, Physiotherapy, and Dance of the Federal University of Rio Grande do Sul. All evaluations were performed individually in only one session of approximately 1 hour. Participants were instructed not to use analgesic medication 24 hours before the evaluations.

Initially, the participants remained at rest, sitting in a chair with their arms relaxed at the side of their body. They remained in this resting position for 15 minutes. After this period, blood pressure (BP) was measured as a safety measure in preparation for the maximum treadmill test that was performed later (MAPA, Meditech, model ABPM-04). A systolic BP below 140 mm Hg and a diastolic BP below 90 mm Hg was considered as adequate BP[19].

Afterwards, the participants were instructed to respond to the Visual Analogue Scale (VAS) and the Oswestry indexes that assess pain and disability, respectively. Then, they were positioned on the treadmill to begin the maximal test. This test had the objective of evaluating the peak oxygen uptake (VO_{2peak}). The participants were instructed to avoid both the consumption of caffeine and exercise within 24 hours of the test and to avoid eating within 3 hours of the test. We used an INBRAMED treadmill (Porto Alegre, Brazil) and a VO2000 portable gas analyzer from MedGraphics (Ann Arbor, USA). The protocol involved the use of an incremental load, with an initial velocity of 6 km/h and an inclination of 1% for 2 minutes. Afterwards, the inclination was maintained at a fixed level and we increased the velocity to 1 km/h every 2 minutes until the participant reported exhaustion. The assessment was considered valid when some of the following criteria were met at the end of the test: the estimated maximal heart rate was reached [220 minus the participant's age, in beats per minute (bpm)], a respiratory exchange ratio greater than 1.15 was reached, and an effort perception of 19 [Borg Rating of Perceived Exertion (RPE) Scale, scale range of 6-20)] was appraised[20]. Lastly, the final stage of the evaluation session consisted of completing the World Health Organization Quality of Life (WHOQOL) questionnaire, which evaluates general quality of life in four different domains (physical, psychological, social, and environmental).

Training

Before starting the training periods, the participants performed four sessions of familiarization with the technique of deep-water running and with the aquatic environment. Deep-water running is carried out with the help of a float vest, which keeps the individual upright without using the foot support at the bottom of the pool. The elbows should be flexed at 90º, the hands closed, and the movement of the upper limbs alternating relative to the movement of the lower limbs.

Study participants were trained on non-consecutive days, twice a week for a period of 12 weeks. In case of failure to participate on one of the training days, an extra session for recovery was scheduled. The trainings were performed in the evening during consecutive hours, administered by the same instructor with experience in aquatic exercises. The classes had a duration of 45 minutes, which were consisted of warm-up, the main exercise period, and stretching. The warm-up period consisted of a walk at a slightly self-selected intensity. The main exercise period included deep-water walking and/or running at the intensities prescribed for each phase of the training and lasted for 35 minutes. Finally, the priority of the stretching portion was to stretch the main muscles used during the main exercise period.

The intensity prescription of both groups was administered with intensities defined according to the heart rate of the second ventilatory threshold (HR_{VT2}). During the classes, each participant used a heart rate monitor to control the training heart rate (HR) and were allowed a variation of 5 bpm above or below the targeted HR. Table 1 shows the periodization of the 12 weeks of training at moderate-intensity training and training at high-intensity training.

Table 1. 12-week periodization of deep water walking/running training at moderate intensity.

Week	Volume x Intensity	Total time
1, 2, 3 and 4	7x (3min 85% HR_{VT2} + 2min < 85%HR_{VT2})	35 min
5, 6, 7 and 8	7x (4min 90% HR_{VT2} + 1min < 85%HR_{VT2})	35 min
9, 10, 11 and 12	7x (4min 95% HR_{VT2} + 1min < 85%HR_{VT2})	35 min

HR_{VT2}: heart rate of the second ventilatory threshold.

To determine the HR_{VT2} used in the prescription, a maximal deep-water running test was performed. The participants performed the test in a stationary position and at the depth of the shoulders. Participants were attached to the edge of the pool using a cable connected to the float vest. In this way they performed the stride of the race in a deep pool, and with each musical beat one leg should be positioned in front. The test protocol consisted of an initial rate of 85 beats per minute (bpm) for three minutes, increasing by 15 bpm every two minutes, until the individual indicated exhaustion or until the participant does not keep pace with the test. One of the evaluators monitored whether the individual's stride was within the rhythm of each phase of the test. HR was collected every 10 seconds using a heart rate monitor. The HR_{VT2} was determined by HR deflection point observed in the graph FC by the intensity[12].

Statistical analysis

Descriptive statistics (mean and 95% confidence interval) were used to report the results. Sample characterization data (at baseline) of both groups (HIT and MIT) were compared by independent T-test and chi-square test. Generalized estimating equations (GEE) and the Bonferroni post hoc test were used to compare the means of all dependent variables (in intention-to-treat and per protocol analysis). Furthermore, the effect size (ES, using Cohen's d) was calculated from the difference in post-training values between the HIT and MIT groups, and classified as small (between 0.2 and 0.5), moderate (between 0.5 and 0.8), or large (0.8 or more)[21]. The statistical significance level was set at α=0.05 for all tests and the statistical software SPSS (version 22.0) was used for all analyses.

Results

The study started with 22 participants, with 11 in each intervention group. In the MIT group, three patients did not finish the study, one due to changes in working hours, one due to illness, and another by withdrawal. In the HIT group, there were four losses, as two participants abandoned the study and two did not conclude an intervention due to health reasons (Figure 1). All dropouts were invited to return to the final evaluations to perform the intent-to-treat analysis, however, only two participants originally in the HIT group attended. Baseline charac-

Figure 1. Flow diagram showing the participant's enrollment process, allocation, follow-up and the analysis.

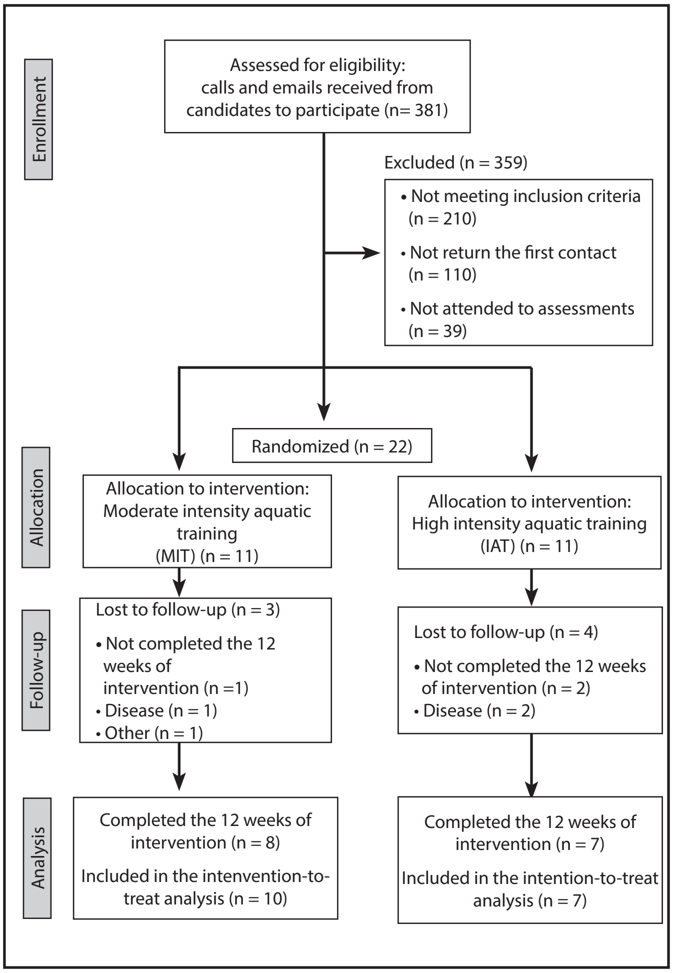

Table 2. 12-week periodization of deep water walking/running training at hight intensity.

Week	Volume x Intensity	Total time
1, 2, 3 and 4	7x (3min 95% HR_{VT2} + 2min < 85%HR_{VT2})	35 min
5, 6, 7 and 8	7x (4min 100% HR_{VT2} + 1min < 85%HR_{VT2})	35 min
9, 10, 11 and 12	7x (3min 100% HR_{VT2} + 1min 105% HR_{VT2} + 1min < 85% HR_{VT2})	35 min

HR_{LV2}: heart rate of the second ventilatory threshold.

terization of the participants is presented in Table 2. All characteristics were similar between the groups (p>0.05).

The results regarding pain, disability, and VO_{2peak} can be observed in Table 3. Decreases in pain and disability were observed in both groups, as per protocol analysis (pain: p<0.001; disability: p<0.001) and the intention-to-treat analysis (pain: p<0.001; disability: p<0.001) after the training intervention. VO_{2peak} did not change after the training intervention; these results were confirmed according to the protocol (p=0.675)

Table 3. Patients' characteristics.

	MIT	HIT	*p* value
Age (year)	41 (31 to 50)	35 (23 to 48)	0.666
Body mass (kg)	76 (47 to 105)	73 (47 to 85)	0.811
Height (cm)	1.66 (1.55 to 1.77)	1.64 (1.47 to 1.80)	0.660
BMI (kg/m²)	27 (19 to 35)	27 (25 to 30)	0.737
Duration of symptoms (months)	60 (-26 to 145)	77 (-39 to 193)	0.647
Gender (F/M)	04/04	05/02	0.398

MIT: moderate intensity aquatic training; HIT: high intensity aquatic training. Comparisons were performed by Independent T-test; α=0.05. Data are expresses as mean and confidence interval 95%.

and the intention-to-treat analyses (p=0.531). In addition, no differences in pain, disability, and VO_{2peak} were observed between the groups.

The results regarding quality of life and its domains can be observed in Table 4. The physical domain in the intention-to-treat analysis showed significant differences in the time effect (p=0.011), demonstrating a significant improvement in both groups with the interventions performed. However, in the protocol analysis, a significant interaction (p=0.042) was observed in the physical domain. In the post hoc analysis, we observed that both groups maintained their physical domain values from pre- to post-training and a significant difference was observed only between the post-training groups (p=0.009); higher scores in the physical domain were demonstrated in the HIT group compared to that of the MIT group.

In the intention-to-treat analysis of the psychological domain, significant changes with the interventions performed were not present, nor were there differences between the groups in this domain. However, a significant interaction was observed in the protocol analysis (p=0.003). In the post hoc analysis, a significant difference was observed between the post-training groups (p<0.001), as higher scores in the psychological domain were observed in the HIT group compared to those in MIT group. In addition, only the HIT group demonstrated significant improvements when pre- and post-training outcomes were compared. In contrast, the MIT group maintained its values.

The social domain showed a significant interaction in both the intention-to-treat analysis (p=0.019) and the protocol analysis (p=0.013). In the post hoc analysis, differences were observed between post-training groups (intention-to-treat: p<0.001; per protocol: p<0.001) and a significant improvement was observed in this domain only for the HIT group, from pre- to post-intervention (intention-to-treat: p=0.013; per protocol: p=0.010). The MIT group maintained its values after the intervention. The environmental domain had a significant effect on time in both the intention-to-treat analysis (p=0.020) and the protocol analysis (p=0.032). Furthermore, showing no difference between groups and no significant interaction in the environmental domain.

Finally, the general quality of life presented significant interaction in the intention-to-treat analysis (p=0.001) and in the protocol analysis (p=0.006). Post hoc analysis demonstrated a significant improvement from pre- to post- intervention only in the HIT group, both in intention-to-treat analysis (p<0.001) and in protocol analysis (p=0.002). The MIT group maintained its values regarding time.

Table 4. Pain, Oswestry disability Index and VO_{2peak} for moderate intensity aquatic training (MIT) and high intensity aquatic training (HIT) before and after 12 weeks of training.

Intention-to-treat analysis	MIT			HIT		
	Baseline	12 weeks	Change	Baseline	12 weeks	Change
Pain (100 mm VAS)	57.0 (45.4 to 68.6)	18.8* (11.4 to 26.3)	-38.2	58.4 (45.9 to 70.7)	27.4* (11.0 to 43.8)	-31.0
Oswestry Disability index	10.1 (7.4 to 12.9)	6.0* (3.3 to 8.7)	-4.1	14.4 (10.6 to 18.3)	9.2* (6.5 to 11.8)	-5.2
VO_{2peak} ($ml.kg^{-1}.min^{-1}$)	44.5 (39.1 to 49.9)	44 (38.5 to 50.3)	0.5	46.2 (37.3 to 55.1)	43.5 (36.7 to 50.2)	-2.9
Per protocol analysis	**MIT**			**HIT**		
	Baseline	**12 weeks**	**Change**	**Baseline**	**12 weeks**	**Change**
Pain (100 mm VAS)	57.0 (45.4 to 68.6)	18.8* (11.4 to 26.3)	-38.2	59.4 (45.9 to 72.9)	28.2* (7.8 to 48.6)	-31.2
Oswestry Disability index	10.1 (7.4 to 12.9)	6.0* (3.3 to 8.7)	-4.1	14.5 (10.2 to 18.8)	8.2* (5.8 to 10.6)	-6.3
VO_{2peak} ($ml.kg^{-1}.min^{-1}$)	34.3 (39.1 to 57.1)	37.4 (38.5 to 50.3)	3.1	37.9 (35.1 to 53.2)	40.1 (34.8 to 53.2)	2.1

Data are expresses as mean and confidence interval 95%; α=0.05. *p<0.05 for time effect (baseline vs. 12 weeks). Generalized estimated equation; Bonferroni correction.

Table 5. Quality of life for the moderate intensity aquatic training (MIT) and high intensity aquatic training (HIT) before and after 12 weeks of training.

Intention-to-treat analysis	MIT			HIT		
	Baseline	12 weeks	Change	Baseline	12 weeks	Change
PHYd	63.7 (55.1 to 72.3)	66.7* (56.6 to 77.3)	3.0	52.9 (45.7 to 60.2)	65.0* (58.6 to 71.4)	12.1
PSYd	63.2 (54.5 to 71.4)	62.5 (56.0 to 68.9)	-0.7	64.2 (54.2 to 74.5)	71.7 (60.9 to 82.3)	7.5
SOCd	63.9 (46.8 to 80.9)	54.2[a] (45.0 to 63.3)	-9.7	59.8 (47.6 to 72.1)	80.0[b]* (70.1 to 89.9)	20.2
ENVd	60.4 (54.3 to 66.5)	64.8* (56.9 to 72.8)	4.4	59.7 (53.8 to 65.5)	65.6* (59.6- to 71.6)	5.9
OQL	63.5 (50.9 to 74.0)	62.5 (47.5 to 77.5)	-1.0	53.4 (43.4 to 63.4)	75.0* (65.2 to 84.8)	21.6
Per protocol analysis	**MIT**			**HIT**		
	Baseline	**12 weeks**	**Change**	**Baseline**	**12 weeks**	**Change**
PHYd	60.1 (55.6 to 64.6)	56.2[b] (52.4 to 60.1)	3.9	55.9 (46.2 to 65.7)	63.4[a] (59.6 to 67.2)	7.5
PSYd	60.4 (55.8 to 65.0)	54.2[a] (51.3 to 57.0)	-6.2	57.4 (48.8 to 65.9)	67.7[b] (61.7 to 73.7)	10.3
SOCd	63.9 (46.8 to 80.9)	54.2[a] (45.0 to 63.3)	-9.7	59.2 (44.4 to 74.1)	83.3[b]* (73.3 to 93.3)	24.1
ENVd	60.4 (54.3 to 66.5)	64.8* (56.9 to 72.8)	4.4	60.4 (53.3 to 67.5)	67.2* (60.5 to 73.9)	6.8
OQL	62.5 (50.9 to 67.9)	62.5 (47.5 to 77.5)	-1.0	56.9 (45.9 to 67.9)	78.1* (67.9 to 88.3)	21.2

PHYD: physical domain; PSYD: psychological domain; SOCD: social relationship domain; ENVD: environment domain; OQL: overall quality of life. Data are expresses as mean and confidence interval 95%; α=0.05. *p<0.05 for time effect (baseline vs. 12 weeks). Different letters: p<0.05 for groups effect (MIT vs. HIT). Generalized estimated equation; Bonferroni correction.

In the analysis of the ES, the comparison of the MIT and HIT groups showed a large magnitude of effect for the following domains and their respective analyses: the physical domain in the intention-to-treat (0.99 [0.12 to 1.86]) and in the protocol analyses (0.99 [0.12 to 1.86]), the psychological domain in the protocol analysis (1.40 [0.48 to 2.32]), and the social domain in the intention-to-treat (1.30 [0.43 to 2.16]) and in the protocol analyses (1.59 [0.65 to 2.53]). A moderate magnitude of effect was shown for the disability index in the intention-to-treat analysis (0.56 [-0.13 to 1.26]), and for general quality of life domain in the intention-to-treat (0.53 [-0.27 to 1.34]) and protocol analyses (0.68 [-0.17 to 1.53]). Small effect was observed for pain in the intention-to-treat (0.30 [-0.39 to 1.00] and in the protocol analyses (0.27 [-0.45 to 0.99]), for the disability index in the protocol analysis (0.40 [-0.31 to 1.11]), for VO_{2peak} in the intention-to-treat (0.07 [0.63 to 0.76]) and in the protocol analyses (0.03 [-0.72 to 0.77]), for the psychological domain in the intention-to-treat analysis (0.46 [-0.34 to 1.26]), for the environmental domain in the intention-to-treat (0.06 [-0.73 to 0.85]) and the protocol analyses (0.17 [-0.65 to 2.53]), and for general quality of life domain in the intention-to-treat analysis (0.53 [-0.27 to 1.34]).

Discussion

Overall, the results demonstrated that both the HIT and MIT interventions were effective in improving pain and disability in people with chronic low back pain. Regarding quality of life, the group that performed the intervention at a higher intensity experienced more significant results, highlighting the importance of the social domain and general quality of life. Both groups presented significant improvements in the physical and environmental domains. The results agree in part with our hypothesis, since we believed that both groups would show improvements in the outcomes evaluated. However, we believed that the high-intensity group would stand out in the improvements found, due to our hypothesis that they would experience a more marked improvement in physical capacity. Contrary to our belief, this did not change in both groups after the intervention.

In relation to pain and disability results, these corroborate the literature that shows that aerobic exercises in the aquatic environment are effective for improvements in these parameters[1,15,16]. It is believed that physical exercise causes stress-induced analgesia, releasing cortisol and adrenaline into the bloodstream, and consequently increasing the practitioner's pain threshold[1]. Chatzitheodourou *et al.*[17] suggest that this behavior is maximized at higher intensities, however, our study does not support this theory. It appeared that regardless of training intensity, both groups experienced similar improvements in both pain and disability. In this sense, Hoffman & Al'Absi[22] believe that intensities above 50% of maximal oxygen uptake (VO_{2max}) are already sufficient to provide an analgesic effect of exercise in patients with chronic low back pain. In the present study, the MIT group started training at an intensity of 85% of HRVT2 and progressed up to 95% of HRVT2, and thus these intensities were enough to observe a significant improvement in pain and disability.

In addition, it should be noted that these results demonstrate that aerobic exercise performed as deep-water running, whether at moderate or high intensity, does not present adverse effects on patients, such as increased pain or disability, but rather a significant reduction in these parameters. In this way, high intensities can be prescribed for individuals with chronic low back pain in deep-water walking/running with safety. Still, we emphasize that aquatic exercise modalities present important characteristics, especially for patients with musculoskeletal problems involving pain. Among these, we highlight the possibility of practicing aerobic exercises at higher intensities due to reduced joint impact[23,24] and spinal decompression[11]. Along with reaping these benefits, the aquatic environment provides characteristics of greater security, greater tolerance of the exercise, and, consequently, a more pleasant experience with greater adhesion to an aquatic exercise regimen. Finally, it should be noted that in the literature, reductions in pain scores of greater than 20% are considered clinically relevant and in the present study, there was a mean reduction in pain scores of 60% in both intervention group[25].

According to data published in the literature, the improvement of pain and disability seems to be related to improvements in physical fitness[5–7] and in this context, the present study evaluated VO_{2peak} as a means of measuring physical fitness. However, the two interventions tested were not effective in improving this parameter; they were only effective in maintaining it, which demonstrates that improvements in pain and disability can occur even if there are no improvements in physical fitness. In the literature, studies that used frequencies of three or more sessions per week for aerobic training showed significant improvements in VO_{2peak} or VO_{2max} in patients with chronic low back pain[14,26]. In elderly patients, Kanitz *et al.*[27] observed a significant increase in VO_{2peak} after a 12-week deep-water running intervention with three sessions per week. Thus, the weekly frequency of the present study - twice per week - was perhaps not enough to provide significant improvements in cardiorespiratory parameters. In addition, the participants of the present study started the study with mean VO_{2peak} values of 44.75 $ml.kg^{-1}.min^{-1}$, values that classify cardiorespiratory fitness as "good" for men and "excellent" for women[28]. Thus, the high initial VO_{2peak} values of the participants in the present study reflect a smaller amplitude for the possibility of improvements, compared to sedentary or elderly participants, which characterized the participants of the aforementioned studies. Thus, once again, it is believed that a higher weekly frequency may have been more effective in providing improvements in cardiorespiratory parameters. In addition, it is believed that because the training and the assessment of physical fitness were carried out in different environments, perhaps there was no transfer of the benefits of training to the assessment. However, it is noteworthy that the assessment in land environment was chosen precisely to verify the benefits of the aquatic modality in the environment in which the participants live, and the maximum test in aquatic environment was performed only for the training prescription.

In contrast to the aforementioned outcomes, differences in the quality of life parameter were evident between the groups, demonstrating that exercise intensity may have an influence on this parameter in individuals with chronic low back pain. The environmental and physical domains were the only areas that improved equally with the interventions. In relation to the physical domain, which is related to pain, discomfort, energy, and sleep[29], it showed significant improvements in both groups and no difference between them. This result corroborates the findings of the present study related to pain and disability.

However, the improvement in physical domain was only observed in the intention-to-treat analysis. Regarding physical quality of life, since the MIT group showed different behavior pertaining to this outcome in both analyses, and the HIT demonstrated similar behavior in both analyses, one should be cautious in attributing beneficial effects to aquatic training of moderate intensity.

Another important domain of quality of life is the psychological domain, which is related to positive feelings and the capacity for thinking, learning, and self-esteem[29]. Significantly higher scores for this domain were presented in the HIT group during the post-training period, but only in the analysis per protocol, which brings us to recognize a direct relationship between this outcome and the protocol of high intensity performed. The high-intensity exercise may have presented a greater challenge to the practitioners, which may lead to more positive behavior over time[30,31]. In addition, in both analyses, the social domain and general quality of life showed significant improvements, but only in the HIT group. Thus, the high-intensity intervention seems to be more effective for improvements in quality of life compared to the moderate-intensity intervention.

The literature indicates that improvements in pain and disability directly reflect improvements in the quality of life of patients with chronic low back pain[32]. In the present study, the groups significantly improved in both the pain and disability parameters, but these improvements were reflected more in the group that trained at high intensity. The influence of intervention intensity on quality of life is not elucidated in the literature, as no studies have been found that observe the effects of different training intensities on the quality of life in patients with chronic low back pain or in any other patient population. Thus, the results of this study appear to be innovative in the literature, and they introduce a gap for further research.

The main limitations of this study were the small number of participating patients and the low weekly frequency of training for participants already considered as active with good-to-excellent physical fitness ratings. Thus, for future studies, a larger sample size and training at a higher weekly frequency are suggested.

From the results of the present study, we can conclude that aerobic training in aquatic environments seems to be effective for improving pain symptoms and reducing the disability of people with chronic low back pain. These improvements seem to be independent of the intensity at which the training is performed, including high-intensity training that proved safe for these participants. Still, these improvements are not necessarily related to an increase in physical capacity, since VO_{2peak} values were maintained throughout the intervention in both groups. In addition, improvement in pain and disability does not directly reflect the status of all areas of quality of life. In this case, the group that performed the intervention at high intensity highlighted unique domains, as they experienced more significant improvements in the social, psychological, and general quality of life domains. In contrast, the physical and environmental domains improved similarly in both groups.

Thus, aerobic exercise of deep-water walking/running may be indicated for patients affected by chronic low back pain. Furthermore, for the participants in this study who were classified as having good-to-excellent physical fitness, the two intensities, moderate and high, can also be indicated without any impairment in the parameters of pain or disability. However, in order to have a positive impact on the quality of life of these patients, high-intensity training is more effective. As for improvement in cardiorespiratory fitness, we suggest a higher weekly frequency of training. Nonetheless, it is emphasized that the interventions were effective in maintaining cardiorespiratory fitness.

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Conflict of interest

The authors do not declare a conflict of interest.

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Original article

COVID-19 and home confinement: data on physical activity

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Summary

In March 14th 2020, the Spanish Government declared the "State of Emergency" due to the pandemic caused by the COVID-19 and all the population was forced to "shelter-at-home" for two weeks. Citizens had less than 24 hours to prepare for the self-quarantine. The goal of the present was to assess Spanish citizens' physical activity practice at the end of the first week of the home quarantine. A total of 1858 Spanish citizens, 674 males and 1184 females (M = 40.18, SD = 15.84 years) agreed to participate. The study is descriptive in nature, based on an on-line questionnaire conducted seven days after the mandatory shelter-at-home health order issued by the Spanish Government. It included The International Physical Activity Questionnaire, Anthropometric parameters, Sociometric and COVID-19 information. Global results showed that the vast majority of the confined population was below the World Health Organization recommendations on Vigorous Physical Activity, Moderate Physical Activity or a combination. Physical activity practice was dependent on personal factors such as gender, age or weight, but also on contextual factors such as living with a dependent person or the type of house (square meters, having a balcony or a backyard). Insufficient physical activity has been considered a prominent risk factor for non-communicable diseases, mental health and, consequently, quality of life. Mandatory shelter-at home orders like the ones issued due to COVID-19 could be repeated in the future. National authorities should consider the findings from the present study to prevent citizens from putting their health at jeopardy while in confinement.

Key words:
Pandemic. Quarantine. Behavior. Exercise. Health.

COVID-19 y confinamiento en casa: datos de actividad física

Resumen

El 14 de marzo de 2020, el gobierno español decretó el "estado de emergencia" debido a la pandemia provocada por la COVID-19 y la población fue forzada a confinarse en sus casas durante dos semanas. Los ciudadanos tuvieron menos de 24 horas para prepararse. El objetivo del estudio fue evaluar la práctica de actividad física de los españoles al final de la primera semana de la cuarentena en el hogar. Un total de 1858 ciudadanos españoles, 674 varones y 1184 mujeres (M = 40.18, SD = 15.84 años) accedieron a participar. El estudio siguió un diseño descriptivo, basado en un cuestionario on-line distribuido siete días después de decretarse por el Gobierno de España la orden de confinamiento de la población. Incluía el *International Physical Activity Questionnaire,* medidas antropométricas, sociométricas e información relacionada con el COVID-19. Los resultados globales mostraron que la amplia mayoría de la población confinada estaba por debajo de las recomendaciones de la Organización Mundial de la Salud de Actividad Física Vigorosa, Actividad Física Moderada o una combinación. La práctica de actividad física dependió de factores personales como el género, la edad o el peso, pero también de factores contextuales como convivir con una persona dependiente o el tipo de casa (metros cuadrados, disponer de un balcón o de un patio). Una insuficiente cantidad de actividad física ha sido considerada como un factor de riesgo importante para el desarrollo de enfermedades no-comunicables, para la salud mental y, consecuentemente, para la calidad de vida y los ciudadanos españoles confinados tenían niveles por debajo de los recomendados. Órdenes de confinamiento como las que se han decretado a raíz del COVID-19 podrían repetirse en el futuro. Las autoridades nacionales deberían tener en cuenta los resultados del presente estudio para prevenir que los ciudadanos pongan en riesgo su salud durante el confinamiento.

Palabras clave:
Pandemia. Cuarentena. Comportamiento. Ejercicio. Salud.

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Introduction

December 2019 is considered the beginning of COVID-19 in Wuhan, China. The outbreak was declared a Public Health Emergency of International Concern on January 30th, 2020 by the World Health Organization (WHO). On March 13th, Europe became the epicentre of the pandemic. Finally, in March 14th, The Spanish Government declared the "State of Emergency" and population was forced to "shelter-at-home" for two weeks, except for public service (i.e., health, safety, social assistance, food, transport…). To our knowledge, it was the first time that the vast majority of a country's population had to face two weeks of isolation / confinement at their homes. Other countries like China, Korea, Italy, France, Belgium or India issued similar orders, but in some of them only parts of the country were confined and in others, individuals were allowed to go out on the streets to exercise during different periods of time. In Spain, citizens had to remain indoors 24 hours, and they were only allowed to walk their dogs or buy food (except those who had "essential" jobs, previously mentioned). Therefore, the vast majority of the population was facing two weeks of compulsory home quarantine.

In a recent review, Brooks *et al.*[1] identified 24 articles describing the psychological impact of a quarantine. They were conducted across 10 countries and they included five different diseases (SARSm Ébola, 2009 and 2010 H1N1 influenza pandemic, Middle East respiratory syndrome and Equine influenza), participants ranged from 10 health-care workers to 6231 Korean residents, and isolation conditions were very different. Similar isolation / confinement contexts could be found in a prison[2], in Antarctic exploration bases[3], or in space-mission simulated areas[4]. However, in all these contexts, individuals were prepared to face those confinement conditions, and in most cases, they volunteered to be there. In the compulsory shelter-at-home health order issued in Spain in March, a whole country was involved (47 million people aprox.), individuals were not given much time to prepare (less than 24 hours), and they were forced to accept it. Therefore, they were facing a completely new scenario, which could be repeated in the future. Researchers have the duty to study this phenomenon and provide insights for public health policies.

The positive connections between physical activity (PA) and individuals' physical (i.e., musculoskeletal health and function, diabetes, cardiovascular disease…) and psychological (i.e., depression, anxiety…) well-being have been highlighted in many different studies[5,6]. The evidence backing up the starring role of PA in the prevention and supervision of chronic diseases has helped move forward the public health agenda with the goal of improving individuals' quality of life and society healthcare system's cost-effectiveness[7,8]. Unfortunately, recent systematic reviews have pointed out that there is a global pandemic of physical inactivity[9]. Furthermore, the negative trend between 2001 and 2016 increased more in high-income western countries to reach 31% of their population, and in women, who reached a high 42% in Latin America and the Caribbean[10]. The World Health Organization[11] recommends 150 minutes/week of moderate intensity PA (MPA) or 75 minutes/week of vigorous intensity (VPA) or a combination of both, and it believes that "these recommendations can still be achieved even at home, with no special equipment, and limited space". Is this possible under the COVID-19 shelter-at-home mandatory health order in Spain?

Articles published on the COVID-19 crisis have focused on vicarious traumatization[12] or psychological effects[13]. Very little is known about their side-effects like the compulsory shelter-at-home health order issued in Spain. Based on the aforementioned, the goal of this study was to assess Spanish citizens' PA practice at the end of the first week of confinement. The first hypothesis was that it will be below WHO recommendations. The second hypothesis was that it will be different depending on the individual's living conditions.

Material y method

Participants

The present study is descriptive in nature, based on an on-line questionnaire conducted on Friday, April 21st 2020, seven days after the compulsory Shelter-at-Home health order was issued by the Spanish Government. A total of 1858 Spanish citizens, 674 males and 1184 females (M = 40.18, SD = 15.84, age range 16-82 years) from all regions in Spain agreed to participate.

Procedure

First, permission to conduct the study was obtained from the researchers' State Ethics Research Committee (no 2020.165). Second, the research team developed an on-line questionnaire to obtain the needed information. Third, it was distributed via e-mail, WhatsApp, Twitter, Facebook and newspapers. In the first page of the questionnaire, participants were informed that it was completely anonymous, and that they could "stop and exit the questionnaire at any time if you feel emotional discomfort, because participation is voluntary". The STROBE guidelines for reporting observational studies were followed[14].

Instruments

The International Physical Activity Questionnaire (IPAQ)[15]. This tool was designed to assess physical activity (including inactivity) at a cross-national level. The IPAQ has shown sensible measurement properties for the analysis of individuals' physical activity levels between 15 and 65 years of age[16]. In this study, the short version of the questionnaire, 7-day recall, was used[17]. According to Silsbury, Goldsmith and Rushton[18] the IPAQ-7 is "the most appropriate outcome measure for clinical and research use, as it has excellent reliability and moderate correlation with Accelerometry. The short version makes it efficient for clinicians, also making it more cost-effective". The Spanish validated version was obtained from www.ipaq.ki.se. It provides information on the time the individual spends in three physical activity intensity levels (walking, moderate and vigorous), and in sedentary activities. The Metabolic Equivalent of Task (MET) was used to indicate physical activity intensity. It represents 3.5 $mlO_2/kg.min^{-1}$ (energy needed for the basal metabolic rate), and it was grouped in three levels: a) Light (1.6-2.9 METs), b) Moderate (3 – 5.9 METs), and c) High (≥ 6 METs)[19].

Anthropometric parameters. Participants' height, current weight and weight before the compulsory shelter-at-home health order were requested. Based on this information, individual's body mass index was calculated using the following formula: weight (kg) / [height (m)]^2 and these categories: underweight < 18.5, normal weight: 18.5-24.9, overweight: 25.0-29.9, and obese: ≥30.0[20].

Sociometric information. To obtain a global picture of each individual's isolated context, additional questions were included in the study's questionnaire: How many days have you been shelter-at home? Have you been out on the streets? For what reason? How many square meters does the house where you are living have? Can you step out to a terrace/balcony? Can you step out to a porch/backyard? How many people are currently living in the house, including you?

COVID-19 information. To gather information on the coronavirus pandemic, these questions were included: have you tested positive for COVID-19? Are you living with someone who has tested positive for COVID-19? Do you live with someone diagnosed with a COVID-19 risk condition or related disease? Do you live with any dependent person?

Data analyses

All data were analysed using SPSS version 24•0 (IBM Co. LTD, Chicago, IL, USA). Initial analyses showed that data was not normally distributed. Therefore, non-parametric statistics were used. The Mann-Whitney U test was used to assess group differences. Results included size (n) and frequency (%) for categorical variables. Results were considered significant at $p < 0.05$.

Results

Table 1 shows global results on VPA, MPA, LPA ad METs, and individuals who met WHO recommendations of PA weekly practice (VPA, MPA and MVPA) during the compulsory shelter-at-home health order issued in Spain. Globally, participants were far from meeting the recommended 75 minutes/week of VPA, 150 minutes/week of MPA or a combination (MVPA). Based on gender, data showed that only 30% of males and 21•7% of females met the VPA recommendation, 24.9% and 20.9%, respectively, the MPA recommendation, and these numbers increased to 40.9% and 32.5% for those who reached the minimal amount of MVPA weekly.

Table 2 shows means of all the variables assessed, grouped according to PA practice. Regarding VPA, results in males were significantly higher than females, and they, as average (some scored high and others low), met WHO recommendations for weekly PA practice. VPA levels significantly decreased with age, and it was significantly lower in overweight and obese individuals and those who had lost weight during the confinement. It was significantly higher in those who did not have a dependent person in their homes and those who had been out on the streets during the confinement. Finally, the context where the individuals were enclosed was important, because VPA significantly increased in larger houses, in those with a backyard and among large families (≥5 family members). Regarding MPA, it was significantly higher in males, in older individuals, in those who had lost weight, participants who had been in confinement for a longer time (≥8 days), those who had been on the streets, and those in larger houses, who had a balcony or a backyard. Finally, light PA (LPA) was significantly higher in females, in individuals over 40 years of age, in those who lost weight, in those who lived with a dependent person, and in larger houses with a backyard.

On the other hand, data obtained from those individuals who tested positive on Coronavirus or had someone in the house tested positive were included in Table 2, but they cannot be considered conclusive, because the number of subjects were extremely low. Results should be placed "on hold" until more data are obtained.

Discussion

The goal of this study was to assess Spanish citizens' PA practice at the end of the first week of confinement. Global results showed that the vast majority of the population was below WHO recommendations for VPA, MPA or a combination[11]. Moreover, PA practice was dependent on personal factors such as gender, age or weight, but also contextual factors such as living with a dependent person or the type of house.

The first hypothesis was that participants' physical activity would be below WHO recommendations[11] and results confirmed it. Globally, Spanish citizens confined in their houses were far from the recommended

Table 1. Physical activity during confinement.

	n	%	VPA	MPA	LPA	METs
Global results	1858	100	61.42	98.20	336.13	1967.75
VPA recommendations met						
Males	199	29.5	230.39	155.92	311.09	3423.84
Females	255	21.5	213.33	146.67	633.82	3372.47
MPA recommendations met						
Males	168	24.9	122.37	325.06	453.42	3770.27
Females	247	20.9	114.82	312.88	555.58	3982.91
MVPA recommendations met						
Males	276	40.9	159.06	224.13	346.93	3311.94
Females	385	32.5	136.61	225.98	442.63	3443.98

N: number; %: percentage; VPA: Vigorous Physical Activity; MPA: Moderate Physical Activity; MVPA: Moderate-to-Vigorous Physical Activity.

Table 2. Variables under study regarding Vigorous Physical Activity (VPA), Moderate Physical Activity (MPA), Light Physical Activity (LPA) and METs.

	n	%	VPA	MPA	LPA	METs
Gender						
Male	674	36.3	76.30[a]	108.19[a]	259.75[a]	1854.58[a]
Female	1184	63.7	52.98[b]	92.20[b]	379.93[b]	2032.28[a]
Age						
<25	474	25.5	90.58[a]	97.71[a]	243.28[a]	1908.05[a]
25-39	418	22.5	62.60[b]	85.28[b]	287.30[a]	1768.52[a]
40-54	551	29.0	51.64[c]	101.53[c]	381.59[b]	2039.29[a]
>54	415	22.3	38.96[d]	107.38[c]	431.33[b]	214.89[a]
BMI						
Underweight	69	3.7	64.85[ab]	66.50[a]	443.35[a]	2229.47[a]
Normal weight	1064	56.9	71.47[b]	101.01[a]	327.34[a]	2021.43[a]
Overweight	471	25.0	46.94[a]	95.44[a]	334.33[a]	1845.12[b]
Obese	173	9.5	40.52[a]	101.15[a]	346.27[a]	1865.25[b]
Weight difference						
Increased > 1kg	94	5.1	49.74[a]	71.96[a]	205.32[a]	1341.79[a]
Increased 1kg - 0.1kg	299	16.0	53.23[a]	77.16a[b]	293.82[a]	1677.97[b]
No difference	1008	54.4	57.74[a]	104.90[b]	355.84[b]	2039.71[c]
Decreased 0.1kg–1kg	203	10.9	86.96[b]	101.94[b]	290.30[a]	2056.21[c]
Decreased > 1 kg	114	6.1	94.99[b]	119.48[b]	426.84[b]	2477.46[c]
Coronavirus tested						
Negative	1852	99.7	61.55[a]	98.32[a]	336.83[a]	1971.00[a]
Positive	6	.3	20.00[b]	13.33[b]	47.50[b]	370.08[b]
Someone Corona positive						
No	1852	99.7	61.56[a]	98.26[a]	333.96[a]	2219.65[a]
Yes	5	.3	8.00[b]	50.00[b]	75.00[b]	511.50[b]
Someone at risk						
No	1392	74.9	62.09[a]	97.08[a]	323.76[a]	1960.54[a]
Yes	466	25.1	59.41a	101.53[a]	338.20[a]	1989.46[a]
Living with dependent						
No	1645	88.5	63.71[a]	97.08[a]	323.76[a]	1960.54[a]
Yes	213	11.5	43.72[b]	101.53[a]	338.20[b]	1989.46[a]
Days shelter-at-home						
5 days	611	34.0	60.42[a]	103.04[a]	334.52[a]	1973.09[a]
6 days	594	32.0	64.50[a]	95.59[a]	337.39[a]	2006.37[a]
7 days	434	23.4	60.95[a]	99.76[a]	348.22[a]	2031.23[a]
8 or more days	197	10.6	56.50[a]	75.61[b]	292.65[a]	1637.19[a]
Out on the streets?						
No	357	19.2	47.34[a]	73.57[a]	330.81[a]	1738.85[a]
Yes	1501	80.8	64.77[b]	104.05[b]	337.38[a]	2022.20[b]
House size in M^2						
<70	445	24.0	54.05[a]	86.95[a]	297.43[a]	1761.11[a]
70-90	522	28.1	61.12[ab]	89.58[a]	301.34[a]	1780.25[a]
91-120	391	21.0	58.78[ab]	109.92[b]	333.87[ab]	2000.47[b]
>120	410	22.1	67.69[b]	108.25[b]	408.33[b]	2291.17[c]
Do you have a balcony?						
No	815	43.9	59.80[a]	88.23[a]	310.86[a]	1840.55[a]
Yes	1043	56.1	62.68[a]	105.99[b]	355.89[b]	2067.32[b]
Do you have a backyard?						
No	1409	75.8	58.02[a]	91.39[a]	309.44[a]	1840.88[a]
Yes	449	24.2	72.05[b]	119.67[b]	419.90[b]	2367.61[b]
People in the house?						
1	202	10.9	57.61[a]	110.44[a]	306.71[a]	1886.60[a]
2	502	27.0	57.13[a]	99.78[a]	317.16[a]	1876.81[a]
3	503	27.1	66.71[ab]	97.62[a]	361.87[a]	2099.12[a]
4	497	26.7	59.76[ab]	91.56[a]	333.65[a]	1910.14[a]
≥5	153	8.2	68.87[b]	100.48[a]	362.94[a]	2141.41[a]

[a,b,c,d]: Different superscripts in the same column show statistically significant differences at $p < 0.050$; M^2: Squared meters; PA: physical activity.

75 minutes/week of VPA, 150 minutes/week of MPA or a combination. Roughly, less than 1/3 of males and 1/5 of females met these criteria, which slightly increased when considering MVPA scores (combination). However, a vast majority were not able to meet the recommendations. Insufficient PA has been considered a prominent risk factor for non-communicable diseases (i.e., diabetes, strokes, osteoporosis…), mental health (i.e., anxiety, depression, mood disorders…) and, consequently, poor quality of life[10]. Results showed that Spanish citizens confined in their houses for a week were not exercising as much as needed and this could be considered a serious health risk factor. Experts have warned that mandatory shelter-at-home health orders like the ones issued in many different countries due to COVID-19 could be repeated in the future. Therefore, national authorities should consider the findings from the present study to prevent citizens from putting their health at jeopardy while in confinement. In the Spanish case, citizens had less than 24 hours to prepare for the self-quarantine. Clearly insufficient to collect the needed resources to exercise at home. More time and adequate training and materials are needed.

The second hypothesis was that participants' physical activity would be different depending on the individual's living conditions and results confirmed it. Living with a dependent person, the size and type of house and the number of individuals in the house significantly affected participants' PA practice. Those living with a dependent person had significantly lower VPA and higher LPA, since he/she demands specific care that requires time and energy, deriving it from PA. This is in line with previous studies, which found that physical inactivity is usually high among caregivers[21]. On the other hand, larger houses, balconies and backyards were linked to higher PA, since individuals probably had more space and better conditions to exercise. Linked to housing, larger number of individuals living in the same house was also connected with higher VPA. Large families tend to live in bigger houses with more room for exercise. To our knowledge, this is the first study to assess the associations between housing conditions and PA. Previous researchers studied the influence of the neighbourhood social environment[22], but not the inside of the homes. Results from the present study suggest that houses design can promote or reduce inhabitants' PA, and it should be considered.

In conclusion, the shelter-at-home health order issued by the Spanish Government prevented that vast majority of individual from meeting the WHO recommendations of VPA and MPA with all the health-derived consequences. Individuals' weekly practice was dependent on personal factors such as gender, age or weight, but also contextual factors such as living with a dependent person or the type of house. Situations like this one could be repeated in the future, and national authorities should consider the findings from the present study to prevent citizens from putting their health at jeopardy withstanding a quarantine at home.

The present study is not without limitations. The first one is that data is preliminary and the second one is the use of self-reported PA measures. However, there is a need to understand as fast as possible this Public Health Emergency and its impact on human behaviour.

Conflict of interest

The authors do not declare a conflict of interest.

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Comparison of intensity and post-effort response in three interval trainings in young tennis players: running interval, specific interval, and specific intermittent training

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Summary

Introduction: In recent years, considerable interest has been shown in adapting training to the specific characteristics of tennis. The use of intermittent exercise seems to adapt better to the sport's work/recovery structure and using specific movements allows for local adaptations and complex work. Nevertheless, we need to achieve a level of intensity that is at least similar to what is achieved when continuous running is used. The ability to recover between points is also a decisive factor in terms of performance. Our hypothesis is that recovery depends on stimulus type, which means the most suitable stimuli must be chosen to improve this capacity.
Material and method: Our study's goal was to compare the intensity and post-effort behaviour triggered by three types of exercise: continuous running with 2-minute intervals (GIT), rallies with 2-minute intervals (SIT) and intermittent rallies (SIIT). We measured heart rate (HR) and blood lactate levels during the three exercises, as well as the recovery to 130 beats and in the first 10 and 20 seconds post-effort.
Results: Heart rate intensity was significantly higher in SIT than in GIT and lactate levels were higher in both SIT and SIIT compared to GIT. Heart rate recovery is significantly slower in both specific exercises, increasing in the first 10 and 20 seconds with SIIT.
Discussion: We have reached the conclusion that specific training led to greater intensity in the specific exercises. Post-effort response is slower in the specific trainings and paradoxical in the initial seconds of intermittent training

Key words:
Tennis. Specific training. High intensity. Intermittent. Recovery.

Comparación de la intensidad y la respuesta post-esfuerzo en tres entrenamientos interválicos en jóvenes tenistas: interválico de carrera, interválico específico e intermitente específico

Resumen

Introducción: En los últimos años se ha producido un gran interés por adaptar el entrenamiento a la especificidad del tenis. El uso de ejercicios intermitentes parece adaptarse más a la estructura de trabajo/recuperación de este deporte que las actividades continuas. A su vez, utilizar movimientos específicos permite adaptaciones locales y trabajar de forma compleja. Sin embargo, se necesita alcanzar un nivel de intensidad que sea al menos similar al que se logra cuando se utiliza la carrera continua. La capacidad de recuperar entre puntos es un factor decisivo en el rendimiento. Nuestra hipótesis es que la recuperación puede ser diferente según sea el tipo de estímulo y que habrá que escoger los más adecuados para mejorar esta capacidad. No obstante, es necesario que estos entrenamientos tengan una intensidad al menos similar a cuando se utiliza la carrera continua.
Material y método: Nuestro objetivo en este estudio es comparar la intensidad y el comportamiento post-esfuerzo de tres ejercicios: carrera continua con intervalos de 2 minutos (GIT), golpeo de bolas con intervalos de 2 minutos (SIT), golpeo de bolas con intermitencias (SIIT). Hemos medido la HR y el lactato durante los tres ejercicios y la recuperación a 130 pulsaciones, y en los 10 y 20 segundos post-esfuerzo.
Resultados: La intensidad cardiaca fue significativamente mayor en SIT que en GIT, y el lactato superior en SIT y SIIT, respecto a GIT. La recuperación cardiaca es significativamente más lenta en ambos ejercicios específicos, llegando a incrementarse en los 10 y 20 segundos iníciales en SIIT.
Discusión: Concluimos que con el entrenamiento específico se ha alcanzado una elevada intensidad en los trabajos específicos. La respuesta post-esfuerzo es más lenta en los entrenamientos específicos, y paradójica en los primeros segundos en el entrenamiento intermitente.

Palabras clave:
Tenis. Específico. Intensidad. Recuperación. Interválico. Intermitente.

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Introduction

The ability to change direction at speed is essential to performance in sports such as tennis[1]. The ability to undertake a number of actions at a high rate of intensity depends on different factors such as explosive strength[2] and an optimum aerobic level[3,4]. It is therefore interesting to understand the characteristics of different methods of high intensity training in order to ensure improved performance, taking into consideration the duration and intensity of the training and whether motor action is specific or general.

In recent years, studies of specific types of exercises in team sports[5-7] and in tennis[8] have been undertaken, in which high levels of intensity have been identified.

Recovery between specific actions shows highly variable behaviour among sportspeople. Even in sportspeople with a similar level of cardiorespiratory resistance, recovery between intermittent actions appears in very different ways[9].

Monitoring heart rate reduction is a suitable way of measuring an athlete's fitness, while it will also show us if there is positive adaptation to the type of effort, which means training must consider the kind of load created by the characteristics of each different sport[9].

Blood lactate measuring will provide us with data regarding glycolytic participation and the different disposal dynamic, according to the characteristics of the effort.

Therefore, it is of great interest to study the different specific tennis-based exercises and their intensity, but also the analysis of the recovery stages could be specially relevant to deepen in a in a training method that is better suited to the needs of this sport.

Material and method

Participants

The sample consisted of 13 healthy male tennis players. The average age was 17±2 years, the average height 176.5±4.4cm and the average mass 69.5±3.4kg. Weekly training hours and years of play were 12±2h/week and 7±3 years, respectively. All subjects provided their consent at the beginning of the research.

Players frequently play in national level tournaments and each one undergoes an extended pre-season training period of 3 months They are used to general running-based continuous and interval training.

Design and Procedures

Before carrying out the study, a Conconi test was undertaken using an ergometrics test in the laboratory to obtain each subject's maximum heart rate. The ergometric values were taken at 18:00 hours on different days and the subjects were told not to undertake any intense effort during the previous 24 hours or eat any food in the 2 hours before the values were registered. The test consisted of a progression run with a constant 5% gradient at an initial speed of 5km/h, increasing by 1km/h every minute.

The experimental study was carried out at the Asturias Regional Sports Centre *(Centro Regional de Deportes del Principado de Asturias)* during the pre-season period. Running tests were undertaken on a regulation-size grass football field. Specific tennis tests were undertaken on medium-speed synthetic resin tennis courts.

Three test protocols were designed:

– Running interval training: General Interval Training (GIT).
– Interval stroke-based training: Specific Interval Training (SIT).
– Intermittent interval stroke-based training: Specific Intermittent Interval Training (SIIT).

The exercises were carried out over the space of two weeks: first, the running work; then, the stroke-based exercises; and finally, the intermittent stroke-based exercises. Each athlete undertook three tests per week with 72 hours' rest between each test.

Test protocols

– *GIT.* Running at a 90% subjective intensity rate, made up of 3 sets of 3 repetitions, with 130-beat recovery between repetitions and at 120 beats between sets for being a heart rate commonly used in interval training.
  Before the exercise, the players warmed up with a gentle, continuous 10-minute run.
– *SIT.* This exercise used the same structure (3x3x2 minutes) and recovery patterns and were based on forehand and backhand strokes, on both sides of the court (from sideline to sideline) as cross-shots, behind the service box. Movement and shot rate was a 90% subjective intensity, set by the player. To do this, the trainer threw the ball with their hand into the area surrounding the sidelines.
– *SIIT.* This exercise used the same structure of work and recovery between repetitions and sets. Nevertheless, micro-intervals of work and recovery were undertaken in each repetition in the following way: 20-second rally, 20-second recovery, 20-second rally and subsequently 15-second intermittences until the 2-minute period was completed. Interval times were varied to facilitate the initial elevation of HR and to adjust more to the variability of tennis.

Once again, the trainer threw the ball at the rate set by the player, hitting with the forehand and backhand and returning to the centre of the court. The recovery intermittence phases were always passive.

As a warm-up for both specific exercises, players undertook a gentle 10-minute rally.

The same monitoring approach was used for the three tests. Polar heart rate monitors were used (Polar RS400 Finland), registering heart rate data at all times. Blood lactate levels were measured with portable analysers Lactate Pro 2 (Arkray, Japan). Blood samples were taken in the ear, at the end of the three sets and 3 minutes after completing the test, taking a sample volume of approximately 0,3 Ml, in order to evaluate lactate levels and recovery.

All the data were subsequently organised, analysed and evaluated.

Statistical Analysis

The two-tailed t-test was used for comparing sample averages, analysing the null hypothesis that the averages are the same compared with the alternative that they are not. With a p-value of 0.05 or lower, a significance level of 95% is achieved.

Results

Heart Rate

A more intense heart rate was achieved in the two specific trainings, with a significant difference in SIT compared to GIT (0.0484) (Table 1). No statistically significant differences were found between the specific exercises (≥0.05), with similar behaviour between the total values and when comparing the different sets.

Lactate

On completing the exercise, it can be seen that lactate levels are significantly higher in SIT and SIIT than in GIT (Table 2). There is also a significant difference in the first set of exercises, with SIT-SIIT > GIT, indicating greater intensity from the very first repetitions of the specific training exercises. There are no differences between the specific play-based exercises.

Recovery heart rate

Recovery in the running-based efforts was faster than in the play-based exercises in all three sets, with 130 beats achieved sooner than in the specific tennis-based efforts (GIT > SIT-SIIT).

As for recoveries in the initial seconds, significant differences can be seen, with swifter reduction in the running-based exercises compared to the play-based ones. HR reduction is also greater between the specific non-intermittent exercises compared to those involving intermittent work and recovery (GIT > SIT, and GIT-SIT > SIIT) (Table 3).

Table 1. Average rates of maximum individual HR as a reference parameter. Average HR and percentage from maximum HR as a benchmark.

	GIT	SIT	SIIT
Maximum individual HR (bits)	198.69	198.69	198.69
Average HR (bits / %)	172.02 / 86.57	180.59 / 90.89	177.87 / 89.52

HR. SIT > GIT 0.0484.
GIT: General Interval Training; SIT: Specific Interval Training; SIIT: Specific Intermittent Interval Training.

Table 2. Lactate averages in mMol/l in sets 1, 2 and 3 in the three types of training.

	GIT	SIT	SIIT
Set 1	4.86	7.04	6.97
Set 2	6.68	6.74	7.46
Set 3	6.63	8.02	8.07

Lact: SIT Set 3 > GIT Set 3 0.0215 / SIIT Set 3 > GIT Set 3 0.0503.
SIT Set 1 > GIT Set 1 0.0011 / SIIT Set 1 > GIT Set 1 0.0101.
GIT: General Interval Training; SIT: Specific Interval Training; SIIT: Specific Intermittent Interval Training.

Table 3. Average time invested in recovery to 130 beats (Recovery 130). Reduce beats in the first 10 and 20 seconds post-effort (Recovery 10 seconds, Recovery 20 seconds).

	GIT	SIT	SIIT
Recovery 130 bits (seconds)	56.36	86.55	76.54
Recovery 10 seconds (seconds)	-5.25	-1.95	1.22
Recovery 20 seconds (seconds)	-13.96	-7.34	-3.06

Recovery 130 beats. GIT > SIT 0.0000 / GIT > SIIT 0.0027
Recovery 10 seconds. GIT > SIT 0.0003 / GIT > SIIT 0.0000 / SIT > SIIT 0.0035
Recovery 20 seconds. GIT > SIT 0.0010 / GIT > SIIT 0.0000 / SIT > SIIT 0.0102
GIT: General Interval Training; SIT: Specific Interval Training; SIIT: Specific Intermittent Interval Training.

Table 4. Lactate average in mmol/l 3 minutes post-effort and the reduction rate between end values and 3-minute post-effort levels.

	GIT	SIT	SIIT
Lactate averages after 3 minutes (mMol)	4.26	5.87	6.70
Reduction rate (mMol)	2.37	2.15	1.37

Recovery lactate. GIT > SIIT 0.0010.
GIT: General Interval Training; SIT: Specific Interval Training; SIIT: Specific Intermittent Interval Training.

Recovery lactate

After three minutes of recovery, significantly lower values were provided with GIT than with SIIT (Table 4). Nevertheless, when the reduction rates or the fall in blood lactate levels are viewed by comparing the end values to those found 3 minutes after, they are not significant, although they are greater in the running-based training (Table 4 and annexed Table 2).

Discussion

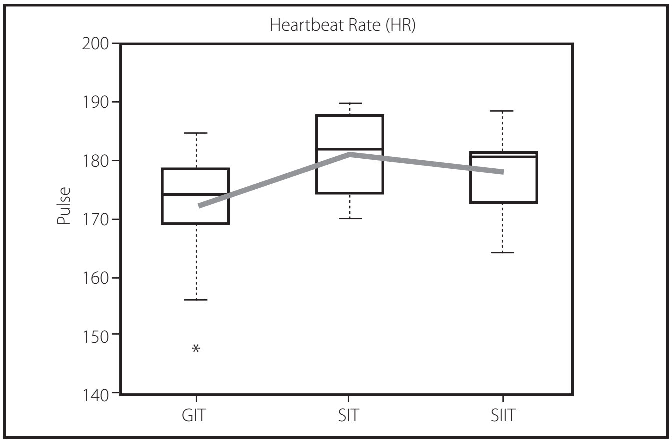
HR Intensity

In our study, the specific tennis-based exercises showed higher HRs compared to the general continuous running exercises (Figure 1), which may be down to the type of movements undertaken (lateral movement, acceleration and deceleration, which all involve constant explosive actions and eccentric tensions). SIT showed a significantly greater HR intensity than GIT. Dellal *et al.*[10] observed in a study with 10 professional footballers using high-intensity intermittent exercises (30:30, 20:20 and 15:15) that specific actions are more glycolytic and show that accelerations and decelerations lead to the higher participation of glycolytic pathways, with higher HR and lactate values.

Lactate intensity

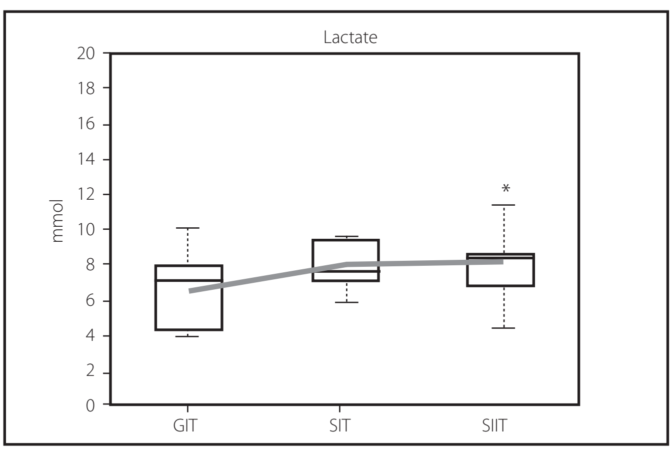
Lactate behaviour is very similar in SIT and SIIT. Nevertheless, significantly higher values are shown between the two types of specific training and the general training exercise (Figure 2). The non-significant difference in heart rate between SIIT and GIT accompanied by significant lactate levels may indicate increased participation of fast twitch muscle

Figure 1. Distribution of individuals' average HR for GIT, SIT and SIIT.



GIT: General Interval Training; SIT: Specific Interval Training; SIIT: Specific Intermittent Interval Training. The box shows the dispersion of the sample, defined by the 25th (lower limit) and 75th (upper limit) percentiles; the red line defines the median and the black lines the upper and lower limits, outside of which values are considered to be outliers. These are marked with red crosses.

Figure 2. Distribution of individuals' lactate levels in GIT, SIT and SIIT.



GIT: General Interval Training; SIT: Specific Interval Training; SIIT: Specific Intermittent Interval Training. The box shows the dispersion of the sample, defined by the 25th (lower limit) and 75th (upper limit) percentiles; the red line defines the median and the black lines the upper and lower limits, outside of which values are considered to be outliers. These are marked with red crosses.

fibres in intermittent training. Protocols involving intermittent work with very short periods of work and recovery may increase the engagement of fast twitch muscle fibres[11]. As in our study, Zouhal *et al.*[12] found higher HR and lactate values in specific football-related efforts compared with high intensity short interval running exercises (15:15).

Heart rate recovery

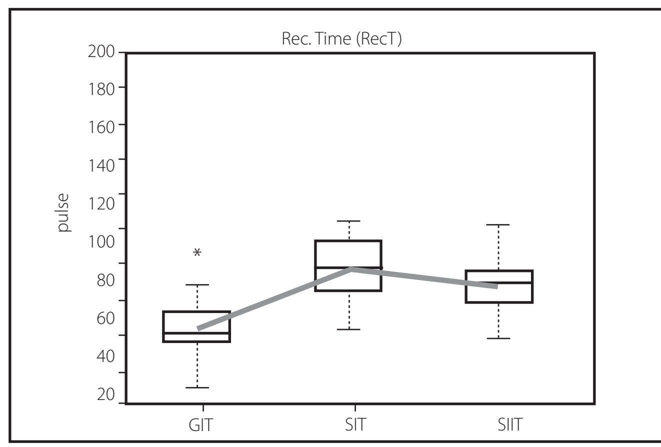
In intermittent sports such as tennis, optimum recovery between points is decisive. Greater engagement of fast twitch muscle fibres and anaerobic participation leads to sympathetic activation[13,14].

We have observed different behaviour in the specific exercises, with slower post-effort recovery (Figure 3). The delay in recovery in SIT compared to GIT may be explained by increased intensity. Nevertheless, intensity in SIIT was not significantly greater, which means that the explanation may lie in the dynamic of the actions, with the increased participation of fast twitch fibres and higher blood lactate concentrations.

When work is intermittent and high intensity, a delay in heart rate activation may be caused in response to the motor action, along with a stage of maximum HR in the initial seconds of recovery[15].

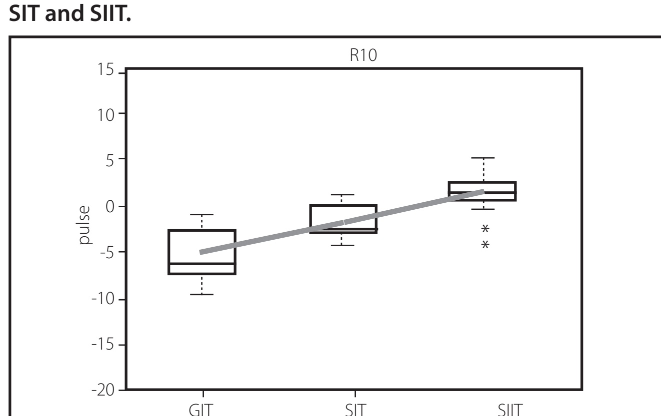
In our study, the response 10 and 20 seconds post-effort was significantly slower in SIIT than in SIT (Figures 4 and 5), showing a post-effort increase in HR. For Hamar *et al.*[16], when work is short and intense, heart rate does not show sudden changes but is slightly higher during the initial seconds of rest.

Figure 3. Distribution of 130-beat recovery for GIT, SIT and SIIT.



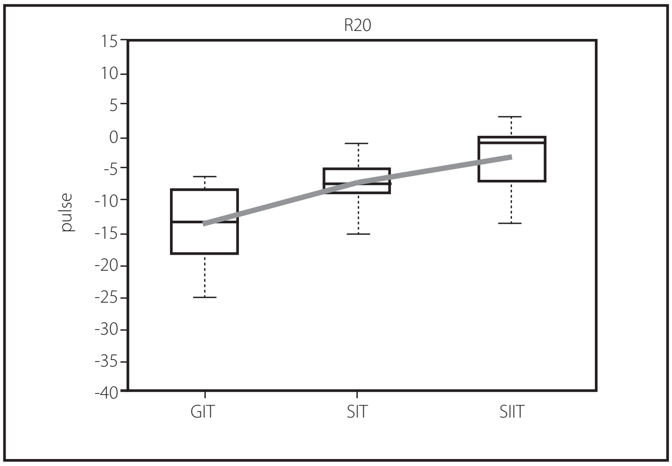
GIT: General Interval Training; SIT: Specific Interval Training; SIIT: Specific Intermittent Interval Training. The box shows the dispersion of the sample, defined by the 25th (lower limit) and 75th (upper limit) percentiles; the red line defines the median and the black lines the upper and lower limits, outside of which values are considered to be outliers. These are marked with red crosses.

Figure 4. Distribution of recovery 10 (R10) seconds later for GIT, SIT and SIIT.



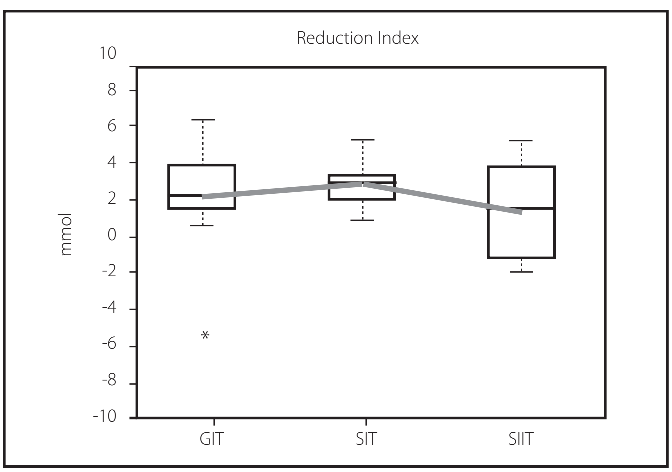
GIT: General Interval Training; SIT: Specific Interval Training; SIIT: Specific Intermittent Interval Training. The box shows the dispersion of the sample, defined by the 25th (lower limit) and 75th (upper limit) percentiles; the red line defines the median and the black lines the upper and lower limits, outside of which values are considered to be outliers. These are marked with red crosses.

Figure 5. Distribution of recovery 20 (R20) seconds later for GIT, SIT and SIIT.



GIT: General Interval Training; SIT: Specific Interval Training; SIIT: Specific Intermittent Interval Training. The box shows the dispersion of the sample, defined by the 25th (lower limit) and 75th (upper limit) percentiles; the red line defines the median and the black lines the upper and lower limits, outside of which values are considered to be outliers. These are marked with red crosses.

Figure 6. Distribution of lactate recovery. Difference between final lactate and lactate after 3 minutes (Reduction Rate) for GIT, SIT and SIIT.



GIT: General Interval Training; SIT: Specific Interval Training; SIIT: Specific Intermittent Interval Training. The box shows the dispersion of the sample, defined by the 25th (lower limit) and 75th (upper limit) percentiles; the red line defines the median and the black lines the upper and lower limits, outside of which values are considered to be outliers. These are marked with red crosses.

Different behaviour can be seen at the 130-beat recovery stage compared to the initial post-effort stages. The immediate response after concluding the exercise is clearly different in SIIT, with an increase during the initial 10 and 20 seconds, constituting paradoxical behaviour. The mechanisms used in post-effort recovery are different in the initial seconds with the deactivation of the sympathetic system, compared with the period after recovery, which depends on the activation of the parasympathetic system[17].

The choice of one type of work or another will be decisive in improving recovery between points (a maximum of 20-25 seconds in a match), which, in many cases, is decisive in tennis.

Lactate recovery

As far as lactate recovery is concerned, the differences are not so clear. While measurements after 3 minutes are significantly lower in SIIT compared with GIT, when the reduction between post-effort measurement and measurement after 3 minutes is taken into account (reduction rate), the difference is not significant. Nevertheless, lower values can be seen in the reduction rate in both specific types of exercise and especially in SIIT (Figure 6). This less significant drop in lactate concentration levels may be down to the increased participation of the glycolytic fibres[11] and a more local activation with a more gradual presence of lactate in the lactacidaemia measurements.

The different behaviour both in terms of heart rate and lactate level recovery in intermittent tennis-based exercises, could be explained by a greater muscle mass involved and a more intense eccentric work. The study shows that this type of training can act specifically on the short rest periods that occur during a tennis match.

Conclusion

In our study, players have registered higher HR and blood lactate values in specific efforts, related to increased intensity of work. Specific tennis-based efforts show slower recovery compared to general running exercises. Specific intermittent training has shown paradoxical behaviour in the initial seconds of recovery, with a raised HR in the first 10 and 20 seconds. Consequently, specific training allows for work to be undertaken at sufficiently high levels of intensity so as to allow for maximum training of aerobic potential. Specific intermittent training allows for high intensity complex training, with action affecting the immediate recovery mechanisms that are so decisive for tennis players' performance.

Conflict of interest

The authors do not declare a conflict of interest.

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Optimum timing in creatine supplementation for improved sporting performance

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Summary

Creatine is a sports supplement with high scientific evidence on its effects on performance and with emerging health's results, including for vegetarian athletes and older adults. The creatine type and effective doses have been well studied, presenting consistent results. However, not many studies have evaluated the ingestion timing in terms of its interaction with the creatine effects. The aim of this review is to analyze the different existing scientific literature on creatine supplementation protocols and their interaction with the timing of ingestion, in order to assess whether there is a greater effect of the ergogenic dose of creatine considered effective when It is ingested before, post workout or at another time of the day. The results of this work presented different types of protocols and doses in creatine supplementation, despite being diverse the protocols shown in the literature, the most effective consisted of a consumption of 0.3 g/kg/d for five days, followed by a consumption of 0.03 g/kg/d, thus achieving a greater reserve of PCr in skeletal muscle. Studies showed greater benefits when creatine intake was carried out in the moments close to workout due to greater blood flow, the studies pointing to significant improvements in post-workout consumption, since creatine can increase the rate of glycogen uptake in muscle and increase insulin sensitivity.

Key words:
Creatine. Sport.
Dietary Supplements.
Athletic performance.

Timing óptimo en la suplementación con creatina para la mejora del rendimiento deportivo

Resumen

La creatina es un suplemento deportivo con una elevada evidencia científica sobre sus efectos en el rendimiento y con resultados emergentes en la salud, incluida la de deportistas vegetarianos y adultos mayores. El tipo de creatina y las dosis efectivas, han sido bien estudiadas presentando resultados consistentes. Sin embargo, no son muchos los estudios que han evaluado el momento de la ingesta en cuanto a su interacción con los efectos de la creatina. El objetivo de esta revisión, es analizar la diferente literatura científica existente sobre los protocolos de suplementación con creatina y su interacción con el momento de la ingesta, con el fin de evaluar si existe un efecto mayor de la dosis ergogénica considerada efectiva de creatina cuando esta es ingerida antes, después del entrenamiento o en otro momento del día. Los resultados de este trabajo presentaron diferentes tipos de protocolos y dosis en la suplementación con creatina, a pesar de ser diversos los protocolos mostrados en la literatura, el más efectivo constó de un consumo de 0,3 g/kg/d durante cinco días, seguido de un consumo de 0,03 g/kg/d consiguiendo de esta forma, una mayor reserva de PCr en el músculo esquelético. Los estudios mostraron mayores beneficios cuando la ingesta de creatina se realizó en los momentos cercanos al entreno debido al mayor flujo sanguíneo, apuntando los estudios a mejoras significativas en un consumo post-entreno, debido a que la creatina puede aumentar la formación de de glucógeno en el músculo y aumentar la sensibilidad a la insulina.

Palabras clave:
Creatina. Deporte.
Suplementos dietéticos.
Rendimiento deportivo.

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Introduction

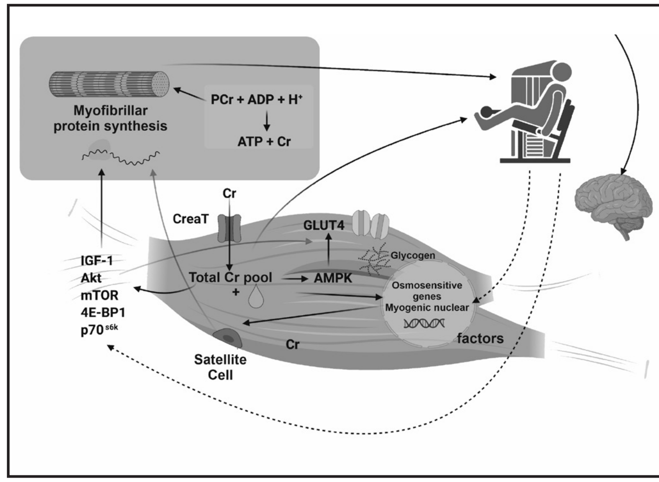
The use of sports supplements (SS) in sport is considerably widespread. In a recent study performed on Spanish athletes from different modalities, it was observed that 64% of them had consumed SS[1]. The reasons behind athletes taking SS are diverse, with the main reported motivation being to improve performance, according to scientific literature[2]. With the aim of finding ways to improve performance, there are some ergogenic aids, such as creatine monohydrate (CrM) with a high level of evidence. In this respect, recently the International Olympic Committee[2] took a positioning in which it assessed the different SS and their degree of evidence, in which creatine (Cr) is considered a SS in Group A, i.e., with a high level of evidence as an ergogenic aid. Over eighty reviews report the ergogenic and therapeutic effect of Cr[3]. Various meta-analyses and systematic reviews[4,5] support these affirmations, observing improvements in lower and upper body strength, in high intermittent intensity training (HIIT), muscle mass and recovery, though few studies indicate positive effects on aerobic performance[6].

Cr (methylguanidoacetic acid) is a natural nitrogenous organic acid[7] which is synthesised endogenously in the liver, pancreas and kidneys from three amino acids: arginine, glycine and methionine, at 1-2 grammes of Cr per day[8], as well as being contributed exogenously through food, which compensates for losses of approximately 2 g/day[9]. Once synthesised, 90% of the Cr is stored in the skeletal muscle in the form of phosphocreatine (PCr) (60%) and free Cr (40%)[10]. The main action of the PCr is linked to the re-synthesis of ATP via the transfer of the phosphate group to ADP. The re-synthesis of ATP measured by the PCr, allows for increased performance during short-duration high-intensity actions, in which the phosphagens channel is the main source of energy. Therefore, the effect of Cr supplementation has been viewed with particular interest in terms of improving performance in high-intensity exercises lasting less than 30 seconds, proving most evident where there are repeated periods of intense exercise, such as strength training, for example[11]. Furthermore, strength training combined with taking Cr, allows for an increase in the intensity of the training, which entails greater adaptations and muscle mass gains[12,13].

Added to the amplifying effect of performance in these kinds of actions, the reaction catalysed by the creatine kinase enzyme has been seen to consume a hydrogen ion (H+), which can contribute to an intracellular buffering action during exercises that entail a high glycolytic pathway activity, and therefore, a lower drop in pH and of neuromuscular fatigue associated (Figure 1).

In terms of the Cr supplementations doses and protocols, a diverse and broad bibliography has been found, however, literary results regarding the most beneficial timing in terms of Cr consumption are not so abundant[14]. The main objective of this review is to analyse the different scientific literature available about Cr supplementation protocols and interaction with intake timing, with the aim of assessing whether there is a greater effect on the ergogenic dose of Cr considered effective when consumed before or after training, or at another time during the day.

Figure 1. Proposed mechanisms of creatine.



Variables to consider in the responses to creatine supplementation

The differences in response to supplementation, must be considered by the different professionals as part of the customisation of the diet and supplementation programme, taking into account variables such as the type of diet and age.

Vegetarian or vegan diet

Cr is found naturally in meat and fish, and in very small quantities in some vegetables, which means that due to the reduction or lack of intake of these food groups among vegetarians or vegans, Cr consumption is lowered or practically absent[15]. Furthermore, if vegan athletes do not introduce vitamin B12 supplementation into their diet, they may suffer a deficiency of this micro-nutrient, interfering with their endogenous synthesis of methionine, and with it, a lower biosynthesis of Cr[16].

Among these demographics, it has been observed that the Cr content in different tissues, such as muscle, plasma, red blood cells, is lower than that of omnivores, though not in brain tissue[17]. Studies performed using an analysis of lateral vast muscle biopsy samples, have observed that total Cr levels (Cr + PCr) are lower in vegetarians than in omnivores, specifically: some 10-15% of the total; 7-10% of PCr and 7-26% of the Cr[18]. This could indicate that CrM supplementation could be of interest for athletes who follow this food pattern, because given the low levels of this amino acid on a muscle level, this could affect performance at high intensity due to the premature appearance of fatigue[19]. Likewise, the results from a recent systematic review[18] reveal how Cr supplementation in vegetarians is effective in increasing Cr and PCr to higher levels than those obtained in omnivores. The minimum recommended intake for this demographic, is around 1 g/d (amount equivalent to that found in one fillet of meat)[20]. Therefore, Cr supplementation among vegetarians could be an efficient ergogenic aid to increase performance, with no current conclusive data available of how this effect may be greater than that observed in omnivores[18].

Age

Despite the vast amount of literature available regarding the effectiveness of Cr supplementation in adult athletes, there is limited data in terms of children or teenagers. This lack of available literature is probably attributable to ethical restrictions, security issues and methodological challenges. Although its use in children and teenagers has commonly been discouraged[21] there is no evidence of any dangers or adverse effects on this demographic[22]. In fact, the only clinically proven side effect is a 1-2 Kg weight increase, with no evidence that its short- or long-term use (as long as the 30 g/d dosage over a period of 5 years is not exceeded) has negative effects on a healthy population from infancy to old age[23].

Some studies have shown that Cr content reduces with age, what is not known is if this is due to low levels of physical activity or the ageing process[24]. Furthermore, the quantity and amount of Type II fibres diminishes progressively with age, with some studies[25] observing that individuals with more type II fibres and a larger transversal session area, respond better to Cr supplementation, which can determine that older adults have an attenuated anabolic response to Cr supplementation[9].

A recent review[26] that assessed Cr supplementation combined with exercise on healthy older adults, reveals a positive effect with at least 12 weeks of resistance training. Its supplementation combined with moderate to high-intensity exercise in older people, would lead to an improvement in muscle health. This issue is particularly important in all countries with progressive ageing, given the special rate of morbidity associated with sarcopenia, such as fractures caused by falls, for example.

In addition to these benefits applicable to training and physical activity in older people, other benefits of Cr supplementation have been found, related to a greater capacity to reason quickly and think abstractly, known as "fluid intelligence", refuting double-blind tests performed on subjects of advanced age, who underwent memory tests[27,28]. A possible useful effect has also been associated, regarding spinal and bulbar muscular atrophy, as during the development of this pathology, there is a drop in intramuscular Cr levels, possibly related to the appearance of muscle weakness in these patients. Clinical trials are currently underway to assess the use of Cr as treatment for this pathology[29]. A relationship has also been observed between supplementing and an improvement in the state of health, despite ageing, with better lipid profile, lower growth of body fat compartment, and a reduction of oxidative stress and bone resorption among other effects[30].

Safety of creatine

To date, not many studies have assessed the safety of Cr with a comparison of its effects on performance or on certain pathologies[31,32]. Studies about safety among males using CrM can be found in scientific literature, observing renal dysfunction, compartment syndrome in the legs, rhabdomyolysis, ischaemia cerebrovascular accident, atrial fibrillation, acute cholestatic hepatitis injury, and toxic hepatitis. However, this data has not been replicated with placebo controlled clinical trials[3].

A recent study has assessed the adverse outcomes of CrM supplementing on non-pregnant post pubertal females, concluding that this supplement is safe for this demographic[3]. A similar conclusion to the results of other reviews performed on males or in mixed-sex studies, in which CrM taken within the dose and guidelines recommended by the different manufacturers and sporting-nutrition organisms around the world, appear to be safe, with no advantages revealed of using other forms of Cr[31], which furthermore tend to have a higher market cost.

Supplementation protocols and optimum consumption dose

The study by Roger Harris *et al.*[20] revealed how CrM supplementation increased muscular Cr content by around 20%. Most of the studies with Cr commonly used a protocol based on the study by Hultman *et al.*[33], in which they compared different protocols and discovered the most effective was supplementing with a load phase of 5-6 days, with a standard dose of 20 g/d or 0.3 g/kg/d, followed by a maintenance phase of 2 grammes a day or 0.03 g/kg/d.

With regards to the Cr load protocol, a recent study performed on 17 trained males, revealed how intakes of 20 g/d over 5 days combined with strength training, produced an increase in performance[34]. However, the vast majority of studies that have assessed the effects of Cr supplementation with the load and maintenance phase, have been performed on males. In the case of females, another trial has been carried out with the aim of assessing an increase in physical aptitude, performance or body composition, in response to four weeks of HIIT training combined with Cr supplementation. In this case, the initial supplementation was 0.3 g/kg/d over 5 days, followed by a maintenance phase of 0.1 g/kg/d for 23 days, combined with HIIT. The study concluded that the addition of Cr did not improve cardiorespiratory aptitude, nor did it improve the body composition of the females tested[35]. However, more studies are required that analyse the influence on both sex and gender of Cr supplementation.

The Cr load phase may increase body weight by approximately 2% due to an increase of intracellular water caused by the osmotic effect of the Cr[36]. It is important to advise that this effect is necessary as different studies have revealed the activation of specific osmosensitive genes in response to Cr supplementation, and therefore, it forms part of the action mechanism[37].

In other supplementation protocols, an intake of only 0.1 g/kg/day has been chosen, though this final protocol requires more days to cause an ergogenic effect[38]. In this respect, Galvan E, *et al.*[32], performed a trial on 13 healthy and physically active adults, who were split into 4 groups, each supplemented with a different dosage of CrM (1.5 g, 3 g, 5 g and placebo, respectively), with the aim of assessing the dependent effects of the doses on safety and performance rates of exercise. The authors conclude that up to 3 g/day is a safe and effective dose in terms of changes in strength and body composition.

Yáñez-Silva A, *et al.*[39] performed a study on young elite football players with the aim of establishing the effects of CrM supplementation on muscle power. To do this, they used low consumption doses, with 0.03 g/kg/d for 14 days. The footballers were split into two groups, with one group consuming Cr the other a placebo. This was also a double-blind study. The anaerobic Wingate test was used to measure the results. Significant improvements were observed comparing power before and after the supplementation period. The placebo group also obtained improvements (influenced by training or external factors), but not as significant as those in the group that consumed Cr.

Another study performed on men40 examined the effect of the so-called "load phase", analysing two methods of dosing daily intake. The subjects were split into two groups, and over 5 days they consumed CrM, the first group taking 4 x 5 g/d and the second group consuming 20 x 1 g/d, which obtained a lower urinary excretion of Cr and methylamine, leading to an estimated increase of Cr in the entire body and most probably in the muscle. The authors concluded that an intake of small doses, distributed evenly throughout the day, generated an improvement in the body and muscle retention of Cr.

Optimum timing in creatine supplementation

Attempts have been made to clarify the optimum timing for Cr consumption, however, studies to this effect are more limited (Table 1) compared to those performed for other supplements[14,41].

Regarding the most beneficial timing for Cr consumption, most studies take Antonio y Ciccone[42] as reference, in which they compare the effects of supplementing before and after training. 19 body-building males participated in this study, competing 5-day programmed training for 4 weeks. The study showed that consuming 5 gr of CrM post-training, generated greater benefits in strength and improvements to body composition compared to pre-training consumption.

In a later study performed by Candow *et. al*[43], they observed that 32 weeks of Cr supplementation (0.1 g/kg) in healthy older adults (50-71 years) immediately after strength training, led to greater lean mass compared to consumption immediately before exercise. However, the muscle strength increases produced by the Cr occurred regardless of the intake timing.

The observation from the Antonio y Ciccone[42] study was not confirmed by the other study performed by Candow *et al.*[44], whose aim was to compare the effects of Cr supplementation before *vs*. after strength training exercise. This time, the sample constituted 22 healthy older adults (9 males, 13 females, between 50-64 years), performing strength training over 12 weeks (3 days a week). They were divided into two groups: with some consuming Cr before training and some after training, compared to a placebo group. During the 12-week training period, both groups experienced a significant increase in lean mass in the whole body, as well as an increase in strength in the lower and upper body without differences between groups. The authors concluded that changes in muscle mass or strength were similar regardless of the timing of consumption.

The same occurred in the study by Cooke *et al.*[45], which assessed the effects of consuming Cr (with 5 g of additional carbohydrates) after exercise on body composition and muscle strength in 20 older adult males (55-70 years) over 12 weeks, participating in a programmed high

Table 1. Study characteristics about the optimum timing for sports supplementation with creatine.

Author	Participants (Number/gender/age)	Type of training	Supplement	Doses	Duration	Time of taking supplement	Results / Conclusions
Cribb and Hayes (2006)	23 / males / 18 -28 years	Strength training	Creatine + protein + glucose	1 g/kg (7 g/100 g de creatine)	10 weeks	Pre-training / post-training vs dawn / dusk	Greater muscle mass gain and increases in muscle strength at times near training
Antonio and Ciccone (2013)	19 / males / 23.1± 2.9 years	Bodybuilding	Creatine	5 g	4 weeks	Pre-training vs. post-training	Improvement in strength and body composition with post-training consumption
Candow *et al*. (2014)	22 (9 males; 13 females) / 50-64 years	Strength training	Creatine	0,1 g/kg	12 weeks	Pre-training vs. post-training	Changes in muscle mass or strength similar regardless of the timing of consumption.
Candow *et. al* (2015)	64 / (38 females; 26 males) / 50-71 years	Strength training	Creatine	0,1 g/kg	32 weeks	Pre-training creatine vs. post-training creatine vs. pre- and post-training placebo	Increases in muscle mass with post-training creatine. Increases in muscle strength with creatine regardless of timing.

intensity strength training plan. After the initial 7-day "load" phase, participants received instructions to take the supplement within 60 minutes after exercise. Taking CrM after exercise did not provide a greater improvement in body composition and muscle strength than the strength training alone. Although this study did not compare different timing of supplement consumption, these results should be considered in this review.

The aim of another study[46] was to examine the effects of supplementation before and after training, with supplementation at another time of the day (morning and night) on muscle hypertrophy, strength and body composition, in a 10-week strength programme, demonstrating greater muscle mass gains and muscle strength increases when the supplement was taken around the time of training. In this case the supplement contained protein, Cr and glucose.

One review[14] focused on assessing the effect of the timing of Cr consumption on muscle hypertrophy and strength, including some of the studies described linked to timing in our review, and although to date this literature is limited, it appears that Cr supplementation before and after resistance training sessions increases the mass and strength of lean tissue. The review suggests that taking Cr after training, provides greater muscular benefits than when it is taken prior to training[14]. Taking this supplement around the time of training may be more beneficial than taking Cr at another time of day, due to the increased blood flow and the sodium-potassium pump activation[46] following the entry of Cr into the muscle.

In turn, studies are required that demonstrate the influence of circadian rhythms on Cr supplement timing, to discover the effects on performance in morning versus evening training.

Conclusion

The most effective Cr supplementation protocol comprised the consumption of 0.3 g/kg/d over five days, followed by a consumption of 0.03 g/kg/d, thus achieving a better PCr reserve in the skeletal muscle.

The studies revealed greater benefits when the Cr consumption was performed around training times, due to greater blood flow, with studies indicating significant improvements in post-training consumption, as Cr may increase the formation of glycogen in the muscle and increase sensitivity to insulin.

Conflict of interest

The authors claim to have no conflict of interest whatsoever.

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The effects of exercise and intermittent fasting on health: a systematic review

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Summary

Objectives: This research aimed to systematically review the scientific evidence regarding the effects on health of combining exercise and fasting, as well as to determine if their impact is greater than when both activities are performed separately.
Material and method: A search of following databases was performed: MEDLINE through PubMed, Scopus, SportDiscus, Cochrane Library and CINAHL, by combining the keywords "Intermittent Fasting", "Ramadan", "Time Restricted Feeding" and "Physical Exercise". The methodological quality was determined using the Physiotherapy Evidence Database (PEDro) scale.
Results: Of the 711 results found in the first search, only four studies were definitely selected. The methodological quality of the analyzed trials turned out to be "fair" in three studies and "good" in one of them. The results obtained show that fasting combined with exercise turns out to be more effective in improving the body composition-related parameters, such as body weight, body mass index (BMI), waist circumference, fat mass and fat mass percentage. An improvement in glucose, insulin resistance, HDL and LDL cholesterol, systolic and diastolic blood pressure, triglycerides and maximal oxygen uptake were also observed.
Conclusions: The combination of intermittent fasting with physical exercise is an effective and interesting strategy to improve cardiovascular and metabolic health. This strategy appears to be an effective method to improve people's health through variables related to body composition, as well as the level of glucose, cholesterol and triglycerides.

Key words:
Fasting. Physical Exercise. Obesity. Overweight.

Efectos del ejercicio físico y el ayuno intermitente en la salud: una revisión sistemática

Resumen

Objetivos: Esta investigación tuvo como objetivo revisar sistemáticamente la evidencia científica al respecto de los efectos que tiene en la salud el hecho de combinar ejercicio físico y ayuno intermitente, así como determinar si su impacto es mayor que cuando ambas actividades se realizan de forma separada.
Material y método: Se llevó a cabo una búsqueda en MEDLINE a través de PubMed, Scopus, SportDiscus, Cochrane Library y CINAHL, mediante la combinación de las siguientes palabras clave "Intermittent Fasting", "Ramadan", "Time Restricted Feeding" y "Physical Exercise". La calidad metodológica fue determinada mediante la escala Physiotherapy Evidence Database (PEDro).
Resultados: De los 711 resultados obtenidos tras la primera búsqueda, cuatro ensayos clínicos aleatorizados (ECAs) fueron definitivamente incluidos en el estudio. La calidad metodológica de los ensayos analizados resultó ser "regular" en tres estudios y "buena" en uno de ellos. Los resultados obtenidos muestran que el ayuno combinado con ejercicio resulta ser más eficaz en la mejora de parámetros relacionados con la composición corporal, tales como el peso corporal, el índice de masa corporal (IMC), la circunferencia de cintura, la masa grasa y el porcentaje de masa grasa. También se observó una mejora en la glucosa, la resistencia a la insulina, el colesterol HDL y LDL, la presión arterial sistólica y diastólica, los triglicéridos y el consumo máximo de oxígeno.
Conclusiones: La combinación de ayuno intermitente con ejercicio físico tiene efectos beneficiosos en la salud cardiovascular y metabólica. Dicha estrategia parece ser un método efectivo para mejorar la salud de las personas a través de variables relacionadas con la composición corporal, así como con el nivel de glucosa, colesterol y triglicéridos.

Palabras clave:
Ayuno. Ejercicio físico. Obesidad. Sobrepeso.

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Introduction

Sedentary behaviour is a factor related to overall mortality and associated with an increased risk of coronary heart disease, diabetes and colon or breast cancer[1]. Therefore, strategies to promote physical activity should be developed primarily in order to improve people's health.

One of the strategies to promote physical activity is to increase exercise, since it has been shown that this modifies associations between sedentary behaviours and mortality from cancer and cardiovascular disease[2]. Performing regular exercise has also been associated with a lower risk of both morbidity and mortality[3], benefits for mental health and a delayed onset of dementia[1].

Nutritional strategies are also considered another factor to be taken into account in modifying healthy habits. Certain nutritional strategies have been seen to help improve people's health. One of these is intermittent fasting, which consists of a period with no or only low caloric intake. Different ways of approaching this exist: fasting for 16 hours every day, fasting for 24 hours every other day and fasting for two days every week on non-consecutive days, for instance[4]. During fasting, around 20% of energy requirements are usually ingested, while on normal diet days, intake is generally "ad libitum"[5]. Tinsley & La Bounty[6] conclude that consideration of this strategy can be recommended as a valid method for individuals interested in improving their body composition and overall health.

Both strategies show positive effects on health, and so combining the two has been considered key when it comes to improving quality of life. Typically, these strategies have been used together when treating, due to its prevalence, obesity. Obesity has become a major public health problem globally[7], so the interest in developing working methods that could help curb the epidemic is clear.

Vieira *et al*.[8] wrote a systematic review with meta-analysis which covered randomised clinical trials (RCTs) assessing the effect of aerobic exercise lasting less than 120 minutes in a state of fasting on adults aged between 19 and 59. These interventions were compared with the same exercise after previously consuming a meal containing at least 25 grams of carbohydrates. The authors concluded that performing low-to-moderate intensity exercise when fasting increased fat oxidation during the activity, although they also pointed out that no changes in free fatty acid concentrations were observed between when the activity was carried out in combination with fasting and when it was not. They also observed large variations in glucose and insulin concentrations when exercise was carried out when fasting. In another systematic review with meta-analysis, Keenan *et al*.[9] studied the effect of combining resistance training with intermittent fasting, chiefly to study the effect on lean body mass in recreationally active subjects, while also observing the effect on fat mass, weight and protocol adherence. They concluded that lean mass is maintained but that fat mass may be reduced.

Notably, although intermittent fasting has mainly been studied in order to improve people's health, research has also been conducted on its usefulness when it comes to enhancing sports performance. Aird *et al*.[10] conducted a systematic review with meta-analysis looking into the effects of fasting compared to normal food intake on adults aged over 18 in terms of metabolic adaptations and subsequent performance, taking into account continuous aerobic and anaerobic or intermittent exercise, and point out that eating before prolonged aerobic exercise (> 60 minutes) improves performance. However, fasting or feeding had no effect regarding performance in aerobic exercise of shorter duration. The authors conclude that both conditions (fasting and normal diet) can affect performance, highlighting potential beneficial metabolic adaptations that fasted exercise may induce in peripheral tissues. Levy *et al*.[11] published a systematic review looking into the effects of intermittent fasting on performance in high-intensity, endurance and muscle-strengthening exercise, and found that fasting did not bring any benefits to performance.

It should be noted that the systematic reviews consulted conclude that a lack of relevant scientific evidence makes it difficult to know to what extent this strategy offers beneficial effects. Bearing this in mind, this study is necessary chiefly in order to systematically review the scientific evidence of the effects of combining exercise and fasting on the health, and also to determine whether the impact is greater than when the two activities are performed separately.

Materials and methods

Search strategy

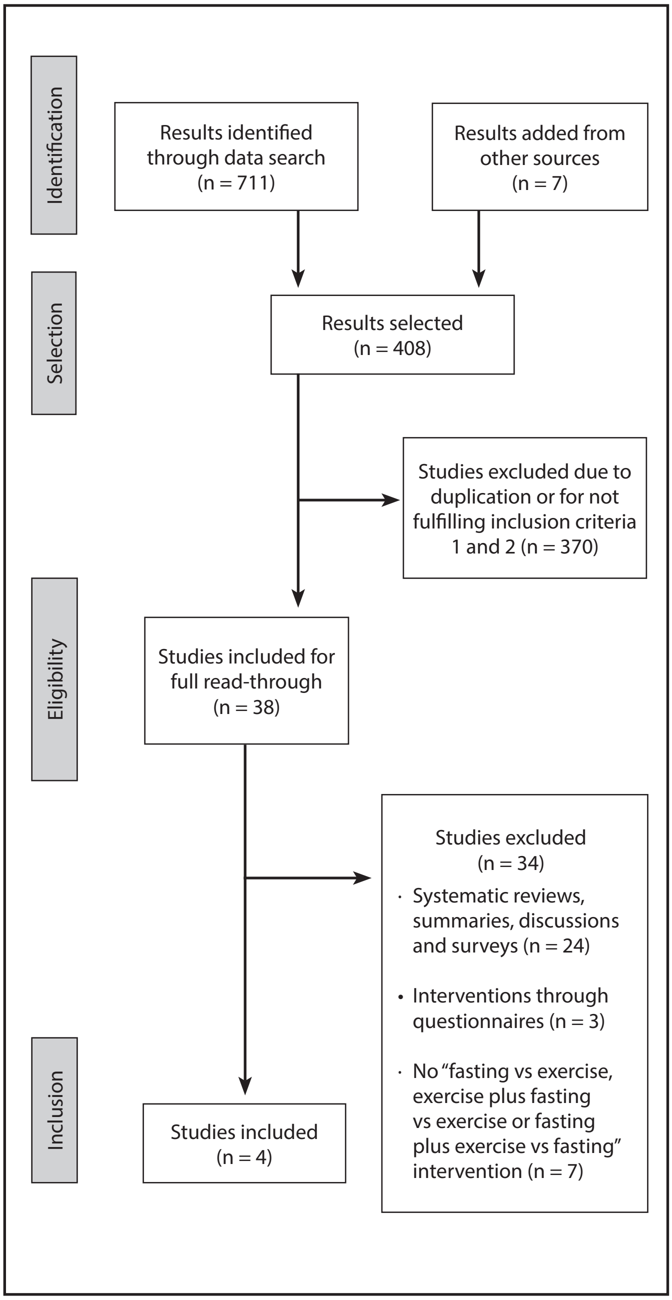
The search strategy used was designed to find RCTs examining the effect of physical activity and fasting or compared the impact of the two therapies on health-related variables. A search was carried out in the databases PubMed, Scopus, CINAHL, SportDiscus and the Cochrane Central Register of Controlled Trials, without any time restrictions. The following search formula was used: (*"Intermittent Fasting"* OR *Ramadan* OR *"time restricted feeding"*) AND (*"physical exercise"*).

The following studies were excluded: a) those which did not include physical exercise or intermittent fasting as part of the intervention, b) those that did not have a randomised controlled design, c) those that included traditional fasts (e.g. Ramadan), and d) those written in languages other than English, Spanish, French or Portuguese.

Selection procedure

When the duplicate studies had been eliminated, an initial selection was made in which the title and/or abstract of each paper was consulted and studies were classified as "included" for a reading of the full text or "excluded" according to the criteria specified above. Papers whose titles and abstracts failed to provide sufficient information were selected for full review. When these studies had been examined, those trials which did not meet the inclusion criteria were counted out. After performing this process, 34 studies were excluded for various reasons, and four studies were finally selected.

Figure 1. Flowchart of the systematic review process.



Data extraction

A table was created to identify the following aspects of the studies finally selected: the characteristics of the sample (number of participants, age, BMI and state of health), intervention type and characteristics, the study variables, the assessment tools and significant results. The data extraction procedure was not blind, the names of the authors and the titles of the papers being known.

Methodological quality

The methodological quality of the studies considered RCTs was assessed using the PEDro *(Physiotherapy Evidence Database)* scale. This scale scores 11 items: selection criteria, random allocation, concealed allocation, similarity at baseline, subject blinding, therapist blinding, assessor blinding, suitable follow up, intention-to-treat analysis, between-group comparison and point and variability measures. All the items except the one that assesses selection criteria were used to calculate the final score for each article, which ranged from 0 to 10 points. In line with Sánchez-Lastra *et al*[12], those studies which obtained scores of 6 or more on the PEDro scale were considered to be of "good" quality, and those which received scores of five points or less were considered to be of "fair" quality.

Results

The first search in the databases gave 711 results, to which seven from other sources were added. After removing duplicate studies, 408 papers remained, whose titles and abstracts were reviewed. Following this analysis, 370 articles were excluded and 38 were analysed in their entirety. This process led to the elimination of 34 studies which did not meet the specified criteria, leaving a total of four RCTs which were finally included.

Designs and samples

The characteristics of the intervention and the variables analysed are shown in Table 1. The four studies selected included comparisons of fasting and exercise with just fasting and just exercise in people with obesity or overweight[13-16].

The sample size of the studies included ranged from 45[16] to 112[15] participants, with a mean age of between 33[16] and 49[13,14]. The proposed interventions ranged from 8[15,16] to 12 weeks[13,14].

They consisted of a combination of strength training and moderate-intensity aerobic endurance exercise[15,16], and just aerobic exercises[13,14]. As for fasting, the studies chose a diet restriction in which the participants only consumed 25% of their daily energy intake, eating between 12:00 and 14:00, and then having meals *"ad libitum"* on the other days1[3-16].

None of the studies reported adherence or possible undesirable effects. However, four studies did include the participant dropout rate, these being 81[15], 19[13,14] and 10 subjects[16].

Main results

Comparison of fasting and exercise with just fasting and just exercise

A total of four studies reported significant results in body weight, their all concluding that both the combined strategy and the intervention which consisted of just fasting led to a significant decrease in

Table 1. General characteristics of the studies included.

First author (year)	Sample	Intervention	Variables analysed (assessment tool)	Significant results
Bhutani *et al.*, (2013)	**Obese** **Sample size:** 83 **Distribution and age (years):** G1: 16 (45 ± 5) G2: 16 (42 ± 2) G3: 16 (42 ± 2) CG: 16 (49 ± 2) **BMI (kg/m²)** G1: 35 ± 1 G2: 35 ± 1 G3: 35 ± 1 CG: 35 ± 1	**Duration:** 12 weeks **G1:** Moderate-intensity programme using exercise bikes and elliptical trainers. The length of the training was progressively increased by 5 minutes and 5% HRmax in weeks four, seven and ten and was combined with a fasting regime with controlled intake lasting four weeks in which the participants consumed 25% of their basic energy needs on the fasting day (24 h) and ate "ad libitum" on the normal diet day (24 h). For the next eight weeks, the subjects continued not eating on the fasting days. **G2:** Fasting regime with controlled intake lasting four weeks in which the participants consumed 25% of their basic energy needs on the fasting day (24 h) and ate "ad libitum" on the normal diet day (24 h). For the next eight weeks, the subjects continued not eating on the fasting days. **G3:** Moderate intensity programme using exercise bikes and elliptical trainers. The length of the training was progressively increased by 5 minutes and 5% HRmax in weeks four, seven and ten. **CG:** Daily life activities.	- Body weight (balance beam scales) - BMI (kg/m²) - Fat mass (bioimpedance) - Lean mass (bioimpedance) - Waist circumference (flexible measuring tape) - Total cholesterol - HDL cholesterol - LDL cholesterol - Triglycerides - Fasting plasma glucose - IR (HOMA-IR = fasting plasma insulin x fasting plasma glucose) - Systolic blood pressure (heart rate monitor and automatic digital blood pressure device) - Diastolic blood pressure (heart rate monitor and automatic digital blood pressure device) - HRmax (heart rate monitor and automatic digital blood pressure device)	**Adherence:** NI **Dropped out:** 19 **Completed the programme:** 64 **Adverse effects:** NI **Intragroup (pre vs post)** - Decrease in body weight, BMI and waist circumference in G1, G2 and G3. - Decrease in fat mass in G1 and G2. - Decrease in lean mass in G2. - Increase in HDL cholesterol in G1. - Decrease in LDL cholesterol in G1. - Decrease in systolic and diastolic blood pressure in G2. **Intergroup (pre vs post)** - Body weight and BMI decreased more in G1 than in G2 and G3. - Fat mass and waist circumference decreased more in G1 than in G2, G3 and GC. - Fasting plasma glucose decreased more in G1 and G2 than in GC in week 12.
Bhutani *et al.*, (2013)	**Obese** **Sample size:** 83 **Distribution and age (years):** G1: 16 (45 ± 5) G2: 16 (42 ± 2) G3: 16 (42 ± 2) CG: 16 (49 ± 2) **BMI (kg/m²)** G1: 35 ± 1 G2: 35 ± 1 G3: 35 ± 1 CG: 35 ± 1	**Duration:** 12 weeks **G1:** Moderate intensity programme using exercise bikes and elliptical trainers. The length of the training was progressively increased by 5 minutes and 5% HRmax in weeks four, seven and ten and was combined with a fasting regime with controlled intake lasting four weeks in which the participants consumed 25% of their basic energy needs on the fasting day (24 h) and ate *"ad libitum"* on the normal diet day (24 h). For the next eight weeks, the subjects continued not eating on the fasting days. **G2:** Fasting regime with controlled intake lasting four weeks in which the participants consumed 25% of their basic energy needs on the fasting day (24 h) and ate *"ad libitum"* on the normal diet day (24 h). For the next eight weeks, the subjects continued not eating on the fasting days. **G3:** Moderate intensity programme using exercise bikes and elliptical trainers. The length of the training was progressively increased by 5 minutes and 5% HRmax in weeks four, seven and ten. **CG:** Daily life activities.	- Weight (balance beam scales) - Fat mass (bioimpedance) - Waist circumference (flexible measuring tape) - Systolic blood pressure (ultrasound imaging) - Diastolic blood pressure (ultrasound imaging)	**Adherence:** NI **Dropped out:** 19 **Completed the programme:** 64 **Adverse effects:** NI **Intragroup (pre vs post)** - Decrease in weight and waist circumference in G1, G2 and G3. - Decrease in fat mass in G1 and G2. **Intergroup (pre vs post)** - Body weight decreased more in G1 than in G2 and G3. - Fat mass and waist circumference decreased more in G1 than in G2, G3 and GC.

(keep going)

First author (year)	Sample	Intervention	Variables analysed (assessment tool)	Significant results
Cho *et al.*, (2019)	**Overweight and obese** **Sample size:** 112 **Distribution and age (years):** G1: 9 (34.5 ± 5.7) G2: 8 (33.5 ± 5.0) G3: 9 (38.6 ± 8.2) CG: 5 (42.6 ± 10.6) **BMI (kg/m²)** G1: 28.0 ± 2.6 G2: 27.8 ± 3.4 G3: 26.9 ± 3.9 CG: 25.8 ± 3.4	**Duration:** 8 weeks. **G1:** Muscle-strengthening exercise (40 min, 3 times/week) and aerobic exercise (20 min, 2-3 times per week) combined with fasting, consisting of consuming 25% of the participants' recommended daily energy intake on each day of fasting (24 h) and eating *"ad libitum"* on each normal diet day (24 h). On the days of fasting, they had a meal between 12 noon and 2 p.m. to maintain the same times of fasting. **G2:** Consumption of 25% of the participants' recommended daily energy intake on each day of fasting (24 h) and eating *"ad libitum"* on each normal diet day (24 h). On the days of fasting, they had a meal between 12 noon and 2 p.m. to maintain the same times of fasting. **G3:** Muscle-strengthening exercise (40 min, 3 times/week) and aerobic exercise (20 min, 2-3 times per week). **CG:** Daily life activities.	- Weight (balance beam scales) - BMI (kg/m²) - Fat mass (bioimpedance) - Fat percentage (bioimpedance) - Fasting plasma glucose - RI (homeostatic model assessment of insulin resistance – HOMA-IR) - Total cholesterol - HDL cholesterol - LDL cholesterol - Triglycerides - VO_{2max} (Modified Bruce protocol)	**Adherence:** NI **Dropped out:** 81 **Completed the programme:** 31 **Adverse effects:** NI **Intragroup (pre vs post)** - Decrease in weight, BMI and fat mass in G1, G2 and G3. - Decrease in glucose in G1 and G2. - Decrease in triglycerides in G1. - Increase in VO_{2max} in G1. **Intergroup (pre vs post)** - Weight, BMI and fat mass decreased more in G1 and G2 than in GC. - Triglyceride levels increased in G2 compared with G3.
Oh *et al.,* (2018)	**Overweight and obese** **Sample size:** 45 **Distribution and age (years):** G1: 12 (37.3 ± 7.3) G2: 13 (32.9 ± 7.3) G3: 10 (35.7 ± 7.9) CG: 10 (40.6 ± 10.0) **BMI (kg/m²)** G1: 27.5 ± 2.6 G2: 27.6 ± 2.8 G3: 28.3 ± 4.1 CG: 26.3 ± 3.0	**Duration:** 8 weeks **G1:** Strength training and aerobic exercise three days per week combined with a nutritional strategy, consisting of three days of fasting with 25% recommended daily intake (the participants ate between 12 noon and 2 p.m.) and four days eating *"ad libitum".* **G2:** Nutritional strategy, consisting of three days of fasting with 25% recommended daily intake (the participants ate between 12 noon and 2 p.m.) and four days eating *"ad libitum".* **G3:** Training programme, consisting of strength training and aerobic exercise three days per week. **CG:** Daily life activities.	- Weight (bioimpedance) - BMI (kg/m²) - Waist circumference (flexible measuring tape) - Fat mass, kg (bioimpedance) - Fat mass, % (bioimpedance) - Fasting plasma glucose - IR (HOMA-IR) - Triglycerides - Total cholesterol - HDL cholesterol - Systolic blood pressure (NI) - Diastolic blood pressure (NI)	**Adherence:** NI **Dropped out**: 10 Completed the programme: 35 Adverse effects: NI **Intragroup (pre vs post)** - Decrease in weight and fat percentage G1 and G2. - Decrease in BMI and waist circumference in G1, G2, G3 and GC. - Decrease in fat mass in G1. - Decrease in glucose, IR and triglycerides in G1. - Increase in HDL cholesterol levels in G1, G3 and GC. **Intergroup (pre vs post)** - BMI, fat mass and fat mass percentage decreased in G1 compared with GC. - Triglyceride levels decreased in G1 compared with G2 and GC.

HR: heart rate; HRmax: maximum heart rate; CG: control group; G1: intervention group 1; G2: intervention group 2; G3: intervention group 3; HDL: high density lipoprotein; BMI: body mass index; LDL: low density lipoprotein; mg: milligrams; min: minutes; NI: not indicated; PM: post meridiem; IR: insulin resistance; IST: sprint interval training; VO_{2max}: maximum oxygen consumption.

this variable[13-16], while just exercise had the same effect in three of the studies[13-15]. The combined strategy was more effective compared to the other groups[13-15].

The body mass index (BMI) results were significant in three of the studies, their concluding that the variable decreased significantly after the three interventions[14-16]. The combined strategy seems more effective than taking no action[15,16] or only fasting or only doing exercise[14].

Significant reductions in waist circumference were also observed in three studies after the three interventions[13,14,16], the combined strategy proving more effective than the others[13,14].

Table 2. Results of the methodological quality assessment using the "*Physiotherapy Evidence Database* (PEDro)" scale.

First author, year	PEDro items										Score	Quality
	1	2	3	4	5	6	7	8	9	10		
Bhutani, 2013	+	-	+	-	-	-	-	+	+	+	5/10	Fair
Bhutani, 2013	+	+	+	-	-	-	-	+	+	+	6/10	Good
Cho, 2019	+	-	+	-	-	-	-	+	+	+	5/10	Fair
Oh, 2018	+	-	+	-	-	-	-	+	+	+	5/10	Fair

1: subjects randomly allocated; 2: allocation concealed; 3: groups similar at baseline; 4: blinding of subjects; 5: blinding of therapists; 6: blinding of all assessors; 7: suitable follow-up; 8: analysis by intention to treat; 9: between-group statistical comparisons; 10: point measures and measures of variability.

As for fat mass, the four studies yielded significant results, all reporting data favouring the combined strategy[13-16]. Just fasting proved significant in three studies[13-15], while only doing exercise led to a significant reduction in fat mass in just one study[15]. The combined group seemed to achieve better results compared with the other interventions[13,14] and with just the control group[16]. The percentage of fat mass was only statistically significant in one study, in which reductions were noted after a combination of fasting and exercise and just fasting. The combined strategy also showed a greater significant reduction compared with the control group[16]. Lean mass showed significant results in one study, which concluded that the only fasting strategy was more effective[14].

A significant reduction in glucose was observed in two studies, suggesting that the combined strategy is the most effective way to reduce glucose levels[15,16]. Indeed, it would seem that intermittent fasting carried out alone may affect glucose levels[15]. One study obtained significant results for the variable, showing a reduction after both the combined strategy and fasting compared with not taking any kind of action[14]. A significant decrease in insulin resistance (IR) was also observed in one study following the same intervention[16].

Two studies reported an increase in HDL cholesterol following the combined strategy[14,16]. One of these showed that just exercise or even taking no action at all led to an increase in this variable[16]. LDL cholesterol decreased after applying the strategy consisting of fasting and exercise[14].

Significant decreases were observed in both systolic and diastolic blood pressure in one study[14].

Triglyceride levels dropped significantly in two studies after a combination of fasting and exercise[15,16]. This strategy led to a greater reduction than just fasting or not adopting any change at all[16]. In this regard, Cho *et al.*[15] reported a significant increase in this variable in the group that only fasted compared with the one that only did exercise.

Maximal oxygen consumption increased significantly in one study after both strategies[15].

Methodological quality

Following a methodological assessment of the four studies reviewed, three studies[13,15,16] obtained a score of five on the PEDro scale, considered "fair". One study achieved a score of six, considered "good"[14] (Table 2).

Discussion

The aim of this systematic review was to examine the scientific evidence of the effects of combining exercise and fasting on the health, and also to determine whether the impact is greater than when the two activities are performed separately. Four RCTs were included. Their methodological quality ranged from "fair" to "good". Through RCTs, it is possible to analyse the effectiveness of interventions and examine the cause-effect relationships between interventions and outcomes[17]. The information presented here is of interest to professionals working in medicine and sports in order to make decisions.

A combination of intermittent fasting and exercise was compared with just fasting and just following an exercise programme in the four RCTs included. It should be noted that the training programmes focused mainly on muscle-strengthening exercises and submaximal or moderate-intensity aerobic activities, either jointly or, in the case of moderate-intensity aerobic activities, on their own. The fasting consisted of a diet restriction in which the participants only consumed 25% of their daily energy intake, eating between 12:00 and 14:00, and then having meals *"ad libitum"* on the other days.

In general, the combined strategy led to a significant decline in those variables related to body composition and was considered the best intervention compared with the others for that purpose. As for weight, the data support the conclusions of Redman *et al.*[18] which pointed to greater weight loss in the group that applied both methods. This could be because the training programme was supervised, which could increase its effectiveness and lead to more marked results. Meanwhile, Keenan *et al.*[9] reported a certain inconsistency in the effects of combining resistance training and intermittent fasting on body composition, specifically fat mass and fat mass percentage. Just intermittent fasting also led to improvements in body composition in terms of the variables mentioned. These results are in line with the conclusions reached by Tinsley & La Bounty[6] outlined earlier in this review; intermittent fasting would seem to be a strategy worth considering before restricting daily calorie intake in individuals interested in improving their body composition and overall health. These findings, however, appear to contradict those reported in other studies which observed no improvements in body composition after intermittent fasting every other day or full-day fasting[19,20]. Exercise on its own also proved to be relevant in terms of improving body composition, mainly with reference to weight, BMI and waist circumference. Conversely, a significant decrease in lean mass was observed after intermittent fasting for 12 weeks, which contrasts with the results obtained by Keenan *et al.*[9], who observed no change in this variable following the combined strategy.

Abnormal cholesterol metabolism is considered predictive of the development of cardiovascular disease[21]. This study concluded that HDL cholesterol levels increased following interventions in which exercise played a leading role, either in combination with fasting or on its own. This is consistent with the observations made in some other studies[22-24], while the results do not seem consistent in others[25]. The data on LDL cholesterol disagree in the trials included in this review, only one reporting a significant decrease after the combined intervention.

The combined strategy led to a decrease in glucose, triglyceride and IR levels, suggesting that caloric restriction in combination with exercise is the best way to reduce the levels of these variables[16]. The systolic and diastolic blood pressure results in one trial differ from those obtained in the other studies included in this review, a decrease in values being noted in the group that only fasted.

Finally, it should be pointed out that this review involves a set of limitations which need to be borne in mind when interpreting the results obtained. The number of trials which met the inclusion criteria was low. Furthermore, the heterogeneity of the trials makes it difficult to draw any firm conclusions. It should also be stressed that the methodological quality of the studies stood between "fair" and "good". Subject allocation was concealed in three of the studies reviewed[14–16]. The same number of trials[13–16] were not followed up suitably. None of the trials involved blinding of assessors, therapists or subjects. The sample size was small in most of the studies included. Finally, the interventions were only considered in the short term, meaning that any long-term effects which the interventions analysed might produce would require further study.

Conclusion

The combined strategy of exercise and intermittent fasting would seem to be an effective way of improving the health of people through variables related to body composition and glucose, cholesterol and triglyceride levels. Further research with more robust designs is needed in order to analyse the long-term effects of intermittent fasting and exercise.

Conflict of interest

The authors declare that they are not subject to any type of conflict of interest.

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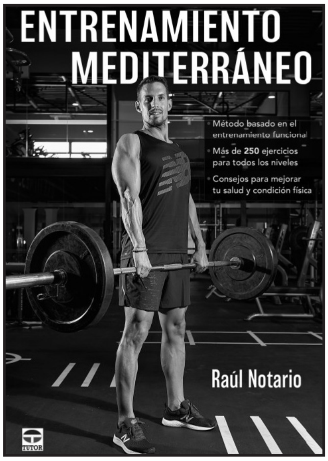

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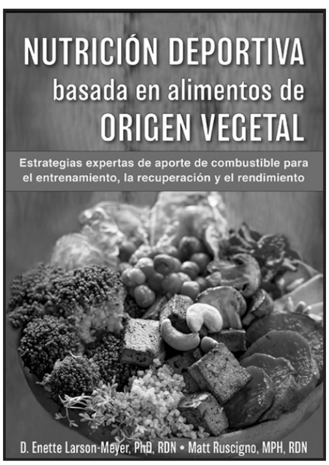

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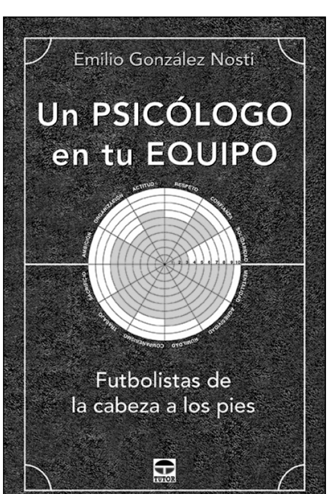

UN PSICÓLOGO EN TU EQUIPO

Futbolistas de la cabeza a los pies

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El fútbol se exterioriza en los pies, pero comienza en la cabeza. Para ser un jugador extraordinario, es decir, de los pies a la cabeza, el orden del procesamiento es a la inversa, de la cabeza a los pies. En deporte nos han mostrado cómo medir y entrenar todas las fuerzas y habilidades posibles: velocidad, explosividad, fuerza máxima… Pero nadie, hasta ahora, nos ha enseñado a entrenar la única fuerza que mueve el mundo, la de la voluntad, generada por el "músculo" más potente, el cerebro.

Este libro explica, desde la experiencia de su autor, Emilio González Nosti, cómo trabajar eficazmente aspectos psicológicos de los futbolistas de todos los niveles: desde fútbol base hasta profesionales, y aplicable a todas las disciplinas deportivas de equipo. Aborda, entre otros, aspectos como: pretemporada, capitanes, preparar psicológicamente al equipo para competir, entrenamientos, en el partido, dinámicas, suplentes y gestión del talento.

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