ISSN: 0212-8799

212

Volumen 39(6)

November - December 2022

Archivos de medicina del deporte

Órgano de expresión de la Sociedad Española de Medicina del Deporte

ORIGINAL ARTICLES

REVIEW

SMD Sociedad Española de Medicina del Deporte

CELAD Comisión Española para la Lucha Antidopaje en el Deporte

CSD Consejo Superior de Deportes

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Sociedad Española de Medicina del Deporte

Archivos de medicina del deporte

Revista de la Sociedad Española de Medicina del Deporte

Afiliada a la Federación Internacional de Medicina del Deporte, Sociedad Europea de Medicina del Deporte y Grupo Latino y Mediterráneo de Medicina del Deporte

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Publicidad
ESMON PUBLICIDAD
Tel. 93 2159034

Publicación bimestral
Un volumen por año

Depósito Legal
Zaragoza. Z 988-2020

ISSN
0212-8799

Soporte válido
Ref. SVR 389

Indexada en: EMBASE/Excerpta Medica, Índice Médico Español, Sport Information Resource Centre (SIRC), Índice Bibliográfico Español de Ciencias de la Salud (IBECS), Índice SJR (SCImago Journal Rank), y SCOPUS

Archivos
de medicina del deporte

Volumen 39(6) - Núm 212. November - December 2022 / *Noviembre - Diciembre 2022*

Summary / Sumario

Doping in sport and cardiovascular risk

Dopaje en el deporte y riesgo cardiovascular

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doi: 10.18176/archmeddeporte.00107

Introduction

Although the definition in the World Anti-Doping Code (hereafter Code)[1] describes 11 different actions and behaviours that can be considered doping, in practical medical terms, the most usual problem is handling drugs that might be on the list of prohibited substances and methods (hereafter List)[2]. The possession or the use or attempted use of any of these substances, their administration or attempted administration or, of course, trafficking or attempted trafficking, the presence of any of them or their metabolites or markers in a physiological sample from an athlete can caused serious problems for the athlete and also the professional.

Medical and deontological ethics and rules must guide our conduct, including the principle of 'non maleficence *(primum nil nocere)*'. This is the guiding light for healthcare professionals who should never act without weighing up the risk-benefit balance.

In the field of sport, and also in the medical profession, even for doctors working specifically in sports medicine, it is widely received that these prohibited substances can improve sporting performance and in turn represent a danger to athletes' health or even their lives, so that this 'non maleficence' principle prevents ethical doctors from handling these substances to enhance sports performance.

However, if we take a closer look at the definition of these substances in article 4.3 of the Code, we will see that there are three criteria for the World Anti-Doping Agency (WADA) to classify a substance as prohibited:

Scientific or medical evidence that the substance has the potential capacity to enhance sports performance.

Scientific or medical evidence that the substance represents a risk to the athlete's health.

That the WADA has determined that the use of the substance violates the 'spirit of sport'.

In the Code, the WADA defines 'spirit of sport' as: "The celebration of human spirit, body and mind. It is the essence of the Olympic movement and is reflected in sporting values," and then adds a list of these values, which are just as subjective as the definition itself. This means that this list might contain substances that do not enhance sporting performance and also substances that do not represent a health risk. This all gives the WADA licence to declare any performance-enhancing or dangerous drug as prohibited.

In countries with an advanced anti-doping system, as in Spain, this means that the anti-doping rules are applied to all offences as administrative rules (Organic Law 11/2021, of 28 December, to fight doping in sport) and in the case of a health risk, they are processed as crimes with a penal punishment (Organic Law 10/1995, of 23 November, from the Criminal Code, article 362, delinquents).

Regarding behaviour from the healthcare professionals, this lack of clarity in the causes of including substances and drugs on the list is causing an attempt to justify the use of prohibited substances by invoking the lack of evidence of a health risk and even talking about "protecting health" with its use.

It is thereby essential to have evidence of the real health risk incurred by the use of prohibited substances among healthy athletes. Evidence has been stacking up over the last ten years[3-7]. We can state that the most compromised physiological system when doing sport and where most of the severe pathologies and sudden death occur in sport is the cardiovascular system[8-18].

The main reason for this editorial is to provide sports doctors with objective data on the real risk of doping by using evidence of its effects on the cardiovascular system. Do to this, we would like to recall and

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recommend reading the publication in 2022 by Adami *et al.*[19] as the official position of the European Cardiology Society throughout its sport cardiology hub, on the cardiovascular effects of doping substances, and other frequently prescribed medicines and ergogenic aids.

In the publication, the authors update the official position of European Society of Cardiology's study group on Sports Cardiology, published in 2006[11]. This work gives a systematic critical review of the evidence on the cardiovascular effects of these substances (with 170 references). It includes a study of the pharmacological and physiopathological mechanisms in the cardiovascular system, their real impact on sports performance and their risk/benefit ratio.

We believe that any doctor working in the field of Sports Medicine should study this official position carefully.

Prohibited substances and cardiovascular risk

We are going to emphasise the cardiovascular risk and the main substances that cause it. This does not mean that there are no other dangerous substances on the list with other types of health risks, but these are the ones recognised by the position of the European Society of Cardiology.

Non-approved substances

We do not think it is necessary to insist on the danger of this type of substances, that have not been approved because studies have not continued as there was some evidence of risks that prevent its use on humans, that were directly discarded due to evidence of severe risks in clinical phases or that are still in clinical trials which have not finished yet. We do not think it is necessary to look at the cardiovascular risks and all the categories in these non-approved substances.

Metabolic modulators are this type of substances where minimum medical ethics immediately advise against their use. These are substances with unknown, potentially severe side effects as they interfere with central aspects of muscular metabolism and they modify the activation of the genetic transcription in a variety of loci, joining specific points of DNA. The list mentions AICAR, Stenabolic, PPAR-delta, Cardarine or Endurobol.

Anabolic-androgenic steroids (AAS)

The use of AAS has demonstrated a 30% increase in mortality, due to cardiovascular causes[8] and defines this increase in mortality due to the rise in atherogenesis, thrombosis and vasospasm. These factors lead to direct myocardial lesions, arterial hypertension, acute myocardial infarction, arrhythmia and sudden death[8,20]. There is now considerable evidence relating AAS consumption with coronary atherosclerosis and the appearance of cardiomyopathies[21-26].

On the other hand, we should consider the selective androgen receiver modulators (SARM) designed to isolate the androgenic effects of the anabolic effects that are caused by the AAS. These are substances considered to be experimental in humans, the list mentions Andarine, Enobosarm (Ostarine), Ligandrol, Testolone, Sarmbolone and Myostane, that are substances with an illegal origin. The quantities detected in recent entries and records in clandestine labs by security forces working with the CELAD reveal that they are being used in possibly massive quantities by athletes. After 20 years of research, they have not been approved due to potential severe effects such as carcinogenesis and cardiovascular alterations[27].

Clenbuterol appears on the list of these anabolic steroids although it seems advisable to study its effects among the beta-2-agonists.

Peptide hormones, growth factors, related and mimetic substances

In this section, the list includes erythropoietin recombinants (rHuEPO) (including Darbopoetin, CERA and similar) and agents that affect erythropoiesis, such as hypoxia-inducible factor activators, and cobalt, Daprodustat, Molidustat, Roxadustat, Vadadustat, Xenon and GATA inhibitors.

The rHuEPOs present many cardiovascular side effects with a potentially severe impact on the health of athletes that use them in a doping context: increase in viscosity of the blood[14-15], increased coagulation and platelet reactivity and risk of thrombosis[7,16].

In the case of other oxygen transport modulators, cobalt chloride is associated with developing dilated cardiomyopathies[3,28], while the mechanism of others can alter the saturation curve in O_2, which can cause hypoxaemia at rest and at sea level, with a high potential cardiovascular risk.

Regarding the use of the human growth hormone (hGH), it is well-known that patients with acromegaly frequently develop arterial hypertension, congestive heart failure and cardiomyopathies6 with concentric remodelling of the left ventricle[10], that might lead to fibrosis, inflammation and end up as myocardium necrosis[11].

Narcotics

Narcotics have a strong effect on the electric mechanisms of myocardium contraction. We know that methadone and Levacetylmethadol increase the time and the dispersion of the QT space on the electrocardiogram, with the consequent risk of polymorphic ventricular tachycardia[29]. Furthermore, reference is made to the appearance of stress cardiomyopathies similar to the Takotsubo (broken heart) syndrome and syndromes similar to Brugada syndrome[30].

Stimulants

There is a well-established relationship between cardiac arrhythmia, especially when a genetic base is known, and the use of stimulants[4]. These substances have profound effects on the neurophysiology of the central nervous system and on the cardiovascular system. They are described as aetiological factors or provoking congestive heart failure, acute myocardium arrest, valvular fibrosis, fibrosis of the heart chambers, cardiomyopathies, pulmonary hypertension and brain arrest and haemorrhage[5,13,31,32], the anatomical and functional changes that stimulants such as amphetamines can cause have been demonstrated as substrates causing sudden death[33].

We cannot forget the mounting evidence of the negative impact of stimulants on thermoregulation, so when taken during sport in a warm, damp atmosphere, they can cause severe effects[34,35].

Beta-2-Agonists

The list comprises Arformoterol, Fenoterol, Formoterol, Higenamine, Indacaterol, Levosalbutamol, Olodaterol, Procaterol, Reproterol, Salbutamol, Salmeterol, Terbutaline, Tretoquinol, Tulobuterol and Vilanterol. All as specific substances.

Clenbuterol is on the list for "other anabolic steroids" and as a specific substance.

In high doses and when taken orally, Salbutamol would be a stimulant and improve anaerobic power and strength. Clenbuterol also stimulates lipolysis. At effective doses these drugs cause tachycardia, trembling, gastrointestinal disturbance, they can have a supraventricular and ventricular arrhythmongenic effect with myocardium ischemia[14,36] and acute heart failure[9,37].

Glucocorticoids

These are prohibited via any injection line, via mouth or nose or rectally. They are known to have a cardiovascular effect with arterial hypertension and dyslipidemia[12,38].

Other contributions

The Position document also compiles evidence of assessing the potential sporting improvements brought about by each of the substances being studied.

We would also like to highlight the interest of this publication due to other aspects such as the detailed description of the potential undesirable cardiovascular effects of many drugs frequently handled by the sports doctor for their patients, although not included on the lists, such as antiarrhythmics, beta-blockers (only prohibited in certain sports) platelet drugs, anticoagulants, benzodiazepines, antidepressants, antiepileptics and anti-inflammatories.

Finally, the review extends to the effects of many sports supplements that can be legally used in sport such as caffeine, creatinine, carbohydrates, Beta-alanine, bicarbonate of soda, nitrates, proteins and energy drinks; and also looks at unhealthy recreational substances and habits such as alcohol, tobacco and nicotine.

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Feliz
año
2023

Original article

Measurement of ankle dorsiflexion: comparison between two different positions

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doi: 10.18176/archmeddeporte.00108

Received: 01/05/2020
Accepted: 18/01/2021

Summary

Background: Several closed-chain activities, including walking, running, squatting or jumping, require normal flexibility of the ankle joint. Reduced ankle dorsiflexion range of motion will limit the forward progression of the tibia over the talus during these skills. A restriction ankle dorsiflexion range of motion has been associated with several clinical conditions in the lower extremities. Weight bearing dorsiflexion measurements has been shown to be more reliable than non-weight bearing and are more clinically relevant. In clinical practice and research, multiple protocols and positions have been utilized when measuring weight bearing ankle dorsiflexion range of motion, although the differences among have not been studied.
Objective: The purpose of this study was to come ankle dorsiflexion range of motion in two different positions: standing and kneeling.
Material and method: Sixty physically active participants (51 men, 9 women; average age 21.6 ± 1.2 years) participated in this study. Weight bearing ankle dorsiflexion range of motion was evaluated, in random order, in two positions: a standard position of the weight-bearing lunge test (WBL-Nor) and with the modified weight-bearing lunge test, one knee on the floor (WBL-Mod).
Results: Statistically significant differences were found ($p < 0.001$; η^2=0.513) between the values recorded during the WBL-Nor (12.5 ± 3.2 cm) vs. WBL-Mod (10.9 ± 3.5 cm).
Conclusion: The standing and kneeling tests of ankle dorsiflexion range of motion cannot be used interchangeably, if the objective is to measure peak ankle dorsiflexion range of motion. It is recommended that this test is performed in standing if the patient/research participant is capable.

Key words:
Foot. Weight-bearing. Range of motion. Articular.

Medición de la dorsiflexión del tobillo: comparación entre dos posiciones diferentes

Resumen

Antecedentes: Varias actividades en cadena cerrada, como caminar, correr, ponerse de cuclillas o saltar, requieren un rango de movimiento normal de la articulación del tobillo. La reducción del rango de movimiento de la dorsiflexión del tobillo limitará la progresión hacia adelante de la tibia sobre el astrágalo durante estas acciones. Una restricción de la dorsiflexión del tobillo se ha asociado con varias disfunciones clínicas en las extremidades inferiores. Se ha demostrado que las mediciones de dorsiflexión en carga son más fiables que las que no soportan carga y son más relevantes clínicamente. En la práctica clínica y en la investigación, se han utilizado múltiples protocolos y posiciones al medir el rango de movimiento de la dorsiflexión del tobillo en carga, aunque las diferencias entre ellas no se han estudiado.
Objetivo: El objetivo de este estudio fue obtener el rango de movimiento de la dorsiflexión del tobillo en dos posiciones diferentes: de pie y arrodillado.
Material y método: Sesenta participantes físicamente activos (51 hombres, 9 mujeres; edad promedio 21,6 ± 1,2 años) participaron en este estudio. Se evaluó el rango de movimiento de la dorsiflexión del tobillo en carga, en orden aleatorio, en dos posiciones: una posición estándar (WBL-Nor) y otra modificada, con una rodilla en el suelo (WBL -Modificación).
Resultados: Se encontraron diferencias estadísticamente significativas ($p <0,001$; $\eta^2 = 0,513$) entre los valores registrados durante el WBL-Nor (12,5 ± 3,2 cm) vs. WBL-Mod (10,9 ± 3,5 cm).
Conclusión: La posición de medición condicionan los valores de la dorsiflexión del tobillo. Si el objetivo es medir el rango de movimiento máximo de la dorsiflexión del tobillo, se recomienda que esta prueba se realice en WBL-Nor.

Palabras clave:
Pie. Carga. Rango de movimiento. Articular.

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Introduction

The knee and ankle are a complex joint that are mobile, flexible, stable, strong, and resistant, responsible to support the body mass, that allows to be engaged in a wide range of movements and activities of daily living[1,2].

Several closed-chain activities, including walking, running, squatting, landing or jumping, require normal flexibility of the ankle joint[3,4]. A restriction of ankle dorsiflexion range of motion (DF ROM) has been linked to lower extremity (LE) biomechanical faults and clinical conditions[5-9]. Restrictions in ankle DF ROM may be due to tightness of the triceps surae[5] or arthrokinematics restrictions in the posterior glide of the talus on the ankle mortise[10]. Reduced ankle DROM will limit the forward progression of the tibia over the talus during activities that require simultaneous knee flexion and ankle dorsiflexion[7]. During closed-chain activities, restricted DF ROM is often accompanied by decreased sagittal plane motion of the knee, hip, and trunk, as well as increased frontal plane motion of the LE[11]. For example, during a squat, restricted DF ROM may result in excessive subtalar joint pronation and midtarsal dorsiflexion[12], tibial and femoral internal rotation, medial knee displacement, and knee valgus[8,13]. Decreased DF ROM was also associated with reduced quadriceps activation and increased soleus activity during the descent portion of a squat[8].

Because of these biomechanical compensations, reduced ankle DF ROM has been associated with increased risk of several clinical conditions, including anterior cruciate ligament (ACL) injury[12], stress fractures[14], plantar fasciopathy[15], Achilles tendinopathy[16] patellar tendinopathy[17], patellofemoral pain syndrome[18] and iliotibial band syndrome[19]. Thus, physical therapists must recognize the importance of accurate assessment of DF ROM during pre-season screening for LE injury risk factors[20,21], as well as when evaluating and treating a variety of lower extremity clinical conditions[22,23].

Historically, DF ROM has been assessed in the clinic using a goniometer or inclinometer in a non-weight bearing position. Intra-rater reliability of measurements of non-weight bearing ankle DF ROM are moderate to good with a goniometer (ICC=0.65-0.89) and good with a digital inclinometer (ICC=0.84-0.95)[20]. However, inter-rater reliability of goniometric measurements has ranged from poor to moderate[24].

Recently, weight bearing tests have increased popularity[25], as this measurement is assumed to more precisely reflect ankle range of motion during functional activities[26]. The weight bearing lunge test (WBLT), as described by Bennell in 1998 measures ankle dorsiflexion isolated to the tibio-talar joint proportional to the patient's body weight[25]. The original WBLT aligned the subject perpendicular to wall and instructed the subject to bend the knee while keeping the heel on the ground. The subjects was repositioned further/closer to the wall until maximal dorsiflexion was achieved, defined as the maximal distance from the wall to the toe while maintaining contact with the wall and keeping the heel on the ground[27]. According to Bennell[26] (1998), 1.0 cm distance from the wall was equivalent to 3.6˚ of DF ROM.

Variations of the WBLT include using an inclinometer to measure the relative angle of the tibia to the ground. The weight-bearing lunge test has demonstrated good to excellent intra-rater (ICC= 0.88 and 0.97) and inter-rater reliability (ICC=0.82 and 0.97), both when measuring distance from the wall or tibial angle[21,26,27]. Along of the time, mobile applications that measure ankle dorsiflexion such as Tiltmeter[28], iHandy, and Dorsiflex iPhone app[29] have become more accessible and clinically useful. The Leg Motion® system (CheckyourMOtion®, Albacete, Spain) is a new, portable device designed to measure WB ankle DROM in a manner similar to the weight-bearing lunge test[3,30]. The Leg Motion® system has been demonstrated to be a reliable and valid measurement of WB ankle DF ROM in healthy participants and allows for test in virtually any location[3,31]. However, there is scarce information about different positions.

Multiple techniques have been utilized in the literature when measuring WB ankle DF ROM, including distance from the wall, digital inclinometry and goniometry[32]. Variations in the position of the contralateral lower extremity are seen as well. Bennell described the position of the untested limb as resting freely in a comfortable position on the floor[26]. The two most common positions utilize a tandem stance, one measuring the front ankle with the knee flexed and the other measuring the rear ankle with the knee extended[32]. While the majority studies perform the WBLT in standing, Balsalobre-Fernandez[29] took measurements with the subject kneeling on the opposite limb. Stanek[33] described the kneeling ankle dorsiflexion although the stepping distance was not standardized across participants.

The hypothesis of this study establishes the existence of significant differences in the result of the WBLT between the standard WBLT position (WBL-Nor) and a modified position of kneeling (WBL-Mod).

To date, no published studies have compared WB DF ROM in a kneeling position with a standing position. The purpose of the present work was to compare ankle DF ROM measurements between the standard WBLT position (WBL-Nor) and a modified position of kneeling (WBL-Mod). A secondary purpose of the investigation was to compare DF ROM measurements between right and left lower extremities in both conditions.

Material and method

Subjects

A priori sample size tests (G* Power 3.1.9.7) revealed that a total of 55 participants would be required to detect an effect side of 0.5, a statistical power of 0.8 and an alpha of 0.05. Therefore, 60 volunteers were recruited to avoid critical data loss.

Participants were recruited from a student population at a University. Sixty healthy, physically active adults (51 males and 9 females, age 21.6 ± 1.2 years, height 175.6 ± 0.3 cm, body mass 74.2 ± 7.3 kg) volunteered to participate in the study. Participants were excluded if they had any joint pathology in the hip, knee or ankle that a caused pain or restricted movement, neuromuscular disease, recent heel or knee pain; or a history of recent lower extremity trauma or elective surgery (in the last six months). The present study was approved by the institutional research ethics committee, and conformed to the recommendations of the Declaration of Helsinki. All participants read and signed an approved, written informed consent document before data collection.

Procedures

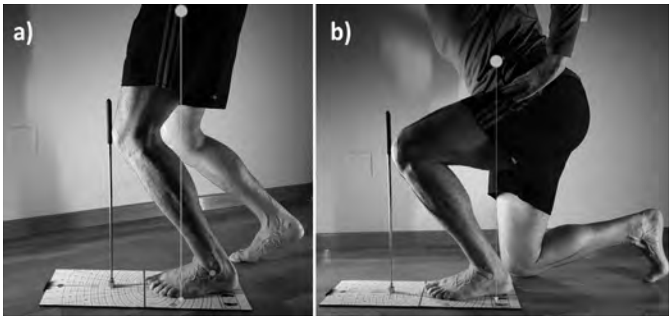
Ankle dorsiflexion ROM was evaluated using the LegMotion® system (CheckyourMOtion®, Albacete, Spain) in two positions: a standard position of the weight-bearing lunge test (WBL-Nor) and with the weight-bearing lunge modified test, one knee on the floor (WBL-Mod). The order of testing was determined by coin flip. All tests were conducted at the same time of the day (9:00 to 14:00) with 2 days (48 hours) between sessions.

For both tests (WBL-Nor and WBL-Mod), all subjects started with their hands on the hips and placed the assigned foot on the middle of the longitudinal line just behind the transverse line on the platform. During WBL-Nor the contralateral foot was placed lateral to the platform, with toes even with the posterior edge of the platform (Figure 1a). During WBL-Mod test the contralateral knee was placed posterolateral to platform, with the femur starting perpendicular to the ground, and the tested foot flat on the platform (Figure 1b). In both positions, the second toe and the center of the heel were placed directly over LegMotion® system (CheckyourMOtion®, Albacete, Spain), in order to attempt to reduce the subtalar joint pronation during the measurement procedure. While maintaining each position, subjects were instructed to perform a lunge in which the knee was flexed with the goal of making contact between the anterior knee and the metal stick. When the subjects were able to maintain heel and knee contact, the metal stick was moved away from the knee (Figure 1). The maximal distance achieved was recorded in centimeters. Three trials were performed for each ankle with ten seconds rest between trials. The third value in each ankle was selected for subsequent analysis of weight-bearing DF ROM[3,31,34].

Data analysis

Data were analyzed using PASW/SPSS Statistics 23 (SPSS Inc, Chicago, IL). After comparing the normality of the data by means of the Kolmogorov-Smirnov test, the Student t test for related samples was applied, establishing the level of significance at $p \leq 0.05$. All the measures were normally distributed, as determined by the Kolmogorov-Smirnov test. Sphericity was tested by the Greenhouse-Geisser method. The dependent variable (DF ROM) was evaluated with a two-way repeated measures analysis of variance (ANOVA) of test x leg. Where significant F values were achieved, pairwise comparisons were performed using the Bonferroni post hoc procedure. Effect size statistic, η^2, was analyzed to determine the magnitude of the effect independent of sample size. Values are presented as mean ± standard deviation (SD).

Figure 1. Leg Motion procedure (a) weight-bearing lunge test (WBL-Nor) and (b) weight-bearing lunge modified test (WBL-Mod).



Results

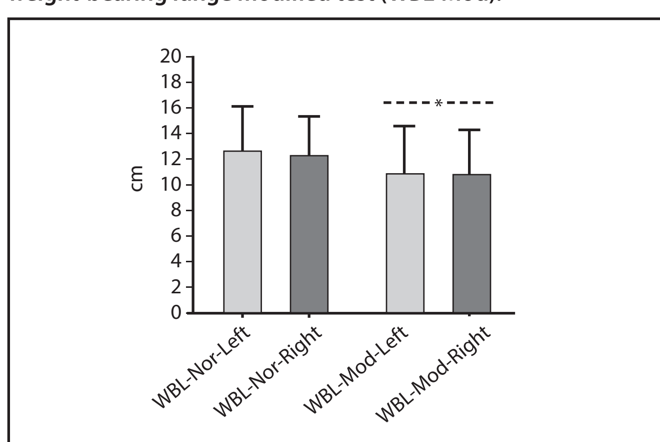
On average, participants in standing (WBL-Nor) achieved greater DF ROM (12.5 ± 3.2 cm) compared to kneeling (WBL-Mod) (10.9 ± 3.5 cm) (Figure 2). This difference, -1.6 cm, 95% CI [1.29, 1.94] was significant ($p < 0.001$), and represented a medium effect size, η^2=0.513.

There was no significant difference between right and left legs ($p > 0.05$; η^2=0.017). ANOVA showed no significant interaction effects between test procedure and legs ($p > 0.05$; η^2=0.014).

Discussion

This was the first investigation to compared the DF ROM between two versions of the weight bearing lunge test: standing (WBL-Nor) and kneeling (WBL-Mod). Significant differences in DF ROM were found between the two positions, with greater DF ROM recorded in the standing position. Several studies have demonstrated greater ankle DF ROM in weight bearing compared to non-weight bearing in healthy subjects. Most authors attribute these differences to the greater moments applied to the ankle joint during weight-bearing[24,32,35,36]. The present method did not allow us to quantify the contribution of the moment applied to the ankle, but some assumptions can be made, based on biomechanical principles. The WBL-Nor position allows a greater anterior excursion of the body's center of mass (COM), approximated just anterior to S2, than the WBL-Mod position (Figure 1). A more anterior center of mass increases the distance from the ankle joint to the body weight vector, this increasing the torque at the ankle joint. Additionally, in the kneeling position, a larger percentage of the individual's body weight is presumably accepted through the non-tested LE. Thus, the force of the body weight vector in the WBL-Mod position is less than in

Figure 2. DF ROM of weight-bearing lunge test (WBL-Nor) and weight-bearing lunge modified test (WBL-Mod).



* Significantly different than WBL-Nor.ms

the standing position. The combination of a greater moment arm and greater force through the body weight vector in the WBL-Nor position results in a much larger moment dorsiflexion moment about the ankle in standing. Thus, these findings of greater DF ROM in the standing WBL position are consistent with other studies demonstrating increased DF ROM with increased DF moment through the ankle[24,35,36].

Subjects in this study demonstrated a statistically significant difference in DF ROM between the WBL-Nor and WBL-Mod positions ($p < 0.001$). The mean WBL-Nor DF ROM in this study was 12.9 ± 3.2 cm, compared to 10.9 ± 3.5 cm in the WBL-Mod position. The WBL-Nor data is consistent with other studies that have utilized the tape measure or LegMotion system ® with healthy young adults, with mean distances ranging from 10.3 to 12.0 cm and standard deviations of 2.7-3.0 cm[3,21,30,37-39]. This difference is clinically relevant based previous publications that have determined the minimal detectable change of the WBL-Nor to be 1.1 - 1.6 cm[21,36,40].

This data did not show any differences between the right or left ankles for either the WBL-Nor or WBL-Mod positions. This is consistent with previous works that have found minimal differences between limbs in the WBLT[3,29,30,39]. Hoch and McKeon[38] noted that the majority of healthy subjects exhibited asymmetry of DF ROM of 1.5 cm or less, but there was not limb bias observed in the asymmetries. Reid[41] has suggested using a cutoff of 2.0 cm or greater of asymmetry as a clinically relative impairment.

A limitation to this investigation was the sample of participants used in this study took part physically active and therefore, the results cannot be generalized to a non-sporting population. Another limitation that there was no measurement to the the nature of the restriction in ankle DF-ROM[42].

There are two benefits of this study. First, the test can be performed on patients for whom weight-bearing is contraindicated in a standard position of the weight-bearing lunge test (WBL-Nor). Second, it isn´t difficult for a single observer to measure dorsiflexion with flexed knee. It is simple to administer, that allows health professional directly assess the ankle dorsiflexion range of motion while adopting a comfortable testing position.

Conclusion

Healthy subjects demonstrated greater DF ROM during the WBLT when performed in the standing position compared to a kneeling position. Given the results of the current study, if the objective of the test is to measure peak passive ankle dorsiflexion, it is recommended that this test is performed in standing if the patient/research participant is capable. Not only was there an effect of position on peak passive dorsiflexion where greater values were achieved in standing, but the difference was clinically relevant based on the published minimal detectable change (MDC)[21,32].

Declaration of interest statement

The last author declared potential conflicts of interest. He has patented the LegMotion® system (CheckyourMOtion®, Albacete, Spain).

Acknowledgments

The authors thank all the participants which, without their help, we were not able to conduct the study.

Conflict of interest

The authors do not declare a conflict of interest.

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Original article

Effects of repeated-sprint hypoxic training on physical fitness of active adults

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doi: 10.18176/archmeddeporte.00109

Received: 23/12/2020
Accepted: 22/09/2021

Summary

Due to the time is, commonly, a barrier to exercise, the scientific community has paid attention to a new model of training. Repeated-sprint hypoxic training is now considered an effective time-efficient method for improving physical performance in different sport modalities. However, few researchers have studied the effect of this strategy in healthy untrained or moderately trained individuals. Depending of the prior fitness status, different findings may be obtained. Therefore, this study determined the effects of 4 weeks of repeated-sprint in hypoxia on cardiorespiratory fitness and anaerobic capacity in healthy men. Twenty-four physically active males (were randomly assigned to repeated-sprint in normoxia (n=8; 0.20 FiO_2), in hypoxia (n=8; 0.14 FiO_2) or a control group (n=8). Participants of both exercise groups developed eight training sessions consisted of 2 sets of 5 all-out cycling sprints of 10 s with a recovery of 20 s between sprints and 10 min between sets. Repeated sprint ability, vertical jump performance and estimated maximal oxygen consumption were tested at baseline, 7 days and 2 weeks after the last session. Seven days after the last sessions, significant differences (p<0.05) between normoxia (+7.8%; p<0.001; ES=1.66) and hypoxia groups (+9.9%; p=0.000; ES=1.42) compared with control group were found in estimated maximal oxygen consumption. In the hypoxia group, the number of sprints to exhaustion (7 days Post +55.6%; ES=1.40; 2 weeks Post +10.0%; ES=1.80) improved with a large effect size at 7 days and 2 weeks after the last sessions compared with baseline. Eight sessions of repeated-sprint training in hypoxia conditions could produce improvements and delayed effects on anaerobic capacity.

Key words:
Hypoxia. Sprint interval training. Physical conditioning. Cardiorespiratory fitness. Jump performance.

Efectos del entrenamiento de esprints repetidos en hipoxia sobre la condición física de adultos activos

Resumen

La comunidad científica ha prestado atención en los últimos años a un nuevo modelo de entrenamiento, debido a que la falta de tiempo es comúnmente la principal barrera para la práctica deportiva. En este contexto, el entrenamiento de esprint repetidos en hipoxia es considerado como una prometedora estrategia para mejorar el rendimiento físico en diferentes modalidades deportivas. Sin embargo, existen pocos estudios que investiguen los efectos sobre población moderadamente entrenada o sedentaria. Así, este estudio determina los efectos de un entrenamiento de esprint repetidos en hipoxia sobre la condición física de hombres sanos. Veinticuatro hombres fueron asignados aleatoriamente a un grupo normoxia (n=8; 0.20 FiO_2), hipoxia (n=8; 0.14 FiO_2) o control (n=8). Después de ocho sesiones de esprint repetido en cicloergómetros de 10 s, la habilidad de esprint repetido, el rendimiento en el salto vertical, así como el consumo de oxígeno fueron evaluados en la línea base y a los días y 2 semanas de la última sesión de entrenamiento. A los 7 días, se observaron diferencias significativas entre normoxia (+7,8%; p<0.001; ES=1,66) e hipoxia (+9,9%; p=0,000; ES=1,42) comparado con el grupo control en el consumo máximo de oxígeno estimado. En hipoxia, el número de esprint hasta la extenuación (7 días Post +55,6%; ES=1,40; 2 semanas Post +10,0%; ES=1,80) también mejoró con tamaño del efecto elevado a los 7 días y 2 semanas de la última sesión comparado con la línea base. El protocolo de 8 sesiones de esprines repetido en hipoxia podría producir mejoras y retrasar los efectos sobre el rendimiento anaeróbico de hombres sanos.

Palabras clave:
Hipoxia. Sprint repetido. Condición física. Resistencia cardiovascular. Salto vertical.

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Introduction

In the clinical and sport context, improving or maintaining muscular strength, power, and endurance are goals commonly pursued by individuals practice physical training programs[1]. Over last decades, the scientific community has paid attention to high-intensity training such an effective time-efficient training method for improving physical performance in athletes[2]. Due to the most commonly cited barrier to physical activity is lack of time[3], there is today a surge of research interest focused on examining the effects of short sprints and all-out efforts[2]. In this sense, all-out repeated-sprint training has been shown as high-intensity training regimen capable to enhance exercise performance with a lower training volume[4].

Last decades, greater improvements in exercise performance of athletes of different sport modalities have been shown when high-intensity is carried out under hypoxic condition[5]. Innovative 'live low-train high' methods have emerged as 'repeated-sprint training in hypoxia' (RSH), based on maximal "all-out" efforts of short duration (<30 s) with incomplete recoveries[6,7]. Specific adaptations have been attributed to RSH, which differ from intermittent hypoxic training (IHT) adaptations. Maximal intensity accompanied with the drop in arterial oxygen content favour the usage of fast twitch fibers[8] and the compensatory vasodilation[9]. Increasing in muscle mitochondrial, capillary density[10] and stimulation of markers of mitochondrial metabolism and biogenesis[11] may enhance the anaerobic energy system contributing to greater improvements in anaerobic capacity and cardiorespiratory fitness[12].

Recently, it has been shown that RSH led to greater exercise performance than the same training in normoxia in athletes[5-8,13-18], as well as obesity population[19]. However, controversial results are shown and, no additional effect on performance outcomes were found in other reports[20].

On the other hand, the exercise program effectiveness is not only determined by short-term effects, unless the maintenance of the benefits achieved during the detraining period is essential[21]. After high-intensity programs, the beneficial training effects usually return to near resting values within only 2 weeks of detraining after programs[22]. In this sense, adding a hypoxic stimulus may allow for more systemic and muscular adaptations due to elevated hypoxic and oxidative stress in conjunction with pertinent neuromuscular and neuromechanical loading[23,24]. Lasting for at least three weeks post-intervention of RSH training, Yo-Yo performance and repeated-sprint ability of elite field team-sport kept increasing[25]. In obese women, RSH was an effective alternative for improving cardiovascular respiratory fitness when compared to the same normoxic training, even after of 4-weeks the cessation of the training program[19]. However, studies on the maintenance of exercise-induced performance benefits after cessation of training are rare.

Meanwhile RSH has been investigated in different modalities athletes[25], few researchers have investigated the effect of this strategy on performance in healthy untrained or moderately trained individuals. Depending of the prior fitness status, different findings may be found[26]. Therefore, the present study aimed at determining the effects of four weeks of RSH on cardiorespiratory fitness and anaerobic capacity in active adults. We hypothesized that RSH would lead to greater enhancement in aerobic as well as anaerobic parameters performance.

Material and method

Study design

The study was designed as a randomised blinded controlled trial. Participants were randomly assigned to one of the three groups of the study: control (CON; n=8) that completed only testing sessions, normoxic repeated-sprint training (RSN; n=8) or repeated-sprint training in hypoxia (RSH; n=8). One week prior to baseline measurements, participants visited the laboratory for familiarisation with experimental trials and fitness testing. A general questionnaire was completed to collect medical and personal data before entering the study. Subjects in both groups were instructed to maintain their usual physical activities during the study period. All participants were assessed at three time points: at baseline (Pre), in the 7 days after the last session (Post) and 2 weeks after the last session (Det). All time points for evaluations consisted of the same measurements.

Participants

Participants were recruited from the Sports Science Faculty of the University of Extremadura. Inclusion criteria, assessed during a screening visit, were: healthy men, physically active (per week: >75 min moderate-to-vigorous physical activity or 150 min moderate physical activity) and have not been acclimated or recently exposed to altitude (above 1,500 m for more than 6 hours per day (i.e., no overnight sleep at altitude), during the last 3 months). Exclusion criteria included contraindications to exercise and medication that may have affected on their daily activities.

Twenty-four physically active males (age: 23.1±3.6 years; body mass: 72.6±6.7 kg; BMI: 23.6±3.5 kg·m^{-2}) volunteered for this study. Compliance training was calculated as the number of sessions completed divided by the 8 possible sessions available per participant. All the participants should have to complete at least 80% of the sessions. Subjects were informed of the experimental protocol and after signing the informed consent became part of the study. This project was approved by the Bioethics Committee of the Council of Europe of the University of Extremadura and carried out according to the Declaration of Helsinki. Participant's characteristics are shown in Table 1.

Training sessions

Participants started the training protocol 1 week following baseline. During the 8-weeks study period, 8 training sessions were completed over 4 weeks, 2 days per week, supervised by an experienced member of the research group. Sessions were scheduled with at least 1 day of

Table 1. Participant's characteristics at baseline

	CON (n=8)	RSN (n=8)	RSH (n=8)
Age, years	22.8 ± 4.8	24.4 ± 3.5	22.1 ± 2.6
Weight, kg	70.2 ± 6.7	71.4 ± 5.8	69.3 ± 10.4
BMI, kg·m^{-2}	22.3 ± 0.5	23.1 ± 2.7	23.7 ± 2.5

Values are mean ± SEM. BMI: body mass index.

rest between for optimal recovery (Monday and Wednesday or Tuesday and Thursday) and participants were requested to train at the same time throughout the 8 sessions. Each session consisted of repeated-sprint during cycling in a hypoxic chamber (CAT 310, Louisville, Colorado, USA) built in our laboratory (459 m of altitude, 24ºC and 40% relative humidity). RSH group breathed an oxygen fraction (FiO_2) at 0.14 ± 0.003 (simulate an altitude of 3,400 m above sea level) controlled with an electronic device (HANDI+, Maxtec, Salt Lake City, Utah, USA). Oxygen content within the chamber could be reduced by insufflating nitrogen, which was produced from chamber air through a molecular sieve. Normoxic repeated-sprint training group exercised at FiO_2 of 0.20 corresponding to sea level in the laboratory. Blinding of the subjects, the system also ran for normoxic repeated-sprint training with normoxic airflow into the chamber.

Training sessions were performed in a cyclosimulator with an integrated potentiometer (Cycleops 410 pro, Cycleops, Madison, USA). Cycling provides a lower risk of leg muscle injury (by minimal eccentric contraction), which was the most important reason for selecting this exercise mode. After 10 min of warm-up at 60 watts (W), all training sessions consisted in 2 sets of 5 repeated 10 s all-out sprints with a recovery of 20 s between sprints and a recovery period of 10 min at 120W between sets, ending with a 5 min recovery at 120 W. The maximum power of each sprint was registered and monitored by the potentiometer in real time via the potentiometer data screen itself. Between training sessions there were at least 48 hours of rest for an optimal recovery.

Testing sessions

In all time points, assessments were carried out over 2 sessions. On the morning of the first day, body composition and jump performance were measured. Then, after 45 minutes, subjects performed a Yo-Yo Intermittent Recovery Test at level 1. On the second day, the subjects took a Repeated sprint ability (RSA) Test.

- *Body mass index:* height and weight were measured following standard procedures. Body mass index was derived from height and weight using the accepted method ($BMI = weight/height^2$, $kg{\cdot}m^{-2}$).
- *Repeated sprint ability test:* The subjects conducted a repeated sprint test under normoxic conditions, comprising the largest number of 10 seconds all-out sprints (maximal pedalling) with a 20-sec active rest between sprints at 120 W[27]. Subjects were given very strong verbal encouragement and performed as many sprints as possible until exhaustion. A minimum of 70 rpm or less after 5 s of sprinting was set as the criterion to stop the test. The total number of sprints was registered.
- *Jump Performance:* to test the lower limb explosive strength performance an Optojump platform connected to a personal computer were used (OptojumpNext, Microgate, Bolzano, Italia). Jump height of the widely knows squat Jump (SJ) and Counter-movement Jump (CMJ) protocols were registered. Two trials were performed for each of the jumping tests (SJ and CMJ). A 10 s rest within and a 90 s rest between jumping tests were set. The best trial was retained for analysis and the jumping height was calculated from the flight time[28].
- *Yo-Yo Intermittent Recovery Level 1 Test:* participants performed twenty-meters shuttle runs with increase of the velocity until the exhaustion. Periods of 10 s of active recovery were developed between runs. Total distance covered (including the last incomplete shuttle) was registered and used to estimate maximal oxygen consumption (VO_{2max}) using the equation: VO_{2max} $ml{\cdot}kg^{-1}$ min^{-1} = [IR1 distance (m) * 0.0084] + 36.4[29].

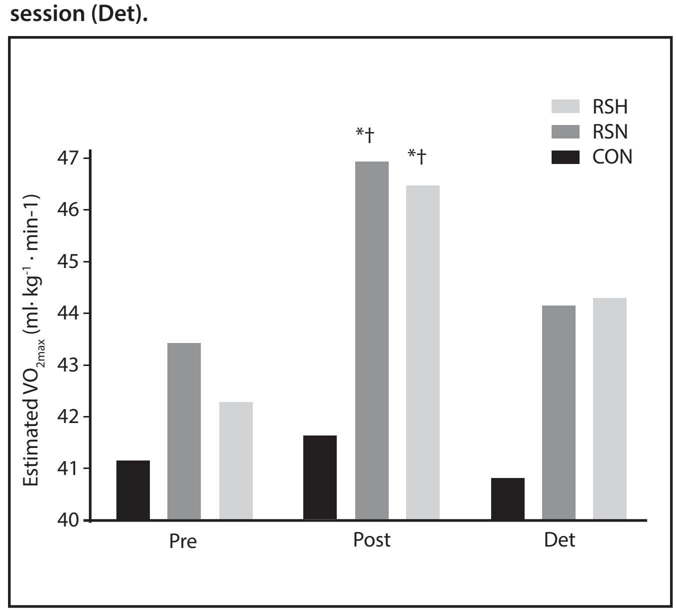
Statistical analyses

The statistical package SPSS v.20 for MAC (IBM, New York, USA) was used for statistical analysis. Before the analysis, the Kolmogorov–Smirnov test and Levene's test were calculated to identify data homogeneity. Then, two-way repeated measures analysis of variance (ANOVA) was used to compare responses in each variable. Bonferroni post hoc analysis was used to identify where changes occurred. To establish statistical significance, $p<0.05$ was used. The effect size was calculated for all variables between pre- and post-testing. The magnitude of the difference was considered as a small (0.2), moderate (0.5) or large (0.8) effect size (ES).

Results

Compliance with training prescription was 100% in the RSH group and 91.39% in the RSN group. Effects of training about estimated VO_{2max} obtained in the Yo-Yo Test are shown in Figure 1. After training, estimated VO_{2max} increased significantly in both RSN (p=0.02) and RSH (p=0.04) groups compared with control group. Statistically significant differences within groups with a large ES were found in the RSN group

Figure 1. Estimated VO_{2max} with Yo-Yo Test at baseline (Pre), in the 7 days after the last session (Post) and 2 weeks after the last session (Det).



Estimated VO_{2max}: maximal oxygen uptake; CON: Control Group, RSN: Repeated-Sprint Normoxia, RSH: Repeated Sprint Hypoxia. *Significant difference (p < 0.05) compared to Pre-. †Significant difference (p < 0.05) compared to CON.

Table 2. Repeated sprint and jump ability results before and after intervention.

		Pre (A)	Δ (% A-B)	Post (B)	Δ (% B-C)	Det (C)	d Cohen (A-B)	d Cohen (B-C)
Number of sprints, n	CON	5.5 ± 0.8	-2.7	5.3 ± 1.6	+17.0	6.2 ± 1.2	0.14	0.70
	RSN	5.0 ± 1.2	+24.0	6.2 ± 2.2	-9.7	5.6 ± 0.9	0.71	0.39
	RSH	4.5 ± 1.7	+55.6	7.0 ± 1.8	+10.0	7.7 ± 1.9	1.40	1.80
SJ Height, cm	CON	32.3 ± 6.8	-4.6	30.8 ± 7.1	-6.2	28.9 ± 6.0	0.23	0.28
	RSN	30.1 ± 5.0	+0.7	30.3 ± 6.2	+5.3	31.9 ± 5.6	0.04	0.26
	RSH	29.5 ± 3.0	+2.0	30.1 ± 3.6	+14.3	34.4 ± 5.4	0.19	0.95
CMJ Height, cm	CON	34.2 ± 3.9	+5.3	36.0 ± 4.7	-5.3	34.1 ± 4.6	0.41	0.40
	RSN	35.5 ± 7.6	+0.8	35.8 ± 5.7	-5.3	33.9 ± 5.4	0.03	0.34
	RSH	30.9 ± 4.2	+6.1	32.8 ± 3.8	+10.7	36.3 ± 4.4	0.98	0.88

Values are mean ± SEM. CON: Control Group; RSN: Repeated-Sprint Normoxia; RSH: Repeated-Sprint Hypoxia; Δ: absolute change; d Cohen: Effect size; SJ: squat jump; CMJ: countermovement Jump.

(+7.83%; p=0.001; ES=1.66) and RSH group (+9.95%; p=0.000; ES=1.42) between Pre and Post evaluation.

The training effects on RSA and jump performance are shown in Table 2. The number of sprints until exhaustion and jump performance did not show significant improvements compared with control group. In within group analysis, RSH showed a large ES between Pre and Post (+55.56%; ES=1.40) and Pre and Det (+10%; ES=1.80) in the number of sprints. Increases in SJ and CMJ height were also found in RSH group with a large ES between Pre and Post and between Pre and Det (SJ: +2.03% and +14.3%, ES=0.98 and ES=0.88, respectively; CMJ: +6.15% and +10.7%, ES=1.28 and ES=0.88, respectively).

Discussion

The present study aimed at determining the effects of four weeks of RSH on cardiorespiratory fitness and anaerobic capacity in active adults. The main finding was that the combination of repeated-sprint and hypoxic stimulus could not lead to an additional effect on cardiorespiratory fitness compared with the same protocol in normoxia conditions. After training, significant differences were found in estimated VO_{2max} in RSN group compared with control group, as well as RSH group with respect to the control group. However, the anaerobic capacity, showing through the number of sprints to exhaustion, may tend to increase under hypoxia conditions. The greater large effect sizes found in RSH group leads us to think that significant changes could be obtained from higher sampling. Besides, delayed effects on anaerobic capacity with a large effect size were shown after 2-weeks of cessation of the program. In any case, finding no significant differences, the results must be taken with caution.

Cardiorespiratory fitness

Hypoxic training has been commonly used to improve cardiorespiratory capacity over years. The stress of hypoxic exposure, in addition to the training stress, may increase the adaptations experienced with exercise alone and will lead to greater improvements in performance[30]. Whereas previous studies reported that RSH induced greater improvements on cardiorespiratory capacity in elite athletes[14,18,25] and obese people[19], the present study did not show additional effects of RSH on estimated VO_{2max} through Yo-Yo Intermittent Recovery tests. Despite aerobic field-based protocol may be preferred over laboratory-based protocols due to an increase in ecological validity for performance measurement in sport-field[18], the lack of additional benefits of RSH over RSN is the non-specificity of training relatively to the test implemented[31].

Anaerobic capacity

Based on previous studies, RSH, when compared with that under normoxia, may be more useful for enhancing anaerobic capacity[4], by increases the contribution of the anaerobic energy system during all-out sprint exercise[32]. The results observed in the present study are partially agreed with meta-analysis' aggregated findings[7] that indicated RSH vs. RSN improved in RSA. In contrast, other studies found that RSH equally improved RSA performance compared with RSN[14,18,20,25,33]. Many factors may be contributing to these controversial results[7] such as level of athlete and/or protocol design. Similarly to Hamlin *et al.* (2017) and Beard *et al.* (2019), improvements in RSA performance were reported when a multiple-set protocol of RSH was applied[7]. Although the mechanisms for the anaerobic capacity are still under debate, RSH may induce greater improvements of oxygen utilization by the fast-twitch fibers during 'all-out' maximal repeated sprints performed in hypoxia[8].

Surprisingly, in the present study, anaerobic capacity continued improving after two weeks of detraining in RSH group. These findings are especially relevant in a population where cessation of training is common for holidays[19]. As previous authors have reported, delayed effects on exercise performance could be achieved after RSH protocol[19,25]. Although speculative, this phenomenon could be attributed to higher variations of blood perfusion delaying fatigue in the RSA test and improvements in vascular conductance where fast-twitch fibers are better utilised[8]. In parallel, neural adaptations would increase motor unit synchronization and/or agonist muscle activation[34]. Conversely, skeletal muscle molecular beneficial may elicit higher short-term adaptations with a rapid decay and normalization of molecular adaptations after cessation of the training[7]. However, studies on the maintenance of exercise-induced exercise performance benefits after cessation of training are rare and more research is required.

There are some limitations to this study. We cannot ignore that the present study includes a low hypoxic dose with 8 RSH sessions, 800 s sprinting duration over 28 days (mean of the RSH studies was 9.4 ± 3.1 sessions, 1216 ± 527 s sprinting duration over a 27.3 ± 8.4 days period[7]). A factor of importance to the outcome of an altitude-training program is the exercise regimen undertaken during the intervention period[35]. The severity of altitude, time spent training at altitude or type of training represents important factors to consider when designing a training program at altitude. Thus, this lowest volume could partially explain why no significant changes were shown. The small sample size certainly is a weakness in this study. Despite this, there are significant indications that this type of training could have benefits for this population, as shown by the high effect sizes. Besides, the non-specificity of training relatively to the test implemented establishes another important limitation of the present study. Using a field test (Yo-Yo test) predicting VO_{2max} rather than measuring it with metabolic gas analysis have a considerable error for estimating VO_{2max} in adults. For these reasons, the findings of this study should be confirmed in further investigations.

Conclusions

In conclusion, eight RSH sessions performed over four weeks does not appear to have an additional effect on cardiorespiratory capacity in active adults compared with equivalent training in normoxia. However, it could produce improvements in RSA and lead delayed effects on anaerobic capacity. Further studies with protocols designed for double blind and large sample sizes are needed to support the effectiveness of RSH in this population.

Acknowledgments

This research was funded by the Government of Extremadura with funding from the European Regional Development Fund under Grant (Ref: GR18003) and by Cátedra Real Madrid: research project 2014/04RM.

Conflict of interest

The authors do not declare a conflict of interest.

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Original article

Effect of joint mobilization on chronic instability of the ankle: a systematic review with meta-analysis

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doi: 10.18176/archmeddeporte.00110

Received: 23/10/2021
Accepted: 07/09/2022

Summary

The present work aims to analyze the effect of joint mobilization in patients with chronic ankle instability on the outcomes of pain and dorsiflexion range of motion of the ankle after systematic review study with meta-analysis. The period for developing the research and collection was from August 2022. The databases used for collection were CENTRAL, MEDLINE/PUBMED, EMBASE, CINAHL, PEDro and SPORTDiscus, and only randomized controlled trials were included. Studies that included the clinical question by PICO (P = chronic ankle instability; I = joint mobilization; C = placebo and minimal intervention; O = pain and range of motion). The analysis was performed using the Review Manager 5.4.1. The I^2 test was used for heterogeneity of the studies. A total of 6 studies were selected for the meta-analysis in which they measured the range of motion. The findings were statistically significant for range of motion of dorsiflexion (mean difference – MD = 0.86, 95%CI = 0.06;1.66, p = 0.04), however the findings became insignificant after the sensitivity analysis (MD = 0.58, 95%CI = -0.07;1.23, p = 0.08). There was not enough literature for the pain outcome. The study obtained a satisfactory result for joint mobilization when all studies in the literature were grouped, but the result did not obtain statistical significance using better quality studies. Therefore, there is a need for better quality of evidence for the joint mobilization technique, as well as studies with better methodological quality so that we can more accurately state the real effects of this technique. Systematic Review Registration: Prospectively registered with PROSPERO (CRD42020193292).

Key words:
Ankle Injuries. Ankle Joint. Pain. Range of Motion.

Efecto de la movilización articular sobre la inestabilidad crónica del tobillo: una revisión sistemática con metaanálisis

Resumen

El presente trabajo tiene como objetivo analizar el efecto de la movilización articular en pacientes con inestabilidad crónica del tobillo sobre los resultados del dolor y el rango de movimiento de dorsiflexión del tobillo después de un estudio de revisión sistemática con metaanálisis. El período para el desarrollo de la investigación y la colección fue de Agosto de 2022. Las bases de datos utilizadas para la recopilación fueron CENTRAL, MEDLINE / PUBMED, EMBASE, CINAHL, PEDro y SPORTDiscus, y solo se incluyeron ensayos controlados aleatorios. Estudios que incluyeron la pregunta clínica por PICO (P = inestabilidad crónica del tobillo; I = movilización articular; C = placebo e intervención mínima; O = dolor y rango de movimiento). El análisis se realizó utilizando Review Manager 5.4.1. Se utilizó la prueba de I^2 para determinar la heterogeneidad de los estudios. Se seleccionaron un total de 6 estudios para el metaanálisis en el que midieron el rango de movimiento. Los hallazgos fueron estadísticamente significativos para el rango de movimiento de la dorsiflexión (diferencia de medias - DM = 0,86, IC del 95% = 0,06; 1,66, p = 0,04), sin embargo, los resultados se volvieron insignificantes después del análisis de sensibilidad (DM = 0,58, IC del 95% = -0,07; 1,23, p = 0,08). No hubo suficiente literatura sobre el resultado del dolor. El estudio obtuvo un resultado satisfactorio para la movilización articular cuando se agruparon todos los estudios de la literatura, pero el resultado no obtuvo significación estadística utilizando estudios de mejor calidad. Por lo tanto, se necesita una mejor calidad de evidencia para la técnica de movilización articular, así como estudios con mejor calidad metodológica para que podamos enunciar con mayor precisión los efectos reales de esta técnica. Registro de revisión sistemática: PROSPERO (CRD42020193292).

Palabras clave:
Lesiones de Tobillo. Articulación del Tobillo. Dolor. Rango de Movimiento.

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Introduction

Ankle sprains are among the most recurrent injuries in emergency care levels. The loss of time and initial recovery from ankle ligament sprains is less threatening than that of internal knee disorders, for example, but the high frequency and recurrence rate establish it as one of the main clinical and health system concerns, which despite being common, can cause chronic problems and recurrent injuries[1,2].

According to Doherty *et al.*[3], ligament injury presents high social economic costs associated with diagnosis, treatment and loss of work productivity, depending on the severity of the injury, and covers several spheres of the individual. This calls attention to a faster recovery, avoiding the chronicity of the injury and consequently chronic instability. According to Braun[4], symptoms which limit functional capacity and lifestyle are common from 6 to 18 months after an ankle sprain, and if the individual does not seek help, the condition may evolve with constant sprains and become more and more serious.

Some risk factors are cited by Martin[5], such as low amplitude of dorsiflexion ankle, history of previous injuries, not warming up before physical activity or not participating in a preventive program aimed at balance and proprioception. A portion of individuals who suffer from an acute ankle sprain have significant disability due to pain, functional instability, mechanical instability or recurrent sprain after the recovery plateaus 1 to 5 years after the injury[6]. The lower limbs have great functionality, and their immobilization due to injuries presents biomechanical, occupational, and psychological reduction, and consequently compensatory mechanisms to supply the absence of the injured joints.

Bialosky *et al.*[7] states that manual therapy interventions are generally one of the first choices among healthcare professionals and patients; however, systematic reviews have found relatively small effects in relation to their popularity. Also highlights the neurophysiological effects of joint mobilization, in which the proposed model categorizes neurophysiological stimuli originating from a peripheral mechanism (manual therapy), in which there will be control of pain, inflammation and even temporal summation due to spinal cord responses after the technique[8]. Furthermore, gains in relation to the range of motion are achieved after mechanical stimuli directly in the joint, decreasing spasm and exciting pro-inflammatory mediators.

It is worth mentioning that measurement before and after medical or physiotherapeutic interventions is important to define the real loss and some gain in joint function in the future. In the study by Powden *et al.*[9], they observed that the Weight Bearing Lounge Test (WBLT) is a highly reliable test for measuring the dorsiflexion range of motion of the ankle (ROM), since it provides consistency and repeatability among the evaluators, thus making it a validated instrument for clinical practice. In addition, the Visual Analog Pain Scale is validated to assess the intensity of local pain and used worldwide in diversified assessment systems[10-12].

Wright, Lines and Caim[13] report that due to the high frequency of patients with chronic ankle instability and the problems associated with pathology, knowledge of prevention and treatment approaches are of paramount importance for professionals working in the area. Despite medical, physiotherapeutic and outpatient care, poor recovery can offer an opportunity for chronic instability, with an injury cycle occurring to the individual. There is a need to seek better conducts and scientifically based treatment alternatives in order to bring about greater standardization regarding joint mobilization, better recovery of the individual and less repercussions, to prevent disabilities and improve their functionality.

Therefore, the aim of this study is to analyze the effect of joint mobilization in patients with chronic ankle instability on the outcomes of pain and dorsiflexion range of motion of the ankle after reviewing the current literature.

Material and method

Type of research

This is a systematic review with meta-analysis and followed the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses – PRISMA[14] and the Cochrane Handbook for Systematic Reviews of Interventions version 6.2[15]. The period for developing the research and collection was from August 2022. The databases used for collection were CENTRAL (Cochrane Central Register of Controlled Trials, The Cochrane Library), MEDLINE/PUBMED, EMBASE (ELSEVIER), CINAHL (Cumulative Index to Nursing and Allied Health Literature, EBSCO), PEDro (Physiotherapy Evidence Database) and SPORTDiscus (EBSCO), and only randomized controlled trials (RCT) were accepted; there were no language restrictions or publication date. The review was submitted a priori by the International Prospective Register of Systematic Reviews (PROSPERO) platform, with the following credential ID = CRD42020193292 in order to preserve the study data and avoid possible manipulation of study outcomes and/or results.

Inclusion criteria

Studies which included the clinical question by PICO for the purposes of inclusion criteria in the review followed: P = patients with chronic ankle instability; I = joint mobilization; C = placebo and minimal intervention; O = pain and range of motion. Studies were selected that included male or female individuals aged 18 years or older, who had chronic ankle instability and received isolated joint mobilization treatment compared to minimal or false treatment (placebo).

Exclusion criteria

Studies were excluded from the review if: it was clear in the summary that they did not meet the above criteria; if the selected criteria were not clear in the summary, the full article was read and it was then decided to include or exclude it. The reasons for excluding studies after reviewing the full text are detailed in the table "Characteristics of excluded studies" (Figure 4).

Measured outcomes

Pain outcomes were measured by VAS (Visual Analogue Scale) and ROM by Weight Bearing Lounge Test (WBLT).

Collection of studies

The relevant studies were found through a computer-aided search through the PUBMED and PEDro databases. The search terms used were: ankle sprain, ankle instability, chronic, joint mobilization, manual therapy, MWM, Maitland, Mulligan, Pain, range of motion, and dorsiflexion. The terms were searched alone and in combinations in the search, with a search filter for Randomized Controlled Trials. Two reviewers (IS and FS) independently selected studies with the research terms selected a priori and with PICOT. The data selection was not blinded to the authors.

Data extraction

Two reviewers (IS and FS) independently extracted data about the study design, participants, interventions and results. Data extraction was not blinded to the authors. Disagreements about the results of the data extraction were resolved by consensus among the team. If the disagreement persisted, a third reviewer (CK) was consulted.

Methodological analysis

Two reviewers who were not blinded to the work in question (IS, FS) independently assessed the methodological quality of each RCT. Disagreements were addressed by discussion and consensus in the review team (IS, FS AND MK). The 11 criteria recommended by the PEDro Scale were used to assess the methodological quality of randomized clinical trials, each criterion was scored as "Yes" or "No", according to the recommendation of the scale itself, which is from 0 to 10.

Data analysis

The Review Manager 5.4.1 software program (RevMan 5.4.1 – The Collaboration Cochrane) was used to perform the meta-analysis of this review, to calculate the average size of the combined effect of the mean differences (MD) for all group comparisons and the 95% confidence interval (95% CI). The significance value p = 0.05 and 95% CI was observed in all studies, with a value less than or equal to 0.05 indicating a statistically significant difference or correlation. The I2 test was performed to identify possible heterogeneity between studies. The Kappa index was performed to obtain reliability between the two reviewers independently, where the score by PEDro Scale given by the two reviewers of the included studies was compared in the SPSS (Version 22) in relation to the assertiveness between the reviewers; 70% of the times there was the same score, showing good reliability and homogeneity of the reviewers' methodological criteria.

Results

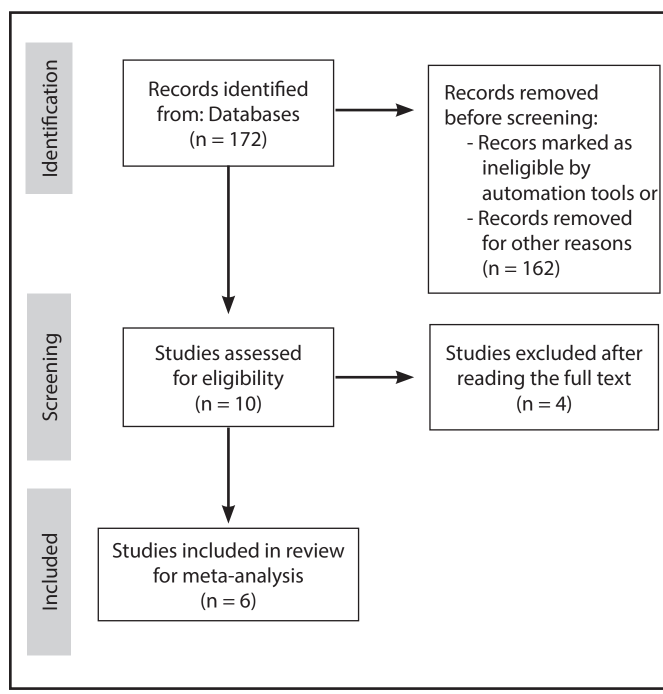
Of 172 study abstracts, 10 were selected for full reading. However, 4 studies were excluded with common reasons for exclusion including wrong intervention, wrong patient population and incorrect study design (Table 1). Thus, 6 studies were selected for the current meta-analysis, which analyzed the following outcomes: ROM and Pain in female or male patients aged 18 or over with chronic ankle instability. ROM was reported in the 6 selected studies, pain was measured in only 1 study, so only ROM was exposed in the meta analysis (Figure 1).

The reliability analysis showed a Kappa's quotient equal 0.714 and 95% CI was between 0.168;1.260 (p = 0.010), showing good agreement.

Table 1. Studies excluded and justification after reading the full text.

Author, Year	Title	Justification
Gilbreath *et al.* 2014[16]	The effects of mobilization with movement on dorsiflexion range of motion, dynamic balance and self-reported function in individuals with chronic ankle instability	There was no randomization of patients in the study.
Yeo *et al.* 2011[17]	Hypoalgesic effect of a passive accessory mobilization technique in patients with lateral ankle pain	There were sub-acute injuries in the study.
Wikistrom *et al.* 2017[18]	Predicting successful treatment with manual therapy in patients with chronic ankle instability: improving self-reported function	It was not compared to placebo or minimal intervention.
Ardèvol *et al.* 2002[19]	Treatment of complete rupture of the lateral ligaments of the ankle: a randomized clinical trial comparing plaster cast immobilization with functional treatment	The duration of the disease was not chronic

Figure 1. Selection of studies for the meta-analysis.



The 6 selected studies assessed ankle mobility before and after treatment, using the WBLT test with or without weight support and comparing minimal intervention or false treatment. The Table 2 shows data extraction from these studies.

All selected studies were methodologically evaluated by 2 non-blinded evaluators following the PEDro methodological quality scale (Figure 2).

The pooled data from four studies with 220 participants with chronic ankle instability were pooled to analyze the effects of joint mobilization on DFROM (MD = 0.86, 95% CI = 0.06;1.66, p = 0.03) and the analysis confirmed significant improvements immediately after treatments (Figure 3).

The results become statistically insignificant after the meta-regression by sensitivity analysis with at least or less studies 07 on the PEDro scale, with 121 patients for analysis of the effects of joint mobilization on DFROM (MD = 0.58, 95% CI = -0.07;1.23, p = 0.08) (Figure 4).

There was not enough data to elaborate the meta-analysis or make a conclusion on the efficacy for the pain outcome using the EVA scale. The certainties of the evidence and the results presented were analyzed as low-quality evidence (downgraded due to imprecision and inconsistency), for is analyzed was performed the recommendations of the The Grading of Recommendations Assessment, Development and Evaluation - GRADE[26] (Table 3).

Figure 2. Risk of bias - PEDro Scale: review authors' judgements about each risk of bias item for each included study.

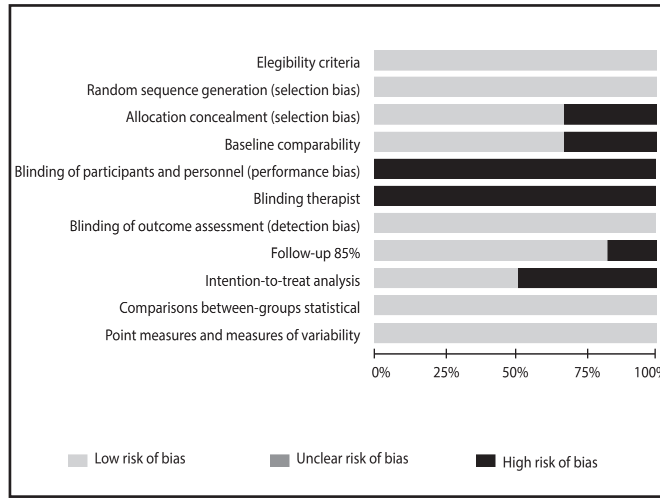


Table 2. Characteristics of the selected studies.

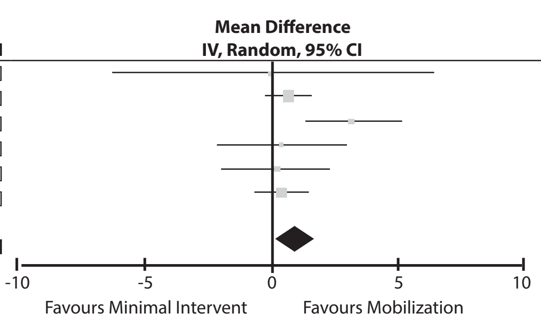
Author, Year	Subjects	Experimental Group	Control Group	Results
Cruz-Díaz *et al.* 2015[20]	n = 57	Ankle joint mobilization	Sham Mobilization	WB and DFROM Statistically significant improvements (p < 0.01)
Vincenzino *et al.* 2006[21]	n = 16	Ankle joint mobilization	No intervention	WB and DFROM Statistically significant improvements (p = 0.02)
Reid *et al*. 2007[22]	n = 23	Ankle joint mobilization	Simulated intervention	WB and DFROM Statistically significant improvements (p = 0.02)
Beazell *et al.* 2012[23]	n = 43	Manipulation of the proximal and distal tibiofibular	No intervention	WB and DFROM No significant differences were observed over time, however, there was a significant increase (p < 0.001) after intervention.
Hoch *et al*. 2010[24]	n = 20	Maitland Grade III of the ankle joint mobilization	Rest	WB and DFROM The results indicated that the treatment of joint mobilization was associated with significantly higher ROM (p = 0.01).
Marrón-Gomez *et al.* 2015[25]	n = 52	Ankle joint mobilization	Sham Intervention	WB and DFROM Statistically significant improvements compared to placebo (p < 0.05).

DFROM: Dorsiflexion Range of Motion; WBLT: Weight Bearing Lounge Test.

Figure 3. Forest Plot contemplating the studies included in the meta-analysis of the immediate effect of joint mobilization on the range of motion of dorsiflexion with weight support, gathering data from six studies (n = 220).

	Joint Mobilization			Minimal Intervention				Mean Difference
Study or subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Beazell 2012	3.9	7.1	13	3.9	10	15	1.5%	0.00 [-6.36, 6.36]
Cruz-Díaz 2015	6	1.6	30	5.3	1.7	31	36.8%	0.70 [-0.12, 1.53]
Gómez 2015	11.5	3.8	18	8.31	1.5	15	13.4%	3.19 [1.28, 5.10]
Hock 2010	12.6	2.7	10	12.2	3.1	10	8.4%	0.40 [-2.15, 2.95]
Reid 2007	10.5	3.7	23	10.3	3.8	23	11.0%	0.20 [-1,97, 2.37]
Vicenzino 2006	4.8	1.5	16	4.4	1.6	16	28.9%	0.40 [-0.67, 1.47]
Total (95% CI)			**110**			**110**	**100.0%**	**0.86 [0.06, 1.65]**

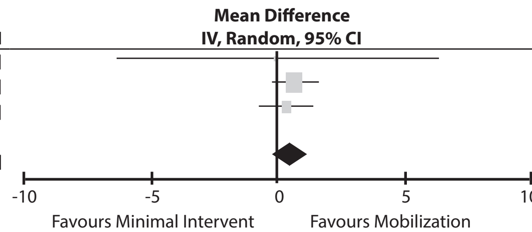
Heterogeneity: Tau² = 0.27; Chi² = 7.03, df = 5 (P = 0.22); I² = 29%
Test for overall effect: Z = 2.12 (P = 0.03)



95% CI: 95% confidence interval; SD: standard deviation; MD: mean difference.

Figure 4. Forest Plot contemplating the studies included in the meta-analysis of the immediate effect of joint mobilization on the range of motion of dorsiflexion with weight support gathering data from three studies with at least 07 on the PEDro scale (n = 121).

	Joint Mobilization			Minimal Intervention				Mean Difference
Study or subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Beazell 2012	3.9	7.1	13	3.9	10	15	1.5%	0.00 [-6.36, 6.36]
Cruz-Díaz 2015	6	1.6	30	5.3	1.7	31	62.1%	0.70 [-0.12, 1.53]
Vicenzino 2006	4.8	1.5	16	4.4	1.6	16	36.9%	0.40 [-0.67, 1.47]
Total (95% CI)			**59**			**62**	**100.0%**	**0.58 [-0.07, 1.23]**



Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.22$, df = 2 (P = 0.90); $I^2 = 0\%$
Test for overall effect: Z = 1.75 (P = 0.08)

Table 3. Explanations of downgrade.

Range of motion (follow up: median 1 week; assessed with: cm)

Nº of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations
6	Randomised trials	Not serious	Serious[a]	Not serious	Serious[b]	None
Nº of patients		**Effect**		**Certainty**		
Joint movilization	**Anyother Intervention**	**Relative (95% CI)**	**Absolute (95% CI)**	⊕⊕◯◯ Low		
110	110	--	MD 0.86 more (0.06 more to 1.66 more)			

CI: 95% confidence interval; SD: standard deviation; MD: mean difference.
a. All studies have inconsistency in the confidence intervals, where there is no overlap between them, proving statistical inconsistency. b. Optimal information size was not met because the number of study participants was low (n < 400).

Discussion

The present study hypothesizes the improvement in DFROM and pain in patients with chronic ankle instability after the intervention suggested from a systematic review and meta-analysis. The results revealed that the data are statistically significant and that there was a clinically relevant improvement for DFROM when all studies were evaluated, without a methodological quality filter. However, the result was statistically insignificant after the meta-regression by sensitivity analysis (n = 03).

It was observed that all 6 studies failed to blind patients and therapists and may contain bias in the data measurement results and in the perception of treatments by patients. Nevertheless, it is known that blinding a therapist is something rare, especially with manual procedures, making it difficult for the authors to obtain the maximum grade. Only two[21,25] failed in the Hidden Allocation item, while two[22,23] failed in the Baseline Comparison. Only one study[24] failed in evaluator blinding, three failed to analyze by intention-to-treat[22,24,25], where patients who did not complete the treatment needed to be followed-up and have all their data collected, even without completing the treatment. All scored in the items Follow-up, appropriate, difference between groups and estimated point and variability.

Only Hock and McKeon[24] did not use Mulligan in his study; in contrast he used the Maitland technique, in which joint mobilization is performed through speed and range of motion degrees.

Low quality evidence observed an increase in ROM between mobilization and control, however, we noticed a deviation in results. We performed a downgrade and lowered the evidence to a high risk level of inconsistency, although the I^2 was low, there was little overlap in the confidence intervals showing different results between studies, and we lowered a level in inaccuracy due to the low number of subjects when grouping all studies.

A systematic review of the quality of clinical practice guidelines for treating ankle sprains carried out by Green[27] shows disparities in relation to graduated joint mobilizations or mobilization with movement, where they are not recommended by Dutch clinical practice guidelines, but are recommended by the American guidelines, and points out that the interpretation of the evidence between the two groups for developing the guidelines is not consistent. More research and robust studies are needed on joint mobilization recommendations for outcomes. Also concludes that most of the guidelines related to ankle sprain treatment are bad or outdated, and the absence of good methodologies is one of the main barriers to implementation.

Doherty *et al*[28] disclosed in his review on the treatment of recurrent ankle sprains that there was moderate evidence of neuromuscular training for patients with chronic instability, while manual therapy had moderate evidence for acute injuries, acting to control inflammation and pain.

Following the review by Weerasekara *et al.*[29], the current literature lacks standardization regarding joint mobilization as well as its real effects, considering that the DFROM can be modified by external factors which are not only the studied technique, but by simply applying the WBLT test (for example).

Based on the concept, joint mobilization mainly has its effects on range of motion blocks and joint pain or immediate periods[30]. From the results of the present study, mobilization does not seem to be effective for DFROM in chronic ankle instabilities, however due to the number of studies and their quality, future studies will help to more accurately express the confidence interval and the size of the studied technique's effect. Studies are also needed for other outcomes and with higher methodological quality so that there is no deviation from the real effects caused by low quality studies.

Pain measures have not been properly evaluated, thus suggesting that other resources with proven efficacy should be applied for local pain relief, taking into account the low quality of available evidence of the effectiveness of joint mobilization on pain.

Our review provides healthcare professionals with guidance on the technique of joint mobilization in patients with chronic ankle instability, emphasizing that decision-making is by the professional in conjunction with the patient and with their professional expertise.

Study limitations

The limitations of the review were the non-blinding of the reviewers, as well as the search only being conducted in two databases, although it is acceptable, it is possible that more studies from other databases could be included using the review filtering. The study samples are small, the short-term results varied between days and months, and it was not assessed whether the results were clinically relevant, only statistically significant, expanding the margin of clinical relevance depending on the professional. We planned to make a funnel plot to evaluate the publication bias if there were at least 10 studies in the meta-analysis. As we did not reach the desired quantity, the interpretation of the graph could have been biased due to the small number of studies.

Conclusion

This study was able to summarize the current efficacy of joint mobilization and pain in patients with chronic ankle instability, as well as its statistical significance and clinical relevance in the best- and worst-case scenarios.

Low-quality evidence suggests that joint mobilization may improve clinical ROM for patients with chronic ankle instability compared with placebo or non-treatment. Thus, there is a need for better quality of evidence for the joint mobilization technique, as well as studies with better methodological quality so that the real effects of the technique can be stated with greater precision.

Conflict of interest

The authors do not declare a conflict of interest.

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Original article

The influence of contextual variables on physical and physiological match demands in soccer referees

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doi: 10.18176/archmeddeporte.00111

Received: 11/02/2022
Accepted: 13/09/2022

Summary

The aim of this paper was to examine how contextual factors affect match demands in amateur referees. Twenty-three field referees participated in this study. Match physical and physiological demands were monitored. Results showed that referees recorded greater total distance ($p < 0.01$), $Power_{mean}$ ($p < 0.01$), $Speed_{mean}$ ($p < 0.05$) and $Cadence_{mean}$ ($p<0.05$) on natural fields compared to artificial turf fields. Greater total distance ($p < 0.01$), $Power_{mean}$ ($p < 0.01$), $Speed_{mean}$ ($p < 0.01$), $Cadence_{mean}$ ($p < 0.05$) and $Stiffness_{mean}$ ($p < 0.05$) were recorded in above-standard fields in comparison to below-standard fields. Referees recorded greater total distance ($p < 0.05$), $Power_{mean}$ ($p < 0.05$) and $Speed_{mean}$ ($p < 0.05$) during matches played with an environmental temperature of over 20º compared to those matches played at temperatures below 10º. Referees' covered more total distance in second-round matches compared to first round matches. Results suggest that the physical demands supported by soccer referees during official matches are influenced by the type of surface, pitch size, environmental temperature and period of the season, however, physiological demands do not seem to be conditioned by contextual factors

Key words:
Field referees. Season period. Field size. Turf. Temperature

La influencia de las variables contextuales en las cargas físicas y fisiológicas de los árbitros de fútbol

Resumen

El objetivo principal de este trabajo fue examinar cómo los factores contextuales afectan a la carga de partido de los árbitros amateur. Veintitrés árbitros de campo de la División de Honor española participaron en este estudio. Para ello se registraron la carga física y fisiológica de partido. Los resultados mostraron que los árbitros registraron una mayor distancia total ($p < 0,01$), potencia media ($p < 0,01$), velocidad media ($p < 0,05$) y cadencia media ($p < 0,05$) en los campos naturales en comparación con los campos de césped artificial. Se registró una mayor distancia total ($p < 0,01$), potencia media ($p < 0,01$), velocidad media ($p < 0,01$), cadencia media ($p < 0,05$) y media de stiffness medio ($p < 0,05$) en los campos más grandes que la media en comparación con los campos por debajo de la media. Los árbitros cubrieron más distancia total ($p < 0,05$), potencia media ($p < 0,05$) y velocidad media ($p < 0,05$) durante los partidos jugados con una temperatura ambiental superior a 20º en comparación con los partidos jugados con temperaturas inferiores a 10º. Los árbitros recorrieron más distancia total en los partidos de la vuelta en comparación con los partidos jugados en la ida ($p < 0,05$). Los resultados sugieren que la carga física de los árbitros de fútbol durante los partidos oficiales, están influenciadas por el tipo de superficie, el tamaño del campo, la temperatura ambiental y el período de la temporada, en cambio la carga fisiológica no parece estar condicionada por los factores contextuales.

Palabras clave:
Árbitros de campo. Periodo de temporada. Tamaño del campo. Césped. Temperatura.

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Introduction

Thousands of amateur soccer matches are played weekly around the world, officiated by field referees and their two assistants from the national level upwards, and with only field referees officiating the majority of matches at grassroots and lower senior competitive levels. From a physical and physiological perspective, refereeing is an intermittent activity that mainly requires the implication of the aerobic system, although it is interspersed with periods of high-intensity requiring the anaerobic system[1,2]. In terms of total distance covered and distance covered at different speeds, amateur referees cover around 10-11 km per match, of which almost 3 km are covered at high intensity (over 13 km·h^{-1}) and approximately 800 m at high speed (over 18 km·h^{-1})[3,4]. In addition, the accelerations and decelerations of referees have also been investigated. In this respect soccer referees cover around 1.5 km accelerating and around 400 m decelerating[3,5,6]. In addition, recent studies have validated the Stryd Power Meter as a suitable device to record the physical demands of referees during official matches[4,7]. Moreover, these studies have reported that the mean power registered by soccer referees during a match is around 120.72 ± 11.75 W. It has also been reported that the mean vertical oscillation presented by referees is 8.00 ± 0.54 cm, the mean ground contact time is 541.21 ± 57.73 m·s^{-1} and the mean stiffness is 9.28 ± 0.56 KN·m^{-1}[4].

Moreover, referees present a mean heart rate (HR_{mean}) above 85% of their maximum HR ($\%HR_{peak}$)[3,8] during matches, while according to the match load recorded using Edward's training impulse (TRIMP), this population recorded 390 ± 34 AU during match-play[9]. Therefore, possessing an adequate capacity to respond to these demands during match play can help them to face matches with sufficient ability to follow the pace of the match and be close to the actions in order to make correct decisions[10,11].

Contextual variables has been previously analyzed in soccer players showing that several of them could influence their physical and physiological demands during match-play, highlighting the level of the opposing teams[12], the match outcome[13], the type of surface[14,15], the environmental temperature[16–18] and/or the period of the season[19], among other factors. Considering the strong association observed between the activity performed by outfield players and field referees[20–22], it could be assumed that such contextual variables could also influence referees' match demands. However, few studies have analyzed the influence of contextual variables such as age, experience and competitive level on the physical and physiological demands encountered by soccer referees during competition[23,24], and only one study has analyzed the influence of the level of the opposing teams on the referees' running activity[25]. In this respect, a gap has been identified in the literature on how contextual factors such as field dimensions or type of field could influence the referees' match demands. This aspect could be important to analyze since official matches at the amateur level are played on fields of different characteristics in terms of type and dimensions. Likewise, there is a lack of studies considering the influence of environmental temperature and the period of the season on the referees' match demands, although Taylor *et al.*[26] observed that warm and cold environments do not influence decision-making ability.

Previous studies have analyzed the evolution of referees' demands as the match progresses showing a decrease in total distance or distance covered at high intensity (>13 km·h^{-1}) during the second half of matches compared to the first half[7,27–29]. Similarly, it was found that amateur referees showed higher values regarding physiological indicators such as HR, lactate concentration and tympanic temperature at the end of the matches and immediately after completion[30]. In addition, neuromuscular fatigue (i.e., distance decrease in horizontal jump performance) after finishing the matches has been previously reported[1]. Other studies have gone further and have analyzed referees' match demands during shorter periods (i.e., 15 min) showing that professional referees' match demands are higher in the initial periods of the match[5,31,32]. However, Ozaeta *et al.*[7] showed that the match demands increased in the last 15 min of the match in amateur soccer referees, so it would be interesting to investigate whether contextual factors may be the reason for the increased match demands.

Attending to the aforementioned information, and to understand the physical and physiological demands in soccer referees as well as to optimize the training process, the aim of this study was twofold: 1) to assess the differences in the physical and physiological responses encountered by soccer referees regarding each contextual variable (i.e., type of turf, pitch size, period of season, and environmental temperature) during official matches, and 2) to analyze the physical and physiological variations during 15 min periods according to each contextual variable (i.e. type of turf, pitch size, period of season, and environmental temperature). We hypothesized that contextual variables could influence the referees' physical and physiological responses during match play.

Material and method

Design

An observational (i.e., descriptive-comparative) design was used to analyze the physical and physiological demands encountered by field soccer referees according to contextual variables (i.e., type of turf, pitch size, period of season, and environmental temperature). A total of 23 official matches were analyzed during the in-season period (i.e., from November to March) of the 2019-2020 season. The data included measures of physical [total distance covered, power, speed, cadence, vertical oscillation, ground contact time (GCT) and stiffness] and physiological [HR_{mean}, $\%HR_{peak}$, HR zones (from zone 1 to zone 5) and TRIMP] match demands.

Subjects

Twenty-three male field referees (age: 25.65 ± 3.30 years; height: 173.4 ± 3.8 cm; body mass: 64.86 ± 5.82 kg; body mass index, BMI: 21.56 ± 1.67 kg·m^{-2}) who officiated soccer matches in the División de Honor de Vizcaya (Spain), participated in the present study. The referees had an experience in the category at least 3 years. All the participants trained at least twice a week and officiated matches in the category twice a month. Participants were informed of the procedures, methods, benefits, and possible risks involved in the study before signing their written consent. This investigation was performed in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of The University of the Basque Country (Code: M10/2018/289).

Procedures

Before the beginning of the match all the officials performed a 10 min warm-up consisting of running, stretching, short sprints and progressive sprints. The 15 min half-time data were excluded from the external and internal match load analysis. All the matches were played between 11 am and 5 pm.

Type of turf. The soccer matches were played on natural grass and artificial surfaces as propose by Stone *et al*. (2016)[14].

Pitch size. According to the rules of the game approved by the International Football Association Board (IFAB) for international matches, the touch line must have a minimum length of 100 m and the goal line a minimum length of 64 m[33]. In this regard, we opted to differentiate fields with a size of over 100 x 64 m (above-standard) versus fields with a size below 100 x 64 m (below-standard).

Period of the season. Two rounds (first and second) were determined as previously used by Mohr *et al*. (2003) with soccer referees.

Environmental temperature. Matches played at below 10º and above 20º were selected because previous studies have mainly focused on matches played at high temperatures (>20º Celsius)[16,17] and this study tried to see if there were differences between matches played at high and low temperatures.

Physical demands. Referees' physical demands were monitored using a Stryd Power Meter (Stryd, Inc., Boulder, Colorado, USA), which was placed over the right soccer boot with a plastic clip regardless of lower limb dominance[34]. The Stryd Power Meter has been shown to be a valid device for measuring external demands in soccer referees[4]. The Stryd was activated following the manufacturer's recommendations for offline use. It records total match data for the following variables: total distance covered (km), mean power (W), mean speed ($km \cdot h^{-1}$), mean cadence ($steps \cdot min^{-1}$), mean vertical oscillation (cm), mean GCT ($m \cdot s^{-1}$) and mean stiffness ($KN \cdot m^{-1}$).

Physiological demands. Referees' HR was monitored during matches with a Polar Team 2 device (Polar Team System™, Kempele, Finland) at 1s intervals. HR_{mean} and $\%HR_{peak}$ were considered for this study, and TRIMP was also calculated. According to the study by Edwards (1993)[35], intensity was represented by the time spent in 5 arbitrary HR zones (Zone 1, 50-60% of HR_{peak}; Zone 2, 60-70% of HR_{peak}; Zone 3, 70-80% of HR_{peak}; Zone 4, 80-90% of HR_{peak}; and Zone 5, 90-100% of HR_{peak}) multiplied by the number of each zone (1, 2, 3, 4, and 5). The sum of values obtained for each zone represented TRIMP, measured by arbitrary units (AU).

Statistical analyses

Data are presented as mean ± standard deviations (SD). Normality of data distribution and homogeneity of variances were tested using the Shapiro–Wilk and Levene tests, respectively. A two–way analysis of variance (ANOVA) was applied in order to test for differences in variables recorded during 15 min in-game periods, with contextual variables (i.e., type of turf, pitch size, period of season and environmental temperature) introduced as between-subject factors, and 15 min periods as a within-subject factor. Data sphericity was evaluated using Mauchly's test, and Greenhouse-Geiser or Huynh-Feldt corrections were applied for non-spherical distributions. The Bonferroni corrections was applied for post-hoc comparisons. Practical significance for pair wise comparisons was assessed by calculating Cohen's d effect size[36]. Effect sizes (d) of above 0.8, between 0.8 and 0.5, between 0.5 and 0.2 and lower than 0.2 were considered as large, moderate, small, and trivial, respectively[37]. Further, ANOVA effect sizes were calculated using partial eta squared (η_p^2), and <0.25, 0.26–0.63 and >0.63 were considered small, medium and large effect sizes respectively[38,39]. All statistical tests were performed using the IBM SPSS Statistics for Mac (IBM Corp., version 20.0, Armonk, NY, USA). Statistical significance was set at $p \leq 0.05$.

Results

Referees' physical demands according to the type of turf during official matches are shown in Table 1. Referees recorded greater total distance ($p < 0.01$), $Power_{mean}$ ($p < 0.01$), $Speed_{mean}$ ($p < 0.05$) and $Cadence_{mean}$ ($p < 0.05$) on natural fields compared to artificial turf fields. However, no significant differences were found in Vertical oscillation-mean, GCT_{mean} and $Stiffness_{mean}$. Neither were differences found in any physiological variable according to the type of turf (Table 2).

Referees' physical demands according to the pitch size during official matches are shown in Table 3. Referees recorded greater total distance ($p < 0.01$), $Power_{mean}$ ($p < 0.01$), $Speed_{mean}$ ($p < 0.01$), $Cadence_{mean}$ ($p < 0.05$) and $Stiffness_{mean}$ ($p < 0.05$) in above-standard in comparison to below-standard fields. However, no significant differences ($p > 0.05$) were found in Vertical $oscillation_{mean}$ and GCT_{mean}. Regarding physiological demands, referees spent more time in Zone 5 in above-standard fields, but no differences were found in any other HR zones, HR_{mean}, $\%HR_{peak}$ or TRIMP (Table 4).

According to the period of the season, during the second round, referees covered more total distance in the matches compared to the matches played in the first round ($p < 0.05$) (Table 5). However, no differences were found in most of the physical ($Power_{mean}$, $Speed_{mean}$, $Cadence_{mean}$, Vertical $oscillation_{mean}$, GCT_{mean} and $Stiffness_{mean}$) or physiological demands (Table 6).

Referees' physical demands according to the environmental temperature during official matches are shown in Table 7. Referees recorded greater total distance ($p < 0.05$), $Power_{mean}$ ($p < 0.05$) and $Speed_{mean}$ ($p < 0.05$) during matches played with a higher environmental temperature (more than 20º) compared to those matches played in temperatures below 10º. However, no significant differences were found in other physical ($Cadence_{mean}$, Vertical $oscillation_{mean}$ GCT_{mean} or $Stiffness_{mean}$) or physiological demands (Table 8).

No significant interaction ($p > 0.05$) was observed in physical and physiological demands within 15 min periods according to type of turf, field, size, period of season or environmental temperature.

Discussion

The main aim of this study was to analyze how contextual variables (i.e., type of turf, pitch size, period of season, and environmental

Table 1. Physical demands registered by soccer referees according to type of turf (i.e., natural and artificial) during official matches.

Physical variables	Contextual variable	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	Entire match	Type of turf	Type of turf x period
Total distance (km)	Natural Artificial	1.57±0.17 1.37±0.21	1.48±0.10 1.40±0.14	1.54±0.13 1.31±0.31	1.46±0.19 1.31±0.16	1.37±0.17 1.29±0.14	1.77±0.27 1.57±0.19	9.18±0.62# 8.25±0.75	$F_{1, 21}$= 10.076 **p = 0.005** η_p^2= 0.324	$F_{5.00, 105.00}$= 0.922 p = 0.470 η_p^2= 0.042
$Power_{mean}$(W)	Natural Artificial	136.21±11.51 120.04±15.55	129.18±14.23 120.02±16.34	125.88±10.19 109.67±7.63	127.35±14.08 117.14±8.89	125.08±18.53 110.87±9.54	126.75±14.55 110.80±11.24	128.36±11.48# 114.84±7.68	$F_{1, 21}$= 11.373 **p = 0.003** η_p^2= 0.351	$F_{5.00, 105.00}$= 0.637 p = 0.672 η_p^2=0.029
$Speed_{mean}$ ($km \cdot h^{-1}$)	Natural Artificial	7.87±0.58 7.08±0.79	7.57±0.56 7.04±0.78	7.27±0.54 6.66±0.56	7.52±0.82 6.96±0.57	7.27±0.78 6.66±0.59	7.37±0.71 6.60±0.75	7.48±0.55# 6.83±0.56	$F_{1, 21}$ = 7.256 **p = 0.014** η_p^2= 0.257	$F_{5.00, 105.00}$ = 0.417 p = 0.836 η_p^2= 0.019
$Cadence_{mean}$ (steps per min)	Natural Artificial	65.80±2.92 63.42±2.24	63.81±1.77 62.79±2.93	63.99±2.01 60.45±3.49	63.88±3.26 63.33±1.62	62.77±3.27 61.36±2.47	62.61±2.64 60.94±1.90	63.80±1.69# 62.07±1.43	$F_{1, 21}$ = 6.855 **p = 0.016** η_p^2= 0.246	$F_{5.00, 105.00}$= 1.274 p = 0.281 η_p^2= 0.057
Vertical $oscillation_{mean}$(cm)	Natural Artificial	8.20±0.95 8.07±0.58	8.04±0.43 8.00±0.58	8.06±0.66 7.86±0.63	8.06±0.58 7.84±0.44	8.08±0.82 8.08±0.73	7.82±0.66 7.88±0.65	8.04±0.61 7.96±0.47	$F_{1, 21}$ = 0.161 p = 0.692 η_p^2= 0.008	$F_{5.00, 105.00}$= 0.412 p = 0.839 η_p^2= 0.019
GCT_{mean}($m \cdot s^{-1}$)	Natural Artificial	504.44±69.91 528.40±80.86	538.74±68.03 563.78±66.95	546.58±81.73 542.36±118.13	527.77±78.40 532.24±80.60	524.30±76.12 572.37±50.22	525.33±56.44 568.23±66.00	527.75±59.67 551.56±58.73	$F_{1, 21}$ = 0.881 p = 0.359 η_p^2= 0.040	$F_{3.820, 80.221}$ = 0.835 p = 0.502 η_p^2= 0.038
$Stiffness_{mean}$($KN \cdot m^{-1}$)	Natural Artificial	9.24±0.56 9.59±1.05	9.24±0.53 9.52±0.92	9.30±0.52 9.31±0.67	8.82±0.43 9.46±0.76	9.07±0.59 9.33±0.70	9.02±0.52 9.12±0.68	9.12±0.36 9.41±0.66	$F_{1, 21}$ = 1.480 p = 0.237 η_p^2=0.066	$F_{5.00, 105.00}$= 1.116 p = 0.356 η_p^2= 0.050

GCT: ground contact time; #Significantly different (p < 0.05) from artificial turf.

Table 2. Physiological demands registered by soccer referees according to type of turf (i.e., natural and artificial) during official matches.

Physical variables	Contextual variable	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	Entire match	Type of turf	Type of turf x period
HR_{mean} (bpm)	Natural Artificial	156.60±10.80 163.00±16.46	159.86±11.89 163.90±12.79	158.59±12.58 159.56±16.18	154.69±14.84 157.53±11.35	155.12±12.51 158.44±10.98	157.84±13.27 157.37±13.42	157.17±12.16 159.83±12.23	$F_{1, 21}$ = 0.311 p = 0.583 η_p^2=0.015	$F_{2.659, 55.836}$= 0.934 p = 0.421 η_p^2= 0.043
$\%HR_{peak}$	Natural Artificial	87.83±2.98 85.13±6.43	88.09±3.13 87.67±5.15	88.08±2.15 87.91±5.24	88.04±2.07 87.98±2.10	86.80±2.33 88.83±2.32	88.20±2.14 85.60±4.10	85.56±2.50 82.28±6.04	$F_{1, 21}$ = 0.406 p = 0.531 η_p^2= 0.019	$F_{2.853, 59.919}$ = 1.774 p = 0.164 η_p^2=0.078
Zone 1 (min)	Natural Artificial	0.194±0.32 0.80±2.30	0.00±0.00 0.18±0.63	0.00±0.00 0.55±1.89	0.02±0.05 0.32±1.07	0.03±0.10 0.15±0.55	0.00±0.01 0.22±0.74	0.25±0.34 2.22±4.21	$F_{1, 21}$ = 2.167 p = 0.156 η_p^2= 0,094	$F_{1.946, 40.869}$ = 0.246 p = 0.777 η_p^2= 0.012
Zone 2 (min)	Natural Artificial	0.29±0.40 0.51±0.62	0.25±0.47 0.45±1.15	0.16±0.22 1.14±2.90	0.47±0.77 1.16±2.35	0.61±0.92 1.14±2.91	0.33±0.62 1.95±3.53	2.12±2,47 6.34±13.04	$F_{1, 21}$ = 1.012 p =0.326 η_p^2= 0.046	$F_{1.709, 35.895}$ = 1.550 p = 0.227 η_p^2=0.069
Zone 3 (min)	Natural Artificial	2.65±1.70 3.38±2.87	2.18±1.62 2.96±3.35	3.20±2.22 3.81±3.51	3.53±2.05 4.39±3.57	3.01±1.73 4.27±3.81	3.30±1.90 5.89±4.50	17.88±8,02 24.70±19.82	$F_{1, 21}$ = 1.044 p = 0.318 η_p^2= 0.047	$F_{5.00, 105.00}$= 1.260 p = 0.287 η_p^2= 0.057
Zone 4 (min)	Natural Artificial	6.90±1.65 5.49±1.96	6.50±1.28 7.02±2.42	6.35±1.27 6.79±2.98	7.10±1.62 6.53±3.04	7.40±1.85 6.90±3.47	9.00±1.45 7.74±4.73	43.25±5.04 40.48±15.23	$F_{1, 21}$ = 0.302 p = 0.589 η_p^2= 0.014	$F_{5.00, 105.00}$ = 1.060 p = 0.387 η_p^2= 0.048
Zone 5 (min)	Natural Artificial	4.55±2.11 4.49±3.23	5.63±2.38 4.25±3.69	5.84±2.69 3.81±3.47	3.50±3.00 2.50±2.04	3.55±1.80 2.47±2.18	5.96±3.44 3.24±3.37	29.04±11.94 20.76±14.54	$F_{1, 21}$ = 2.132 p = 0.159 η_p^2= 0.092	$F_{5.00, 105.00}$= 1.203 p = 0.313 η_p^2= 0.054
TRIMP (AU)	Natural Artificial	59.07±3.82 56.37±11.44	61.25±4.99 59.29±8.12	64.52±7.06 60.48±12.80	57.45±6.00 54.42±9.88	57.63±5.20 55.19±9.66	76.40±8.92 68.96±12.51	376.32±28.53 354.72±53.16	$F_{1, 21}$ = 1.343 p = 0.260 η_p^2=0.060	$F_{2.603, 54.666}$ = 0.644 p = 0.569 η_p^2= 0.030

HR_{mean}: mean heart rate; $\%HR_{peak}$: percentage of their maximum heart rate achieved during the match; TRIMP: training impulse.

Table 3. Physical demands registered by soccer referees according to pitch size (i.e., over standard and below standard) during official matches.

Physical variables	Contextual variable	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	Entire match	Pitch size	Pitch size x period
Total distance (km)	Over standard	1.57±0.17	1.48±0.11	1.51±0.12#	1.41±0.19	1.37±0.15	1.74±0.25	9.08±0.59##	$F_{1, 21}$ = 22.682	$F_{5.00, 105.00}$ = 1.449
	Below standard	1.25±0.12	1.34±0.10	1.23±0.37	1.30±0.14	1.23±0.13	1.50±0.12	7.85±0.58	**p = 0.000**	p = 0.213
									η_p^2 = 0.519	η_p^2 = 0.065
$Power_{mean}$ (W)	Over standard	135.67±11.00	129.93±13.95	121.28±11.22	125.50±12.54	122.57±15.74	123.10±14.00	126.21±10.03##	$F_{1, 21}$ = 17.836	$F_{5.00, 105.00}$ = 1.290
	Below standard	110.95±9.92	112.88±13.42	108.15±8.06	114.22±8.04	106.70±8.78	107.67±11.16	110.41±5.56	**p = 0.000**	p = 0.274
									η_p^2 = 0.459	η_p^2 =0.058
$Speed_{mean}$ ($km \cdot h^{-1}$)	Over standard	7.83±0.6	7.61±0.61#	7.18±0.50	7.48±0.76	7.20±0.69	7.24±0.74	7.42±0.53##	$F_{1, 21}$ = 17.432	$F_{5.00, 105.00}$ = 0.817
	Below standard	6.67±0.52	6.64±0.48	6.44±0.55	6.68±0.23	6.42±0.52	6.35±0.64	6.54±0.37	**p = 0.000**	p = 0.540
									η_p^2 = 0.454	η_p^2 = 0.037
$Cadence_{mean}$ (steps per min)	Over standard	65.50±2.42	63.76±2.25	63.16±2.54	63.75±2.82	62.36±2.90	62.03±2.49	63.39±1.74#	$F_{1, 21}$ = 6.128	$F_{5.00, 105.00}$ = 1.362
	Below standard	62.51±2.40	62.26±2.79	59.80±3.85	63.22±1.52	61.24±2.84	60.97±2.03	61.77±1.26	**p = 0.022**	p = 0.245
									η_p^2 = 0.226	η_p^2 = 0.061
Vertical $oscillation_{mean}$ (cm)	Over standard	8.23±0.88	8.12±0.48	8.08±0.69	8.05±0.57	8.20±0.78	7.88±0.71	8.10±0.61	$F_{1, 21}$ = 1.764	$F_{5.00, 105.00}$ = 0.320
	Below standard	7.94±0.35	7.81±0.54	7.69±0.47	7.72±0.25	7.85±0.71	7.79±0.52	7.81±0.24	p = 0.198	p = 0.900
									η_p^2 = 0.077	η_p^2 = 0.015
GCT_{mean} ($m \cdot s^{-1}$)	Over standard	511.08±66.17	537.64±60.62	550.3±66.70	518.50±83.16	541.41±68.67	541.33±52.93	533.68±51.47	$F_{1, 21}$ = 0.721	$F_{3.852, 80.882}$ = 0.821
	Below standard	530.92±94.38	581.49±73.19	532.64±152.95	552.41±66.07	570.34±59.86	565.04±83.83	555.33±72.81	p = 0.406	p = 0.511
									η_p^2 = 0.033	η_p^2 = 0.038
$Stiffness_{mean}$ ($KN \cdot m^{-1}$)	Over standard	9.20±0.58	9.16±0.60	9.22±0.58	8.96±0.57	8.97±0.56	8.90±0.56	9.07±0.43#	$F_{1, 21}$ = 7.862	$F_{5.00, 105.00}$ = 0.626
	Below standard	9.88±1.17	9.84±0.91	9.47±0.64	9.60±0.78	9.67±0.60	9.41±0.57	9.68±0.57	**p = 0.011**	p = 0.680
									η_p^2 =0.272	η_p^2 = 0.029

GCT: ground contact time; #Significantly different (#p < 0.05, ##p < 0.01) from below standard fields.

Table 4. Physiological demands registered by soccer referees according to pitch size (i.e., over standard and below standard) during official matches.

Physiological variables	Contextual variable	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	Entire match	Pitch size	Pitch size x period
HR_{mean} (bpm)	Over standard	159.50±12.83	162.64±12.84	159.05±16.30	156.38±13.39	157.45±11.58	158.22±14.44	158.84±12.89	$F_{1, 21}$ = 0.006	$F_{2.633, 55.288}$ = 0.308
	Below standard	161.58±17.75	161.21±12.00	159.30±11.02	156.13±12.34	156.15±12.15	156.38±10.77	158.36±10.96	p = 0.939	p = 0.794
									η_p^2 =2.847	η_p^2 = 0.014
$\%HR_{peak}$	Over standard	88.06±2.63	88.40±2.80	87.45±4.93	87.65±2.06	87.10±2.05	86.90±3.79	85.41±2.66	$F_{1, 21}$ = 0.110	$F_{3.985, 83.682 0}$ = 4.200
	Below standard	83.04±7.45	86.82±6.37	88.99±1.62	88.67±1.94	89.53±2.60	86.40±3.36	80.51±6.86	p = 0.744	**p = 0.004**
									η_p^2 = 0.005	η_p^2 =0.167
Zone 1 (min)	Over standard	0.13±0.27	0.00±0.00	0.46±1.76	0.03±0.07	0.02±0.08	0.01±0.04	0.65±1.77	$F_{1, 21}$ = 2.157	$F_{1.989, 41.770}$ = 1.467
	Below standard	1.30±2.90	0.29±0.80	0.05±0.13	0.48±1.37	0.25±0.70	0.33±0.94	2.70±4.92	p = 0.157	p = 0.242
									η_p^2 = 0,093	η_p^2 = 0.065
Zone 2 (min)	Over standard	0.30±0.35	0.17±0.40	0.23±0.43	0.49±0.70	0.47±0.77	0.64±1.58	2.30±2.82	$F_{1, 21}$ = 2.223	$F_{1.709, 35.895}$ = 1.353
	Below standard	0.64±0.75	0.74±1.43	1.62±3.66	1.54±2.97	1.73±3.67	2.38±4.09	8.65±16.37	p =0.151	p = 0.269
									η_p^2 = 0.096	η_p^2 =0.061
Zone 3 (min)	Over standard	2.69±1.83	1.83±1.52	2.97±2.32	3.52±1.89	2.99±1.52	3.74±2.07	17.75±7.57	$F_{1, 21}$ = 2.946	$F_{5.00, 105.00}$ = 0.931
	Below standard	3.76±3.28	4.11±3.82	4.61±3.88	4.93±4.39	5.10±4.69	6.68±5.46	29.19±24.11	p = 0.101	p = 0.464
									η_p^2 = 0.123	η_p^2 = 0.042
Zone 4 (min)	Over standard	6.55±1.50	6.80±1.80	6.33±1.56	7.19±1.60	7.53±1.64	8.72±2.31	43.12±5.22	$F_{1, 21}$ = 0.629	$F_{5.00, 105.00}$ = 1.112
	Below standard	5.26±2.44	6.80±2.42	7.10±3.49	6.00±3.66	6.34±4.33	7.48±5.52	38.99±19.21	p = 0.437	p = 0.359
									η_p^2 = 0.029	η_p^2 = 0.050
Zone 5 (min)	Over standard	4.97±2.41	5.82±2.62	5.67±3.03	3.43±2.51	3.66±1.72	5.45±3.70	29.00±11.15#	$F_{1, 21}$ = 5.958	$F_{5.00, 105.00}$ = 0.701
	Below standard	3.66±3.27	3.04±3.56	2.86±2.99	2.02±2.34	1.58±2.04	2.49±2.62	15.65±14.81	**p = 0.023**	p = 0.624
									η_p^2 = 0.221	η_p^2 = 0.032
TRIMP (AU)	Over standard	59.87±4.93	62.10±4.82	63.52±9.05	57.47±5.30	58.37±4.49	74.68±9.62	376.01±29.10	$F_{1, 21}$ = 3.400	$F_{2.606, 54.732}$ = 0.244
	Below standard	53.19±12.94	56.47±8.83	59.82±13.59	52.49±12.10	52.28±11.46	67.53±13.85	341.78±60.83	p = 0.079	p = 0.854
									η_p^2 =0.139	η_p^2 = 0.011

HR_{mean}: mean heart rate; $\%HR_{peak}$: percentage of their maximum heart rate achieved during the match; TRIMP: training impulse. #Significantly different (p < 0.05) from below standard fields.

Table 5. Physical demands registered by soccer referees according to period of season (i.e., first and second round) during official matches.

Physical variables	Contextual variable	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	Entire match	Round	Round x period
Total distance (km)	First round Second round	1.39±0.19 1.54±0.24	1.44±0.13 1.42±0.12	1.34±0.33 1.51±0.11	1.30±0.15 1.47±0.18	1.30±0.16 1.35±0.16	1.57±0.19 1.78±0.26	8.33±0.75# 9.07±0.77	$F_{1,21}$= 5.452 **p = 0.030** η_p^2= 0.206	$F_{5.00, 105.00}$= 1.538 p = 0.184 η_p^2= 0.068
$Power_{mean}$ (W)	First round Second round	121.19±14.41 134.72±15.07	123.07±14.79 125.21±17.79	113.12±11.07 121.39±11.83	116.82±11.07 127.76±11.42	114.22±11.13 120.73±20.00	115.54±11.75 120.58±18.43	117.50±7.98 124.89±14.35	$F_{1,21}$= 2.572 p = 0.117 η_p^2= 0.113	$F_{5.00, 105.00}$= 1.084 p = 0.373 η_p^2=0.049
$Speed_{mean}$ ($km \cdot h^{-1}$)	First round Second round	7.18±0.75 7.75±0.79	7.20±0.75 7.37±0.73	6.78±0.67 7.11±0.52	6.97±0.67 7.50±0.73	6.81±0.69 7.07±0.80	6.76±0.66 7.16±0.97	6.95±0.55 7.32±0.71	$F_{1,21}$ = 2.023 p = 0.170 η_p^2= 0.088	$F_{5.00, 105.00}$ = 0.814 p = 0.542 η_p^2= 0.037
$Cadence_{mean}$ (steps per min)	First round Second round	63.78±2.67 65.33±2.79	63.78±2.80 62.54±1.95	62.06±4.03 61.89±2.53	63.18±2.53 64.06±2.80	61.62±3.15 62.42±2.53	61.70±2.02 61.61±2.84	62.76±1.72 62.92±1.87	$F_{1,21}$ = 0.139 p = 0.713 η_p^2= 0.007	$F_{5.00, 105.00}$= 1.086 p = 0.373 η_p^2= 0.049
Vertical $oscillation_{mean}$ (cm)	First round Second round	7.98±0.75 8.32±0.74	7.95±0.49 8.09±0.55	7.70±0.54 8.27±0.63	7.77±0.45 8.15±0.52	8.13±0.79 8.01±0.75	7.74±0.66 7.99±0.61	7.88±0.49 8.15±0.55	$F_{1,21}$ = 1.452 p = 0.242 η_p^2= 0.065	$F_{5.00, 105.00}$= 1.916 p = 0.098 η_p^2= 0.084
GCT_{mean} ($m \cdot s^{-1}$)	First round Second round	524.62±85.08 509.36±64.58	555.32±76.66 549.73±56.08	536.85±129.37 553.75±52.94	530.09±80.48 530.09±78.64	548.82±67.82 554.91±66.73	541.01±63.85 560.71±66.86	539.19±66.16 543.83v51.62	$F_{1,21}$ = 0.021 p = 0.885 η_p^2= 0.001	$F_{3.154, 66.232}$ = 0.345 p = 0.803 η_p^2= 0.016
$Stiffness_{mean}$ ($KN \cdot m^{-1}$)	First round Second round	9.33±0.76 9.57±1.03	9.36±0.73 9.45±0.88	9.26±0.40 9.37±0.80	9.24±0.81 9.10±0.58	9.24±0.73 9.18±0.57	9.03±0.52 9.13±0.72	9.27±0.48 9.30±0.67	$F_{1,21}$ = 0.057 p = 0.814 η_p^2=0.003	$F_{5.00, 105.00}$ = 0.420 p = 0.834 η_p^2= 0.020

GCT: ground contact time; #Significantly different (p < 0.05) from second round matches.

Table 6. Physiological demands registered by soccer referees according to period of season (i.e., first and second round) during official matches.

Physiological variables	Contextual variable	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	Entire match	Round	Round x period
HR_{mean} (bpm)	First round Second round	160.84±14.09 159.42±15.42	162.97±13.56 161.07±13.56	158.12±17.29 160.46±10.27	153.63±14.02 159.76±10.56	156.22±13.54 158.00±8.83	155.04±13.61 160.87±12.17	157.66±13.27 159.99±10.66	$F_{1,21}$ = 0.173 p = 0.682 η_p^2=0.008	$F_{2.628, 55.184}$= 1.993 p = 0.133 η_p^2= 0.087
$\%HR_{peak}$	First round Second round	88.15±3.08 83.91±6.69	87.87±5.30 87.82±2.80	87.61±5.14 88.47±2.34	87.18±1.77 89.08±1.91	88.19±2.92 87.62±1.92	86.07±3.96 87.58±2.98	83.87±5.22 83.50±5.01	$F_{1,21}$ = 0.008 p = 0.927 η_p^2= 4.038	$F_{3.086, 64.796}$= 2.931 **p = 0.039** η_p^2=0.122
Zone 1 (min)	First round Second round	0.18±0.41 1.01±2.60	0.18±0.63 0.00±0.02	0.55±1.89 0.00±0.00	0.31±1.07 0.03±0.08	0.18±0.55 0.00±0.00	0.22±0.74 0.00±0.00	1.61±3.79 1.04±2.61	$F_{1,21}$ = 0.165 p = 0.688 η_p^2= 0,008	$F_{2.003, 42.056}$ = 1.395 p = 0.259 η_p^2= 0.062
Zone 2 (min)	First round Second round	0.34±0.63 0.51±0.38	0.37±1.16 0.36±0.49	1.06±2.92 0.26±0.35	1.23±2.37 0.37±0.54	1.16±2.99 0.58±0.46	1.64±3.55 0.74±1.14	5.80±13.24 2.82±2.20	$F_{1,21}$ = 0.492 p =0.491 η_p^2= 0.023	$F_{1.713, 35.977}$ = 1.139 p = 0.324 η_p^2=0.051
Zone 3 (min)	First round Second round	3.12±2.03 2.98±2.96	1.82±2.08 3.66±3.17	2.31±2.01 5.14±3.34	3.81±1.90 4.27±4.09	2.81±1.92 4.91±3.95	4.28±2.19 5.40±5.26	18.16±9.786 26.38±21.16	$F_{1,21}$ = 1.548 p = 0.227 η_p^2= 0.069	$F_{5.00, 105.00}$= 2.962 **p = 0.015** η_p^2= 0.124
Zone 4 (min)	First roundd Second round	6.28±2.21 5.87±1.56	6.72±2.14 6.90±1.87	6.72±2.67 6.44±2.01	6.83±2.67 6.71±2.38	7.59±2.92 6.50±2.73	8.85±3.92 7.56±3.37	43.00±13.50 39.98±9.53	$F_{1,21}$ = 0.363 p = 0.553 η_p^2= 0.017	$F_{5.00, 105.00}$ = 0.509 p = 0.769 η_p^2= 0.024
Zone 5 (min)	First round Second round	4.80±2.53 4.14±3.08	5.62±3.39 3.84±2.78	4.86±3.31 4.47±3.35	2.55±2.31 3.45±2.75	3.02±2.11 2.83±2.09	3.60±2.36 5.50±4.69	24.46±11.85 24.22±16.74	$F_{1,21}$ = 0.002 p = 0.968 η_p^2= 0.891	$F_{5.00, 105.00}$ = 2.503 **p = 0.035** η_p^2= 0.106
TRIMP (AU)	First round Second round	59.39±5.39 55.15±11.99	61.39±7.58 58.52±5.78	60.83±12.75 64.06±7.44	54.26±9.42 57.66±6.80	56.43±9.43 56.02±6.02	69.73±11.29 75.41±11.52	362.02±49.94 366.82±39.18	$F_{1,21}$ = 0.062 p = 0.805 η_p^2=0.003	$F_{2.807, 58.945}$ = 2.689 p = 0.058 η_p^2= 0.114

HR_{mean}: mean heart rate; $\%H_{Rpeak}$: percentage of their maximum heart rate achieved during the match; TRIMP: training impulse.

Table 7. Physical demands registered by soccer referees according to environmental temperature (i.e., below 10º and over 20º) during official matches.

Physical variables	Contextual variable	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	Entire match	Temperature	Temperature x period
Total distance (km)	Below 10º Over 20º	1.40±0.23 1.56±0.22	1.42±0.12 1.48±0.11	1.31±0.35 1.53±0.13	1.31±0.16 1.43±0.17	1.26±0.16 1.41±0.08	1.53±0.19 1.82±0.24	8.23±0.74# 9.23±0.65	$F_{1, 21}$ = 5.024 **p = 0.017** η_p^2= 0.334	$F_{5.00, 105.00}$= 0.757 p = 0.669 η_p^2= 0.070
$Power_{mean}$ (W)	Below 10º Over 20º	120.72±15.64 137.35±13.37	123.69±16.13 128.89±15.63	112.42±11.15 122.00±11.66	113.91±7.64 131.08±9.83	110.44±7.76 127.69±16.44	112.21±9.30 125.72±16.90	115.79±6.51# 128.50±11.98	$F_{1, 21}$= 4.775 **p = 0.020** η_p^2= 0.323	$F_{5.00, 105.00}$ = 0.981 p = 0.465 η_p^2=0.089
$Speed_{mean}$ (km·h^{-1})	Below 10º Over 20º	7.14±0.76 7.92±0.71	7.15±0.78 7.59±0.62	6.72±0.66 7.21±0.44	6.80±0.42 7.71±0.68	6.64±0.60 7.41±0.56	6.63±0.57 7.45±0.84	6.85±0.46# 7.54±0.57	$F_{1, 21}$ = 4.421 **p = 0.026** η_p^2= 0.307	$F_{7.128, 71.276}$ = 0.793 p = 0.598 η_p^2= 0.073
$Cadence_{mean}$ (steps per min)	Below 10º Over 20º	63.83±2.90 65.12±2.64	63.62±3.19 63.30±1.82	62.46±4.39 62.15±2.41	63.03±2.28 63.48±2.47	61.60±3.48 62.71±2.27	61.26±1.98 62.19±2.41	62.73±1.76 63.10±1.69	$F_{1, 21}$ = 0.256 p = 0.776 η_p^2= 0.025	$F_{5.00, 105.00}$= 0.779 p = 0.649 η_p^2= 0.072
Vertical $oscillation_{mean}$ (cm)	Below 10º Over 20º	7.95±0.57 8.46±0.97	7.94±0.54 8.13±0.54	7.67±0.56 8.17±0.70	7.74±0.51 8.24±0.47	7.95±0.60 8.43±0.91	7.77±0.63 8.03±0.76	7.85±0.41 8.24±0.67	$F_{1, 21}$ = 1.924 p = 0.172 η_p^2= 0.161	$F_{5.00, 105.00}$= 0.919 p = 0.519 η_p^2= 0.084
GCT_{mean}(m·s^{-1})	Below 10º Over 20º	533.76±81.10 552.78±76.70	556.15±83.81 549.32±47.29	543.81±147.05 555.39±31.28	547.28±62.07 502.89±91.31	553.54±64.80 537.76±71.44	543.04±67.74 543.09±55.96	545.75±68.52 531.64±40.38	$F_{1, 21}$ = 0.202 p = 0.819 η_p^2= 0.020	$F_{7.892, 78.920}$ = 0.714 p = 0.676 η_p^2= 0.067
$Stiffness_{mean}$ (KN·m^{-1})	Below 10º Over 20º	9.42±0.83 9.37±1.11	9.41±0.65 9.23±0.88	9.36±0.48 9.08±0.76	9.33±0.90 8.99±0.57	9.38±0.76 9.10±0.60	9.05±0.52 8.87±0.58	9.35±0.49 9.12±0.69	$F_{1, 21}$ = 0.734 p = 0.492 η_p^2=0.068	$F_{5.00, 105.00}$= 0.643 p = 0.774 η_p^2= 0.060

GCT: ground contact time; #Significantly different (p < 0.05) from over 20º matches.

Table 8. Physiological demands registered by soccer referees according to environmental temperature (i.e., below 10º and over 20º) during official matches.

Physiological variables	Contextual variable	0-15 min	15-30 min	30-45 min	45-60 min	60-75 min	75-90 min	Entire match	Temperature	Temperature x period
HR_{mean} (bpm)	Below 10º Over 20º	165.50±15.10 158.13±11.34	165.98±15.63 160.52±9.01	163.45±16.50 155.70±14.91	156.00±18.18 156.77±8.47	157.38±16.34 158.32±6.32	158.73±15.85 157.99±13.13	161.09±15.41 157.86±10.08	$F_{1, 21}$ = 0.460 p = 0.638 η_p^2=0.044	$F_{5.271, 52.706}$= 1.757 p = 0.135 η_p^2= 0.149
$\%HR_{peak}$	Below 10º Over 20º	88.48±3.48 86.46±3.60	87.73±6.20 88.57±1.52	89.30±2.07 86.37±6.00	87.48±2.04 87.75±1.98	87.84±3.19 88.19±1.91	86.52±3.03 87.48±4.63	83.70±5.81 84.52±3.95	$F_{1, 21}$ = 0.522 p = 0.601 η_p^2= 0.050	$F_{6.134, 61.336}$= 2.456 **p = 0.033** η_p^2=0.197
Zone 1 (min)	Below 10º Over 20º	0.17±0.43 0.11±0.23	0.23±0.72 0.00±0.00	0.04±0.12 0.76±2.28	0.40±1.22 0.03±0.08	0.23±0.62 0.00±0.00	0.27±0.84 0.02±0.05	1.34±3.94 0.91±2.29	$F_{1, 21}$ = 0.284 p = 0.756 η_p^2= 0,208	$F_{4.059, 42.593}$ = 2.565 p = 0.052 η_p^2= 0.204
Zone 2 (min)	Below 10º Over 20º	0.39±0.71 0.31±0.25	0.48±1.31 0.18±0.47	1.18±3.33 0.32±0.54	1.51±2.67 0.44±0.56	1.57±3.34 0.30±0.44	1.54±3.74 1.12±2.10	6.68±14.96 2.66±3.20	$F_{1, 21}$ = 0.398 p =0.677 η_p^2= 0.038	$F_{3.218, 32.177}$ = 0.769 p = 0.528 η_p^2=0.071
Zone 3 (min)	Below 10º Over 20º	2.70±1.89 3.89±2.91	1.89±2.32 2.64±2.79	2.29±2.32 4.57±3.46	3.80±2.32 4.00±2.98	3.26±1.96 3.58±3.47	4.37±2.46 4.22±4.24	18.30±11.06 22.91±18.33	$F_{1, 21}$ = 0.511 p = 0.607 η_p^2= 0.049	$F_{5.00, 105.00}$ = 2.177 **p = 0.025** η_p^2= 0.179
Zone 4 (min)	Below 10º Over 20º	6.44±2.30 5.93±1.66	6.66±2.38 7.30±1.67	6.71±2.73 5.77±1.79	6.85±2.93 6.72±1.94	7.41±3.25 6.89±2.60	9.05±4.40 7.27±3.27	43.11±15.23 39.89±9.04	$F_{1, 21}$ = 0.167 p = 0.847 η_p^2= 0.016	$F_{5.00, 105.00}$ = 0.896 p = 0.540 η_p^2= 0.082
Zone 5 (min)	Below 10º Over 20º	5.16±2.10 4.26±3.04	5.54±3.68 4.52±2.39	5.24±3.87 4.50±2.97	2.33±2.80 3.38±2.26	2.41±2.00 3.86±1.83	3.66±3.53 5.87±3.89	24.34±14.74 26.40±13.02	$F_{1, 21}$ = 0.295 p = 0.748 η_p^2= 0.029	$F_{5.00, 105.00}$ = 1.491 p = 0.154 η_p^2= 0.130
TRIMP (AU)	Below 10º Over 20º	60.61±4.81 57.44±6.00	61.18±8.46 60.07±4.83	62.29±13.19 60.72±9.13	53.84±11.23 56.71±4.88	54.85±10.28 58.23±5.29	70.98±13.82 73.36±11.86	363.74±57.43 366.54±35.62	$F_{1, 21}$ = 0.031 p = 0.969 η_p^2=0.003	$F_{5.480, 54.901}$ = 1.661 p = 0.154 η_p^2= 0.142

HR_{mean}: mean heart rate; $\%HR_{peak}$: percentage of their maximum heart rate achieved during the match; TRIMP: training impulse.

temperature) affect referees' physical and physiological demands during official matches. This is the first study to analyze this topic, opening up a new line of research that may allow referees' strength and conditioning specialists to be more precise in prescribing training sessions and planning post-match recovery. This study showed that playing on natural grass meant that referees had to cover more distance, using higher power, speed and cadence than on artificial grass. Also, in above-standard fields more distance, power, speed, cadence and stiffness and more time in zone 5 were recorded than in below-standard fields. Also, referees covered more total distance during matches played in the second round in comparison to the first. Finally, more distance, power and speed were recorded in matches with environmental temperatures over 20º than below 10º. No differences were found within 15 min periods according to type of turf, pitch size, season period or environmental temperature in physical and physiological variables.

Knowing whether contextual variables influence the demands of official matches in soccer referees may be of great interest to strength and conditioning specialists in order to plan training sessions and to establish more appropriate recovery strategies. Previous studies carried out with soccer players have observed that contextual factors affect match demands[12–14,16,19,26,40], so it is of interest to analyze whether these factors also affect referees. In this vein, in our study it has been shown that matches played on natural grass imply greater total distance, power, speed and cadence for amateur soccer referees compared to matches played on artificial grass. Although other research has not found significant differences in physical demands between matches played on artificial turf and natural grass[14,15], the artificial turf standards in the aforementioned studies were higher than in the present study. These differences may be due to the fact that first-generation artificial grass (old-aged) decreases ball and game velocity and thus the physical demands on the referee. Likewise, refereeing on above-standard pitches meant greater total distance, power, speed, cadence and stiffness, and time spent in zone 5 than on below-standard pitches. In small sided soccer games it has been demonstrated that bigger soccer fields are related to higher physical demands[41], so this study would confirm the same pattern during official matches.

On the other hand, the fact of covering more total distance during matches played in the second round in comparison to the first could be associated with the pressure involved in playing the last matches of the season when the referees have to be prepared to keep up with the pace of play in matches with high physical and physiological demands. Also, playing with an environmental temperature above 20ºC is associated with more total distance, power and speed than in matches played with an ambient temperature below 10ºC. However, other studies have found that lower temperatures are associated with higher physical demands in professional soccer players[17,18], so the disparity of results found on this aspect may be due to the fact that in amateur leagues cold temperatures below 10ºC can lead to a lower body temperature and therefore to a lower intensity, reducing the physical demands on the referees. These results suggest the need to consider contextual variables during training periodization for this population. However, in general, no differences were found in vertical oscillation, GCT and stiffness, nor in the majority of physiological responses in any of the variables studied. However, this is the first study to analyze the influence of contextual variables on these parameters, so it would be interesting to perform further studies that address the analysis of these variables.

When isolated 15 min periods were analyzed, we did not observe significant differences between contextual variables and referees' match performance in physical and physiological variables, except a significant interaction ($p < 0.05$) between season periods and $\%HR_{peak}$, time spent in zone 3 and time spent in zone 5, but post hoc analysis did not reveal significant differences ($p > 0.05$). These results show that contextual variables do not influence the demands of the match in 15 min periods, although as demonstrated above, these variables influence the demands encountered during the entire match. The scientific literature has shown disparate results according to how physical and physiological demands evolve in referees over the course of matches. While some studies observed that physical demands decrease and physiological demands are maintained as the match progresses[31], other studies have shown that physiological demands also diminish as the match progresses[5], and other studies have shown that physiological demands increase as the match progresses[42]. The responses of the referees in each 15 min period can be associated with the requirements of the game (e.g., score, pace of the match imposed by the players due to their physical and technical capabilities, tactical and strategic decisions, etc.). Hence, there is no clear trend in the evolution of physical and physiological responses during each 15 min period, and in our case, the contextual variables analyzed did not appear to influence this evolution. To conclude, referees may need to be prepared for highly variable demands during a match and be able to respond to them at any time of the match whatever the contextual factors.

Although this study shows that contextual variables have an impact on the knowledge about the physical and physiological demands in amateur referees, it is not without limitations, so we see the need to extend the sample to other categories of grassroots soccer and to professional referees. Considering that there are studies that have proved the validity of subjective quantification methods[43] and more specifically in soccer referees[9,44], including these quantification methods could have provided valuable information to complement the results obtained. Finally, the contextual factors analyzed in this study are limited, which opens up a line of research to take into account other contextual factors such as the style of play of the teams, effective playing time, the referee's physical fitness level, etc.

Conclusions

The results of this study show that the type of surface, pitch size, the environmental temperature and season period influence the physical demands of soccer referees during official matches. Therefore, it is suggested that strength and conditioning specialists should consider the influence of contextual variables on the match demands involved in refereeing activities, in order to prescribe more appropriate training and recovery strategies to face the matches with greater guarantees. Furthermore, the fact that no differences were found within 15 min periods throughout the match according to the contextual variables studied could indicate that it is not possible to determine a specific period in which the contextual variables play a determining role, but rather that the entire match should be taken into account.

Acknowledgements

The authors gratefully acknowledge the support of a Spanish government subproject mixed method approach on performance analysis (in training and competition) in elite and academy sport (PGC2018-098742-B-C33] (2019–2021) from the Ministry of Science, Innovation and Universities (MCIU), the State Research Agency (AEI) and the European Regional Development Fund (ERDF), that is part of the coordinated project New Approach of Research in Physical Activity and Sport from Mixed Methods Perspective (NARPAS_MM) [SPGC201800X098742CV0].

Conflict of interest

The authors do not declare a conflict of interest.

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Injury epidemiology in the men's and women's Spanish roller-hockey league: a descriptive study

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doi: 10.18176/archmeddeporte.00112

Received: 26/04/2022
Accepted: 13/09/2022

Summary

The purpose of the present study is to describe the injury patterns among male and female athletes of the Spanish Rink hockey league.
A cross-sectional study was performed, concerning the time-loss injuries (the athlete is prevented to participate in a training session / game because of the injury registered by the medical staff of every team. 137 athletes were included (98 male, age 26.7 ± 5.9 years; 39 female, age 23.3 ± 4.6 years).
Ninety-four time-loss injuries were recorded, being the most frequent the muscle injury (38 episodes, 40.4%), especially the ones affecting the adductor longus muscle (23 episodes, 60,5% of the muscle injuries). The majority of the registered injuries were classified as mild (1-7 days of time-loss) but the and the median return-to-play was 19.4 ± 29.6 days. Eight episodes of reinjury were described (8.5% of total injuries) and 2 injuries required surgical treatment (2.1% of total injuries).
Concerning female athletes, we can highlight a increased number of ligament injuries in the lower limbs compared with male athletes and the absence of tendinopathies causing time-loss.
The knee injuries were the injuries with a higher return-to-play in goalkeepers.
The present study is the first to describe the injury patterns among rink hockey elite athletes and must set a starting point to study and prevent injuries in this sport.

Key words:
Time-loss injuries. Roller hockey. Epidemiology. Injury surveillance.

Epidemiología lesional en la liga española de hockey patines masculina y femenina: un estudio descriptivo

Resumen

El propósito del presente estudio es describir los patrones lesionales durante una temporada de los deportistas de la máxima competición masculina y femenina de Hockey Patines en España.
Se realizó un estudio descriptivo de las lesiones con baja deportiva (el/la deportista no puede participar como mínimo en un entrenamiento o partido debido a la lesión) recogidas por los equipos biomédicos de cada equipo. Se estudiaron 137 deportistas (98 hombres, con una media de edad de 26,7 ± 5,9 años y 39 mujeres con una media de edad de 23,3 ± 4,6 años)
Se recogieron un total de 94 lesiones con baja deportiva, siendo las más frecuentes las lesiones musculares (38 episodios, 40,4% de las lesiones totales), en especial del músculo aductor largo (23 episodios, 60,5% de las lesiones musculares). La mayoría de lesiones registradas fueron leves (1-7 días de baja deportiva) aunque el tiempo medio de baja fue de 19,4 ± 29,6 días. Se recogieron 8 episodios de relesión (8,5% de las lesiones totales) y 2 lesiones que precisaron tratamiento quirúrgico (2,1% de las lesiones totales).
Al estudiar a las deportistas femeninas destaca que presentaron un mayor número de lesiones ligamentosas de extremidades inferiores en comparaciones con los varones y no se describió ningún episodio de tendinopatía.
Al estudiar las lesiones específicas de los porteros/as se evidenció que las lesiones que causaban más baja deportiva eran las lesiones de rodilla.
El presente estudio es el primero en describir las lesiones en jugadores/as de primer nivel de hockey patines y debe marcar un punto de partida para el estudio y prevención de las lesiones en este deporte.

Palabras clave:
Lesiones. Epidemiología. Vigilancia de lesiones.

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Introduction

Roller hockey (RH) is a sport with a long tradition in Spain, mainly in the regions of Catalonia, Galicia, Asturias and Madrid. The top national division (men's and women's OK Liga) is home to many of the world's best athletes, as Spanish roller hockey has won the most international prizes for the country, with 17 men's world championships and 7 women's world championships[1].

This is a collective, dynamic and complex sport that pits two teams of five players against each other (four players on the rink and a goalkeeper). The players wear classic roller-skates (two pairs of parallel wheels) and use a stick to move a solid, round ball to score a goal[1]. RH is considered a contact sport due to the easy interaction between the dynamic (ball and stick) and static elements (fences and goalposts) in the game, that increases the risk of contact between participants[2-4]. Some factors differentiate RH from other indoor sports: (i) the athletes reach very high speeds (up to 30 km/h) compared to other sports,[2] (ii) the use of parallel wheels causes different turning and braking mechanisms to other skating sports such as Inline hockey and Ice hockey[3], (iii) the speed of the ball can reach 115 km/h[4,5]. It should also be considered that the goalkeeper figure has very different characteristics to a rink player, due to their posture, mobility or their intention to stop a ball moving at very high speeds[6,7]. With these factors in mind, RH can be considered a sport with a high risk of musculoskeletal injuries [8,9], which can influence athletes' performance and their recovery.

Although there are few studies on the injury epidemiology for roller hockey, the available scientific literature points to a high risk of injuries, mainly secondary to traumas[8,10,11]. In any case, studies so far are descriptive based on very small, heterogeneous samples.

Time-loss injuries (TLI) can influence sports performance and the athlete's health, as well as the teams' collective results[12]. The injury surveillance programmes make it possible to analyse injury patterns for a sport, determine the magnitude of the problem, define an initial step to set up injury prevention programmes and find out about new problems to understand the athletes' injury pattern better[12,13].

The aim of this study is to describe the injury patterns for time loss injuries among participants in the top Spanish men's and women's RH division (OK Liga) over an entire season.

Material and method

Study design

Descriptive study using an intentional non-probabilistic sample of 14 teams from the men's and women's OK Liga, the top Spanish senior category for RH (10 teams in the senior men's first division [SM] and four teams in the senior women's first division [SF]). The men's and women's OK Liga in the 2020/21 season comprised 16 teams each.

137 athletes were studied. 98 SM (71.5% of the sample), with an average age of 26.7 ± 5.9 years old (range: 18.1 – 45.2) and 39 SF (28.5%), with an average age of 23.3 ± 4.6 years old (range: 15.9– 35.2). Out of the total 98 SM, 78 (79.6%) were rink players and 20 (20.4%) were goalkeepers and out of the 39 SF, 32 (82%) were rink players and 7 (18%) goalkeepers.

For athletes to be included in the study, they had to meet the following criteria: the athlete should play in the senior team and form part of its original squad. Athletes from lower divisions who only participate occasionally in training/matches were excluded.

All the athletes gave their consent to collect injury data. The study was designed according to the Helsinki Declaration[14], and it was accepted by the Ethics Committee (code 014/CEICGC/2021).

Data

The athletes' data was recorded, and the injury characteristics reported by the medical team of each RH team throughout the 2020/21 season. Data collection began on the first day of the pre-season and ended with the last match in the season. The number of official matches in the season ranged between 35 and 45 depending on the sporting results.

Clinical information referring to the type of injury, injury mechanism and days of time loss was recorded on a previously designed common template.

Injuries that were not related to RH and time loss for medical diseases or other reasons were not recorded.

Definitions, categories and calculation of the injury incidence

The injuries were classified according to the *Orchard Sports Injury Classification System* (OSICS) version 10[15]. The type of injury, location and appearance were compiled according to the Consensus of the International Olympic Committee[13]. The concepts of time-loss injury (TLI) and return-to-play (RTP), were compiled according to the definitions suggested by the *Union of European Football Associations* (UEFA)[16,17].

The definitions used in the study are shown in Table 1.

Statistical analysis

A descriptive analysis was carried out on the time-loss injuries by calculating the absolute frequency and the relative frequency over the total number of injuries in each category of interest for the qualitative variables.

In the case of the quantitative variables, central trend summary measures (mean) and statistical dispersion (standard deviation and range) were calculated.

We calculated the summary measures for the time-loss incidences according to the formula i=n/e, where n is the number of injuries during the study period and e is the respective number of exposed athletes (EA) or participants) with incidence ratios presented as injuries per 100 players per season. Furthermore, the Cumulative incidence ratio (CIR) is calculated to compare the injury incidence ratios between the two genders. The incidences and CIR association measure were calculated using the function *pois.exact* from the *epitools* library and the function *'epi.2by2'* from the epiR library in R, respectively. These calculations estimate the incidence and confidence intervals at 95% using a Poisson distribution. All analyses were performed using SPSS v21 and the R statistics package (The R Foundation for Statistical Computing, Vienna, Austria), version 3.4.

Results

Total injuries (time-loss injuries)

A total of 94 time-loss injuries were recorded (TLI), 61 (64.9%) in SM and 33 (35.1%) in SF.

The TLI average per athlete and season was 0.7 ± 0.9 (0.6 ± 0.8 in SM and 0.9 ± 1 in SF). One SF suffered 4 TLI during the season, 6 athletes had 3 TLI (4 SM and 2 SF), 14 athletes had 2 TLI (9 SM and 5 SF), 44 athletes had 1 TLI (31 SM and 13 SF). 51 athletes (37.2% of the total) did not have any injuries during the 2020/21 season. Among rink players, the injury average was 0.7 ± 0.9 and among goalkeepers it was 0.4 ± 0.7.

There was an average of 6.7 ± 3.22 (range 3-13) TLI per team and season. The average in the male teams was 6.1 ± 3 (range 3-11) and in female teams 8.2 ± 3.6 (range 5-13).

Relative frequencies

The most frequent TLI were muscular injuries with 38 (40.4%) episodes. Muscular injuries mainly affected the thigh, with 30 (31.9%) episodes of muscular injury in this location, of which 23 affected the long adductor muscle, 4 the rectus femoris, 2 the gracile muscle and 1 the semitendinosus muscle. 11 (11.7%) tendon injuries were recorded, all diagnosed in males (Table 1).

The majority of the injuries affected the lower limbs (68.1%), followed by the upper limbs (15.9%), head and neck (11.7%) and trunk (6.4%). For lower limbs, the most frequent location was the thigh, with 34 injuries (36.2%), followed by the knee with 13 (13.8%) and the ankle with 8 (8.5%).

A total of 53 (56.4%) TLI were recorded during training and 41 (43.6%) during matches. Differentiated by gender, out of the 61 TLI recorded in the male league, 37 (60.6%) happened during training and 24 (39.4%) during matches. The female league saw more injuries during matches (n=17, 51.5%) than during training (n=16, 48.5%). Out of the non-contact injuries, the majority happened during training (n=40, 64.5%). Out of the contact injuries, on the other hand, the majority happened during matches (n=22 68.7%) (Table 2).

The location of the injuries classified by player position and gender is shown in Figure 1.

There were 8 episodes of re-injury, 2 of them on the same player. The re-injury rate was 9.3% of the injuries. Three re-injuries happened due to episodes of dynamic osteopathy of the pubis and 3 episodes due to the reappearance of muscular injuries in the long adductor muscle.

Incidence proportion

Table 3 shows the incidence proportion of the TLIs described in the study.

The total injury incidence proportion was 68.6 (CI 95% 61.2-76.8) injuries/100 athletes/season, greater in female rink players, 90.6 (CI 95% 81.1-101.3), than in male rink players 67.9 (CI 95% 58.3-79.1). The cumulative incidence ratio (CIR) between the rink players of both genders to sustain an injury for the whole study period was 1.33 (CI 95%, 1.10-1.61), which indicates that the female players were 1.33 times more likely to be injured than male rink players.

The incidence of muscular injury was 32.8 (CI 95% 25.2-42.5), namely 26.4 (CI 95% 27.1-48.9) in men and 25.6 (CI 95% 15-43.8) in women.

The incidence of tendon injury was 9.5 (CI 95% 5.4-16.6). Out of the 11 tendon injuries, 7 affected the thigh adductor muscles.

The injury incidence in goalkeepers was 44.4 (CI 95% 29.1-67.7). 40 in SM (CI 95% 23.4-68.4) 57.1 in SF (CI 95% 30.1-108.5). The injury incidence in rink players was 74.5 (CI 95% 66.8-83.1).

Return-to-play and severity

The RTP and the injuries described were 19.4 ± 29.6 (range 1-185, mode 2), namely 23.5 ± 34.6 (range 1-185, mode 2) in SM and 11.7 ±14.3 (range 1-60, mode 2) in SF.

Table 1. Definitions used in the study.

Concept	Definition
Time-loss injury	Any physical ailment felt by the athlete that might appear during training or a match that means that the athlete has to miss the next training session or match.[16,17]
Return-to-play	Absence time (in days) from the day of the injury until the athlete can play in a match again or complete a training session.[16,17].
Re-injury	Any injury of the same type and in the same anatomical place as an injury on the same individual in the two months following the RTP.[17]
Injury incidence	Calculated according to the formula i=n/ where n is the number of injuries during the study period and e is the respective number of Exposed Athletes (EA) with an incidence ratio presented in injuries per 100 players per season.[18]
Severity	The severity of the injuries was classified according to the RTP as mild (1 to 7 days), moderate (8 to 28 days) or severe (>28 days) following the classification by Van Mechelen *et al*.[12]
Appearance	Classified as Acute or Progressive appearance.[15]
Causal mechanism	Classified as overuse or a direct trauma (with an opponent or an object in the game).[15]

Adapted from Tuominen **et al.** 2015. [19]

Figure 1. Most frequent locations of TLI in rink players (left) and goalkeepers (right).

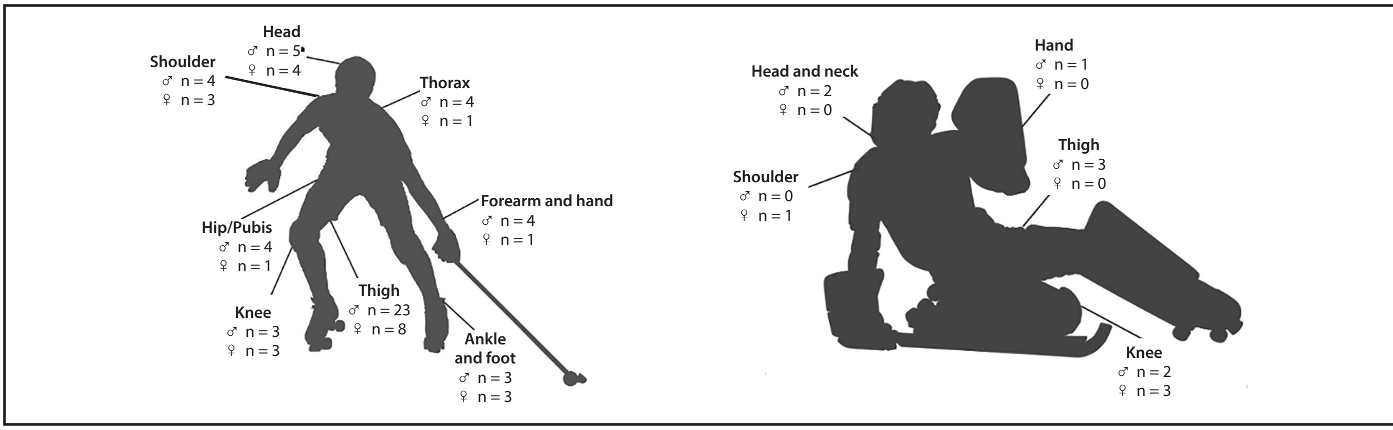

Table 2. Injury characteristics.

	Total N (%)	SM N (%)	SF N (%)
Total injuries	94	61	33
Moment			
Training	53 (56.4%)	37 (60.6%)	16 (48.5%)
Match	41 (43.6%)	24 (39.3%)	17 (51.5%)
Type of injury			
Muscular	38 (40.4%)	28 (45.9%)	10 (30.3%)
Bruising/wound	16 (17%)	7 (11.5%)	9 (27.3%)
Ligament	12 (12.8%)	5 (8.2%)	7 (21.2%)
Tendon	15 (15.9%)	11 (18%)	-
Fracture	7 (7.4%)	5 (8.2%)	2 (6%)
Arthritis	6 (6.4%)	2 (3.3%)	4 (12.1%)
Dislocation	4 (4.2%)	4 (6.5%)	-
Onset			
Acute appearance overuse	28 (29.7%)	16 (26.3%)	12 (35.2%)
Progressive app. overuse	34 (36.2%)	26 (42.6%)	8 (23.5%)
Trauma	32 (34.1%)	19 (31.1%)	13 (38.3%)
Mechanism			
No contact	62 (66%)	43 (70.5%)	19 (57.6%)
Contact with athlete	10 (10.6%)	5 (8.2%)	5 (15.1%)
Contact with object	22 (23.4%)	13 (21.3%)	9 (27.3%)
Severity			
Mild (1-7 days)	46 (48.9%)	25 (41%)	21 (63.6%)
Moderate (8 to 28 days)	28 (29.8%)	20 (32.8%)	8 (24.2%)
Severe (>28 days)	20 (21.3%)	16 (26.2%)	4 (12.1%)

Classifying by severity, 46 injuries were considered mild (1-7 days of RTP), 28 were considered moderate (7-28 days of RTP) and 20 were considered severe (>28 days of RTP) (Table 2).

Muscular injuries presented an average RTP of 18.6 ± 25.2 (range 1-90, mode 2), namely 15 moderate, 14 mild and 9 severe.

Within the injury severity, we can specifically differentiate any that required surgery. These represented 2.1% of the injuries recorded (n=2), with an incidence of 1.72 (CI 95% 4.4-68.1). The two surgical injuries recorded in our study were two glenohumeral dislocations, with an RTP time of 105 and 185 days respectively.

Figure 2. Initial position used by the goalkeeper. On the left, knee on the ground, on the right, in half screen position (author's own work).

Among goalkeepers, the injuries with a longer RTP affected the knee, with an average RTP of 28.6 days± 37.8 (range 4-95).

Discussion

The aim of this study is to describe the injury patterns among participants in the top Spanish men's and women's RH division (OK Liga) throughout an entire season.

Firstly, we should highlight that there are prior studies on injury epidemiology among male RH athletes although there is no prior study involving female athletes. So, the results obtained in male athletes will be compared with the results published to date and the results obtained in female athletes will be used to define a starting point to study injuries in this athlete population. Secondly, none of the studies published previously on RH injuries included athletes from different teams in the same league, thereby broadening the sample and avoiding bias.

Regarding the number of TLI per season, the only two studies published to date in the field of the top Spanish league (in men's teams) demonstrated a higher average number of injuries per player and season (two TLI per player and season in the Reverter study[8] and 1.1 TLI per player and season in the Egocheaga study[10].

The two teams that were crowned league champions were the teams that suffered the most injuries (11 in the male league and 13 in the female league). This could be explained by the higher number

Table 3. Incidence proportion for TLI according to the injury characteristics and the athlete's characteristics

		Total	Senior male				Senior female			
			Male Rink players		Male Goalkeepers		Female Rink players		Female Goalkeepers	
		N	N	Incidence (95% IC)	N	Incidence (95% IC)	N	Incidence (95% IC)	N	Incidence (95% IC)
Total injuries		94	53	67.9 (58.3- 79.1)	8	40 (23,4-68,4)	29	90.6 (81.1- 101.3)	4	57.1 (30.1- 108.5)
Moment	Training	54	36	46.1 (36.3- 58.7)	3	15 (5,2-42,6)	12	37.5 (23.9- 58.6)	3	42.8 (18.2- 100.8)
	Match	40	18	23.1 (15.4- 34.6)	5	25 (11,7-53,4)	16	50 (35.4- 70.7)	1	14.2 (2.3- 87.6)
Appea-rance	Acute overuse	29	14	17.9 (11.2- 28.8)	3	15 (5,3-42,6)	10	31.2 (18.7- 52.2)	2	28.6 (8.8- 92.2)
	Progressive overuse	34	25	32 (23.2- 44.3)	1	5 (0,7-33,8)	7	21.8 (11.4- 42.1)	1	14.3 (2.3- 87.6)
	Trauma	31	13	16.7 (10.1- 27.4)	4	2 (0,8-48)	12	37.5 (23.9- 58.6)	2	28.6 (8.8- 92.2)
Mechanism	No contact	62	40	51.2 (41.3- 63.7)	3	15 (5,3-42,6)	16	50 (35.3- 70.7)	3	42.8 (18.2- 100)
	Contact with athlete	14	6	7.7 (3.5- 16.7)	0	-	8	25 (13.7- 45.6)	0	-
	Contact with object	18	8	10.2 (5.3- 19.7)	4	20 (8,3-48)	5	15.6 (7- 34.9)	1	14.3 (2.3- 87.7)
Severity	Mild	47	21	26.9 (18.7- 38.8)	4	20 (8,3-48)	19	59.4 (44.6- 79.1)	3	42.8 (12.82- 100.8)
	Moderate	28	19	24.3 (16.5- 36)	1	5 (0,7-33,8)	7	21.9 (11.4- 42.1)	1	14.2 (2.3- 87.6)
	Severe	20	13	16.7 (10.1- 27.3)	3	15 (5,3-42,6)	4	12.5 (4.9- 31.3)	0	-
Type of injury	Muscular *Aductor longus* *Rectus femoris*	38 23 4	25 17 1	32 (23.2- 44.3) 21.8 (14.3- 33.2) 1.2 (0.1- 8.9)	2 0 0	10 (2,7-37,2) - -	10 5 3	31-2 (18.7-52.2) 15.6 (7- 34.9) 9.8 (3.2- 27.5	0 0 0	-
	Bruising/wound	16	3	3.8 (1.3- 11.6)	3	15 (5,2-42,6)	9	28.1 (16.1- 48.9)	1	-
	Sprain	13	3	3.8 (1.3- 11.6)	2	10 (2,7-37,2)	6	18.7 (9.1- 38.5)	2	-
	Tendinopathy	11	11	14.1 (8.1- 24.4)	0	-	0	-	0	14.3 (2.3- 87.7)
	Fracture	6	4	5.1 (1.9- 13.3)	1	5 (0,7-33,8)	1	3.1 (0.5- 21.5)	0	28.6 (8.8- 92.2)
	Arthritis	5	2	2.6 (0.6- 10)	0	-	2	6.2 (1.6- 23.9)	1	-
	Dislocation	5	4	5.1 (1.9- 13.3)	0	-	1	3.1 (0.5- 21.5)	0	-

of matches, as the two teams which reached the final had played the most matches. Even so, as data on the training hours is not available, it is not possible to determine a causality involving greater exposure.

Regarding the most frequent anatomical location, the results obtained confirm the trend in prior studies, where lower limbs were the most frequently affected zone, followed by the upper limbs and the head and neck[8,10].

Muscular injury was the most frequently described in the study, which matched findings in the two prior publications on Spanish athletes[8,10]. Neither of these studies defined the affected muscles or the severity of the injuries. The results presented allow us to conclude that the most affected muscle among RH players is the long adductor, accounting for 23 out of the 38 muscular injuries described with an incidence of 19.8 (CI 95% 13.7-28-6). They also describe 11 tendon injuries, for an incidence of 9.5 (CI 95% 5.4-16.6) and the most frequently affected muscle were the thigh adductors. In the study by Florit[26], looking at the incidence of tendinopathy in a professional RH team over 8 seasons, the incidence of tendinopathies that led to time-loss was 10.7 (CI 95% 9.5-12), so the results were similar. In this study, the most frequently affected zone was also the thigh adductor area.

With all these results, we can conclude that the pubis region is the most susceptible to muscular and tendon injuries in RH. These results match the studies published on ice hockey, a skating sport that has been extensively studied, where this zone concentrates most of the overuse injuries[19].

Mechanism

Most of the recorded injuries took place with no contact. These results match the Reverter study[8], carried out on just one team in the OK Liga, with a similar ratio. Studies published in biomechanically similar sports such as inline hockey[20] or ice hockey[19] show that the majority of the injuries described occur in direct contact. RH rules, that severely punish contact compared to other skating disciplines, might favour these differences.

By analysing the causal mechanism of the injuries, we can see that the non-contact injuries take place more often in training, while the opposite happens in competition, where contact injuries are more common. This is explained by the actual nature of the activity, as competition implies greater contact and demands than training. This trend has been seen in other sports such as football[21], but it has not been studied previously in RH and allows us to draw the conclusion that players train differently from how they play.

Head injuries

There has been growing concern in recent years in RH about head injuries and their consequences for athletes. This concern has led to some national federations promoting the use of a protective helmet in lower divisions[22]. Prior studies[9,23] have demonstrated that craniofacial injuries are frequent in RH, although they do not specify whether studies took place among top level athletes. The Reverter study[8] recorded two episodes of concussion and 14 of bruising and injuries in the craniofacial region over two seasons in 23 athletes, with an incidence of 39.1 (CI 95% 31.5-48.5).

The results detected nine TLI affecting the head, with an incidence of 7.7 (CI 4.1-14.5), lower than in the Reverter study, with one single episode of concussion. The differences from the Pelaez study[9], which includes amateur and lower-division athletes and presented a high rate of concussion, can be explained by the greater skill among professional athletes both in terms of skating and when handling the ball and the stick: in other sports such as inline skating, it has been demonstrated that less skating experience increases the risk of injuries[20, 25].

Despite increased awareness-raising on head injuries in the world of sport, there is a risk of infra-diagnosis, both from the athletes and the medical teams[24]. It is important for the federations to provide information to the athletes, technical bodies, medical teams and even families, to remain alert to head injuries and their potential consequences in the long term[25].

Injuries among female athletes

The trends mentioned above, the most frequent location and the causal mechanism, are similar to male athletes. Nonetheless, female rink players are 1.33 times more likely to sustain an injury than their male counterparts.

From the results obtained, it should be highlighted that female athletes were injured more in matches than in training. This may be because, despite women's teams playing at the top level, they are not professionals and do not train for as many hours as the professional men's teams. This statement should be confirmed with a study on the exposure hours looking at both training and match time for men's and women's teams.

It is also worth mentioning that there is a higher proportion of ligament injuries in the lower limbs, mainly knees and ankles, compared to the men.

Finally, there was no evidence of tendinopathies due to overuse. This finding has not been seen in other skating sports and should be studied in greater depth.

Injuries in goalkeepers

The position of the goalkeeper in RH is not only key for the sport,[26] but it has a series of specific features which mean it has to be studied differentially to the field players. The position taken by the goalkeepers, alternating a position lying on the floor with a position kneeling on the floor (Figure 2) causes greater stress on the knee area, so injuries are more frequent in this location compared to rink players.

Given that the goalkeepers use protection, direct bruising injuries were less frequent than for rink players. This breaks the stereotype presented by Trabal[6] that the goalkeeper role is more dangerous than the rink player position.

Consequently, prevention strategies should be devised to avoid knee injuries among RH goalkeepers. There is also a need to improve tools to protect the cervical region among these athletes.

Limitations

The study was performed during the 2020/21 season which was marked by the worldwide Covid-19 pandemic. The Covid-19 cases and the preventive lockdowns during the season might have interrupted training and matches for the teams, which might potentially affect their performance.

The possible effects of the SARS-COV2 infection on athletes remains unknown for now. The results obtained do not correlate with SARS-COV2 infections.

The variability in the configuration of the medical teams for each club might vary the processes to diagnose and treat the injuries.

The hours of exposure in training and matches are not available so it is not possible to make an optimum calculation of the injury incidence (injury incidence rate). Although the aim of our study is only descriptive (not comparative), and the sample is small, this work has assessed a CIR association measure to calculate the incidence proportion among male and female rink players. The injury risk between male and female players seems to be relevant. Even so, in future studies, it would be advisable for information on incidence rates to include exposure hours and to be able to calculate both frequency and association measures and so make these findings more rigorous.

Practical applications

In the top division roller hockey teams in Spain, muscular injuries are the most frequent, particularly long adductor muscle injuries. These injuries affect the athletes' availability for training/playing, so it would be appropriate to design prevention protocols for this type of injury.

Trauma injuries are particularly frequent in the sport, due to its very nature. Traumatic head injuries are a cause for concern and it is important to monitor the prevention strategies (protective helmet) which are still pending implementation from the roller hockey regulatory bodies.

For the first time, the most frequent injuries are defined for female roller hockey players. The results should be a starting point to extend the studies on this population of athletes.

Thanks

To Marc Bosqué, Marc Godayol, Vicenç Rizo, Jordi Boada, Pedro Abal, Aleix Rovira, Roger Sotelino, Marc Pi, Adrià Gimenez, Pol Parareda, Ramón Fernández for their help collecting data.

Conflict of interests

The authors do not declare any conflict of interests.

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Review

Effects of physical exercise on aerobic capacity and quality of life in patients diagnosed with asthma: A systematic review and meta-analysis

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doi: 10.18176/archmeddeporte.00113

Received: 14/07/2021
Accepted: 08/09/2021

Summary

Introduction: Nowadays, asthma is a disabling disease with no cure, and the development of effective non-pharmacological treatments which can alleviate side effects of drugs and pathological symptoms is urgent. Some studies have shown that physical exercise may have beneficial effects in patients with asthma, but results were controversial and inconsistent. More evidence is needed to ensure exercise as possible effective treatment in people with asthma.
Objectives: To examine the effects of physical exercise on aerobic capacity and quality of life in patients with asthma. Also, we analyze the possible moderation effects of the selected covariates. As a final aim, we verified if a correlation exists between benefits on aerobic capacity and those obtained on quality of life.
Material and method: We followed the PRISMA statement to search for randomized controlled trials that used physical exercise as intervention to improve aerobic capacity or quality of life in patients diagnosed with asthma. After data extraction, we conducted a random-effects meta-analysis model with moderation analysis. Then, we inspected the correlation between both outcomes through a multivariate approach. Finally, we performed some additional analyses: methodological quality analysis through the PEDro scale, publication bias analysis through funnel asymmetry tests and funnel plot visualization, and sensitivity analyses by outliers and influential cases detection.
Results: Physical exercise had positive effects on aerobic capacity and quality of life. None of the covariates showed a significant moderation effect. We found a positive correlation between the effects of exercise on aerobic capacity and those caused on their quality of life.
Conclusions: Our meta-analysis reports information that supports the use of physical exercise as part of the management and treatment of asthma. However, more specific studies are needed to find optimal type and dose of physical activity for those patients.

Key words:
Physical exercise. Aerobic capacity. Quality of life. Asthma. Meta-analysis.

Efectos del ejercicio físico en la capacidad aeróbica y la calidad de vida en pacientes diagnosticados con asma: revisión sistemática y meta-análisis

Resumen

Introducción: Actualmente, el asma es una enfermedad incapacitante sin cura, y urge el desarrollo de tratamientos no farmacológicos eficaces que puedan aliviar los efectos secundarios de los fármacos y los síntomas patológicos. Algunos estudios han demostrado que el ejercicio físico puede tener efectos beneficiosos en pacientes con asma, pero los resultados fueron controvertidos e inconsistentes. Se necesita más evidencia para garantizar que el ejercicio sea un posible tratamiento eficaz en personas con asma.
Objetivos: Examinar los efectos del ejercicio físico sobre la capacidad aeróbica y la calidad de vida en pacientes con asma. Además, analizamos los posibles efectos de moderación de las covariables seleccionadas. Como objetivo final, verificamos si existe una correlación entre los beneficios en la capacidad aeróbica y los obtenidos sobre la calidad de vida.
Material y método: Seguimos la declaración PRISMA para buscar ensayos controlados aleatorios que utilizaran el ejercicio físico como intervención para mejorar la capacidad aeróbica o la calidad de vida en pacientes con diagnóstico de asma. Después de la extracción de datos, realizamos un modelo de meta-análisis de efectos aleatorios con análisis de moderación. Luego, inspeccionamos la correlación entre ambos resultados a través de un enfoque multivariado. Finalmente, realizamos algunos análisis adicionales: análisis de calidad metodológica a través de la escala PEDro, análisis de sesgos de publicación a través de pruebas de asimetría de embudo y visualización de gráficos de embudo, y análisis de sensibilidad mediante la detección de 'outliers' y de casos influyentes.
Resultados: El ejercicio físico tuvo efectos beneficiosos en la capacidad aeróbica y en la calidad de vida. Ninguna de las covariables presentó un efecto moderador significativo. Encontramos una correlación positiva entre los efectos del ejercicio sobre la capacidad aeróbica y los provocados en la calidad de vida.
Conclusiones: Nuestro meta-análisis presenta información que respalda el uso del ejercicio físico como parte del manejo y tratamiento del asma. Sin embargo, se necesitan estudios más específicos para encontrar qué tipo y qué dosis de actividad física son los óptimos para estos pacientes.

Palabras clave:
Ejercicio físico. Capacidad aeróbica. Calidad de vida. Asma. Meta-análisis.

SEMED Award for Research 2021

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Introduction

Asthma is a major non-communicable disease whose symptoms (i.e., any combination of cough, wheeze, shortness of breath and chest tightness) affect an estimated 300 million people[1], causing approximately 500,000 deaths[1]. Also, asthma is the most common chronic disease among children[1], which increases a) the global impact of this disease on vital outcomes (e.g., aerobic capacity, quality of life, or activities of daily-living)[2] and b) the urgency to discover new possible treatments and refine those that currently exist[3].

Although there is no definitive treatment for asthma[3], existing evidence shows that the most effective pharmacological treatments against the symptoms of the disease seem to be strategies with combined inhaled corticosteroids and long-acting β agonists[4]. Nonetheless, drug treatment has associated side effects such as weight gain or stress[5], which is detrimental to the quality of life of these patients. Scientific literature shows that physical exercise could be an effective non-pharmacological intervention to reduce these side effects and cope the symptoms of the disease[6], such as the inflammation of the small airways[7]. Several meta-analyses[6,8–10] showed a possible preventive effect of exercise on asthma development[6], and positive effects on asthma control[8,9], aerobic capacity[10], lung function[9], and quality of life[10].

However, the current evidence is scarce, low-quality, and imprecise[11]. A point we must consider is that most of the meta-analyses that have inspected the effects of exercise in asthmatic patients only focused on aerobic exercises (e.g., swimming, walking, leisure biking and hiking)[6,9], being a knowledge gap the potential effects on quality of life and asthma control of other types of physical exercise such as multicomponent or strength. We also found discrepancy on the results (e.g., positive effects[10] vs. null[12] on quality of life), which combined with some methodological concerns (e.g., unexplained high levels of heterogeneity, differences in the age groups studied, or a clear definition of the analyzed variable), makes the information about physical exercise effects on asthmatic patients inconsistent[11]. Everything points that this lack of robustness may hamper the application of physical exercise as an effective non-pharmacological treatment to manage asthma symptoms. Therefore, we analyzed the effects of physical exercise on aerobic capacity (i.e., the maximum oxygen consumption during physical activity) and quality of life, both clinically important outcomes in patients suffering from asthma. We also examined the possible interactions between covariates selected for their evidence in the literature[6] and the effects on the study outcomes. Finally, we inspected the correlation between aerobic capacity and quality of life to detect potential associations between the effects caused in this target population.

Material and method

This systematic review with meta-analysis was reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement[13].

Search strategy

Guided by the PICOS framework, we performed a systematic search in the databases PubMed (MEDLINE), Scopus, Web of Science and SportDiscus from inception to April 2021. The search strategy was based on combining all terms related to the same cluster (e.g., participants or interventions) with OR and finally to combine all clusters with AND. Terms related to the search were "asthma patients", "exercise", "physical therapy", "aerobic capacity", "quality of life" and "randomized controlled trial".

Study selection

We searched for and included: (1) Randomized controlled trials in which (2) aerobic capacity or quality of life were studied in (3) patients who were five years old or older diagnosed with asthma[14] (4) that received an intervention based on aerobic or multicomponent physical exercises as the main element of the intervention (5) compared with non-exercise treatments or another exercise intervention.

As an exclusion criterion, we determined that interventions that consisted in physical exercise plus another healthy lifestyle intervention (e.g., diet) and patients diagnosed with an obstructive pulmonary disease other than asthma were excluded.

Data extraction

All data corresponding to trial patients' characteristics (e.g., sample size, age, sex), descriptive statistics (i.e., pre- and post-sample size, means, standard deviations of experimental and control groups) and outcome description were extracted into a self-made data extraction spreadsheet in Excel. If information was missing, the corresponding author was requested to supply the information or data for inclusion in the analyses.

Data synthesis

As we anticipated considerable between-study heterogeneity, a random-effects meta-analysis model was used to pool effect sizes, which were calculated as standardized mean differences (SMD; Hedges' g[15]). The restricted maximum likelihood estimator[16] was used to calculate the heterogeneity variance tau^2. We used Knapp-Hartung adjustments[17] to calculate the confidence interval (CI) around the pooled effect. We also estimated the prediction intervals (PI) as accurate measures. Then, we conducted a moderation analysis to find possible interaction effects between the pooled effects and the selected covariates (i.e., age, type of exercise, and duration of the intervention) identified by existing evidence[6]. Lastly, assuming a moderate correlation coefficient of 0.41[18], we estimated the correlation between pooled effects using a multivariate approach to find potential associations between aerobic capacity and quality of life in these patients.

All analyses were performed in R statistical software (version 4.0.3)[19]. We used the 'esc' package[20] to calculate the effect sizes (Hedges' g), the *'dmetar'* package[21] contains utility functions to facilitate the conduction of a random-effects meta-analysis model, and the 'meta' package[22] to evaluate biases in meta-analysis (i.e., outliers detection, influential cases analysis, and publication bias).

Additional analyses

Methodological quality

The score extracted from the Physiotherapy Evidence Database was used to evaluate the methodological quality of each trial and avoid the risk of bias[23]. When the score of an article was not shown in the PEDro website, reviewers agreed on a rating of this study following the criteria stipulated by the PEDro scale. Total PEDro scores of 0–3 are considered 'poor', 4–5 'fair', 6–8 'good', and 9-10 'excellent'. However, for trials evaluating complex interventions (e.g., exercise) a total PEDro score of 8/10 is optimal[24].

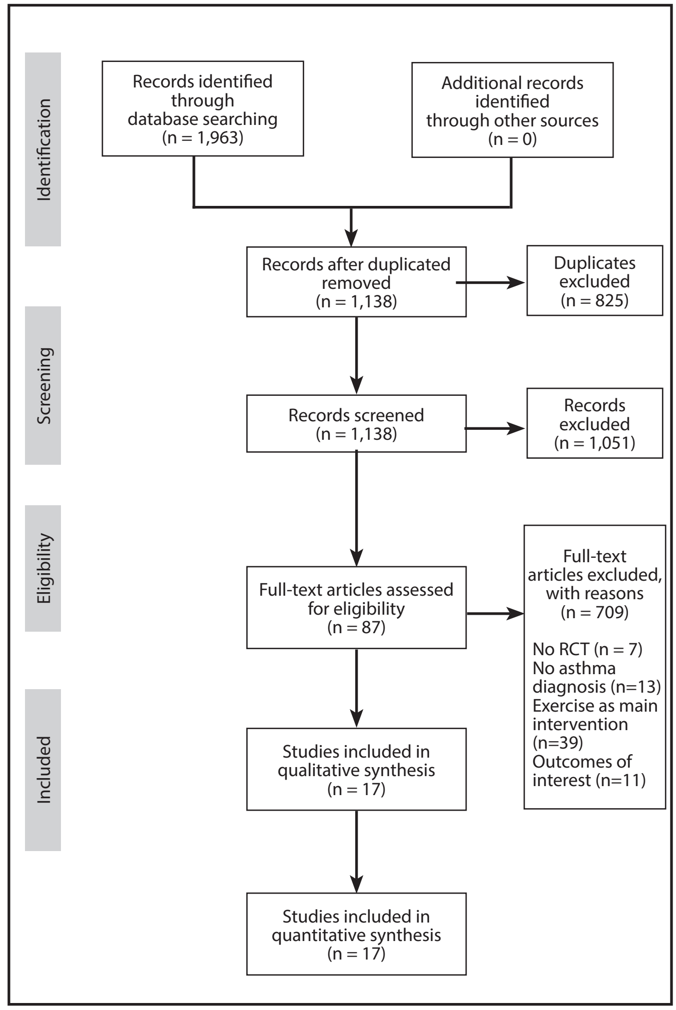
Publication bias

We used the visualization of the standard errors corresponding to each study and its effect size through a funnel plot per outcome. To quantify this possible asymmetry, we used the significance of the Eggers' test[25]. To support these results, we conducted the same analysis under Pustejovsky-Rodges approach[26], an option to conduct Eggers' test with the corrected standard error formula recommended for studies that used SMD as effect size[26].

Sensitivity analyses

To analyze the between-study heterogeneity, we inspected the studies with an extreme effect size (i.e., outliers) and those which heavily pushed the pooled effect of our analysis into one direction (i.e., influential cases). Furthermore, to support the influential cases analysis, we conducted a leave-one-out meta-analysis model[27], which reported the individual contribution to the pooled effect of a specific outcome and to heterogeneity levels (i.e., I^2). After removing the studies detected as outliers or influential cases, we conducted new meta-analytical models and plotted their corresponding forest plots to visualize models' comparison.

Figure 1. PRISMA flowchart of study selection.



Results

Included studies

We identified 1,963 registers through the initial searches. After screening citations by title and abstract, we considered 87 possible eligible studies for inclusion. After removing duplicates and applying the selection criteria, 17 studies[8,28-43] (1,329 patients; 29 effect sizes) were selected for inclusion in this meta-analysis (Figure 1).

The year of publication ranged from 2001 to 2020. A total of 627 (47.18%) of patients were women. The average age was 25.58±18.34 years old (range of 10 - 68.2). The average body mass index (BMI) was 23.11±3.54. The interventions had an average duration of 10.64±3.92 weeks. The interventions used in the included studies were aerobic exercises (n = 16) and multicomponent exercises (n = 13). All studies' characteristics referring to the intervention and control groups details, evaluation tools and main results are presented in Table 1.

Meta-analysis

Our results showed that exercise had positive effects on aerobic capacity in patients diagnosed with asthma (k = 15; Hedges' g = 0.73; 95% CI [0.16, 1.28]; p = 0.01). Also, significant effects were found for exercise on the quality of life of these patients (k = 14; Hedges' g = 0.69; 95% CI [0.26, 1.11]; p < 0.01). Forest plots are illustrated in Figure 2. None of the analyzed covariates showed a significant moderation effect.

For aerobic capacity, the between-study heterogeneity variance was estimated at tau^2 = 0.78 (95% CI: 0.37 - 2.43), with an I^2 value of 84% (95% CI: 75 - 90%). For quality of life, the between-study heterogeneity variance was estimated at tau^2 = 0.28 (95% CI: 0.11 - 1.51), with an I^2 value of 69% (95% CI: 45 - 82%). The prediction intervals ranged from g = –1.25 to 2.71 in aerobic capacity, and from g = –0.56 to 1.93 in quality of life, indicating that negative intervention effects cannot be ruled out for future studies.

Correlation between aerobic capacity and quality of life

We found a positive moderate correlation (r = 0.59) between aerobic capacity and quality of life, indicating that positive effects on aerobic capacity may cause positive effects on quality of life. The pooled effects and the association between outcomes are illustrated in Figure 3.

Table 1. Characteristics of the included studies.

Study	Participants	Age (average)	BMI	Protocol duration	Intervention parameters	Control parameters	Evaluation tools	Main results
Abdelbasset, 2018	38 (23 females)	10	21.8	10 weeks 3 sessions/week 40 min/session	Intensity: 50-70% HR_{max} Type: Walking	Conventional treatment	VO_{2max} 6-MWT PAQLQ	10 weeks of physical exercise had beneficial effects on pulmonary functions, aerobic capacity, and quality of life in children with asthma
Andrade, 2014	33 (12 females)	10	19.8	6 weeks 3 sessions/week ~40 min/session	Intensity: 70-80% HR_{max} Type: Treadmill	Usual care	6-MWT PAQLQ	An improvement was found in functional capacity, maximal respiratory pressure, quality of life and asthma-related symptoms
Basaran, 2006	62 (22 females)	10.4	18.3	8 weeks 3 sessions/week 60 min/session	Intensity: NA Type: Calisthenics + submaximal basketball training	Home respiratory exercises	6-MWT PAQLQ	8-weeks of regular submaximal exercise has benefitial effects on quality of life and exercise capacity in asthmatic children
Coelho, 2018	37 (32 females)	46	28.6	12 weeks 5 sessions/week 30 min/session	Intensity: moderate Type: Walking	Usual care	6-MWT AQLQ	Participants of the intervention group increased their exercise capacity and their daily steps
Dogra, 2011	36 (22 females)	34.1	24.7	24 weeks 3-5 sessions/week NA min/session	Intensity: 70-85% HR_{max} Type: outdoor jogging, treadmill, recumbent, or upright cycling, and ellitical or rowing machines	Usual care	VO_{2max} Mini-AQLQ	A structured exercise intervention can improve asthma control
Fanelli, 2007	38 (NA females)	10.5	18.1	16 weeks 2 sessions/week 90 min/session	Intensity: 70% RM Type: Cycling and/or treadmill and endurance exercises	Educational program	VO_{2max} PAQLQ	Supervised exercise training might be associated with benefitial effects on disease control and quality of life in children
França-Pinto, 2015	43 (34 females)	42	26.4	12 weeks 2 sessions/week 30 min/session	Intensity: Vigorous (anaerobic threshold) Type: Yoga breathing exercises + treadmill	Yoga breathing exercises + sham intervention	VO_{2max} AQLQ	Adding exercise as an adjunct therapy to pharmacological treatment could improve the main features of ast
Jaakkola, 2019	89 (70 females)	39.7	24.9	24 weeks 3 sessions/week ~30 min/session	Intensity: NA Type: Aerobic exercise + muscle training	Usual care	VO_{2max}	Regular exercise improves asthma control
Mendes, 2010	101 (79 females)	39.3	24.8	12 weeks 2 sessions/week 30 min/session	Intensity: 60-70% VO_{2max} Type: Yoga breathing exercises + aerobic exercises	Educational program	VO_{2max} AQLQ	Aerobic training can play an important role in the clinical management of patients with persistent asthma
Moreira, 2008	31 (14 females)	12.7	20.4	12 weeks 2 sessions/week 50 min/session	Intensity: submaximal. Type: Aerobic exercises + strength training + balance adn coordination exercises	Usual care	AQLQ	There is no reason to discourage asthmatic children with controlled disease to exercise
Refaat, 2015	68 (37 females)	37.1	22.5	6 weeks 3 sessions/week 30 min/session	Intensity: 60-80% HR_{max} Type: Cycling, step ups, wall squats and upper limb endurrance exercises	Usual care	AQLQ	Physical training can improve quality of life and pulmonary function in patients with moderate and severe bronchial asthma

(continúa)

Study	Participants	Age (average)	BMI	Protocol duration	Intervention parameters	Control parameters	Evaluation tools	Main results
Sanz-Santiago, 2020	53 (29 females)	11.5	NA	12 weeks 3 sessions/ week 60 min/session	Intensity: moderate. Type: Cycling + resistance exercises	Usual care	VO_{2max} PAQLQ	Combined exercise training improved cardiorespiratory fitness and muscle strength in children
Shaw, 2011	44 (32 females)	21.9	27.1	8 weeks 3 sessions/ week 30 min/session	Intensity: 60% HR_{max} Type: Walking and/or jogging	Usual care	VO_{2max}	Aerobic exercise plus diaphragmatic inspiratory resistive breathing might be useful as an adjunct therapy in asthmatic patients
Turner, 2011	35 (19 females)	67.8	27.7	6 weeks 3 sessions/ week 80-90 min/ session	Intensity: 80% of the average walking speed + Borg scale Type: Walking + cycling + endurance exercises	Usual care	6-MWT AQLQ	Supervised exercise training improves symptoms and quality of life in these patients
Van Veldhsen, 2001	47 (13 females)	10.6	18.5	12 weeks 2 sessions/ week 60 min/session	Intensity: NA. Type: Fitness training + different physical activities	Usual care	VO_{2max}	Physical exercise program not only enhanced physical fitness, but also improved coping behavior with asthma
Wang, 2009	30 (10 females)	10	20	6 weeks 3 sessions/ week ~50 min /session	Intensity: 65% HR peak Type: Swimming	Usual care	VO_{2max}	Swimming may be an effective non-pharmacological intervention for the children or adolescent with asthma
Weisgerber, 2008	45 (24 females)	10.3	23	9 weeks 3 sessions/ week 30 min/session	Intensity: High (8-10 METs) Type: Swimming	Golf intervention	VO_{2max} AQLQ	Results suggest a potentially benefitial role for moderate to vigorous physical activity in childhood asthma

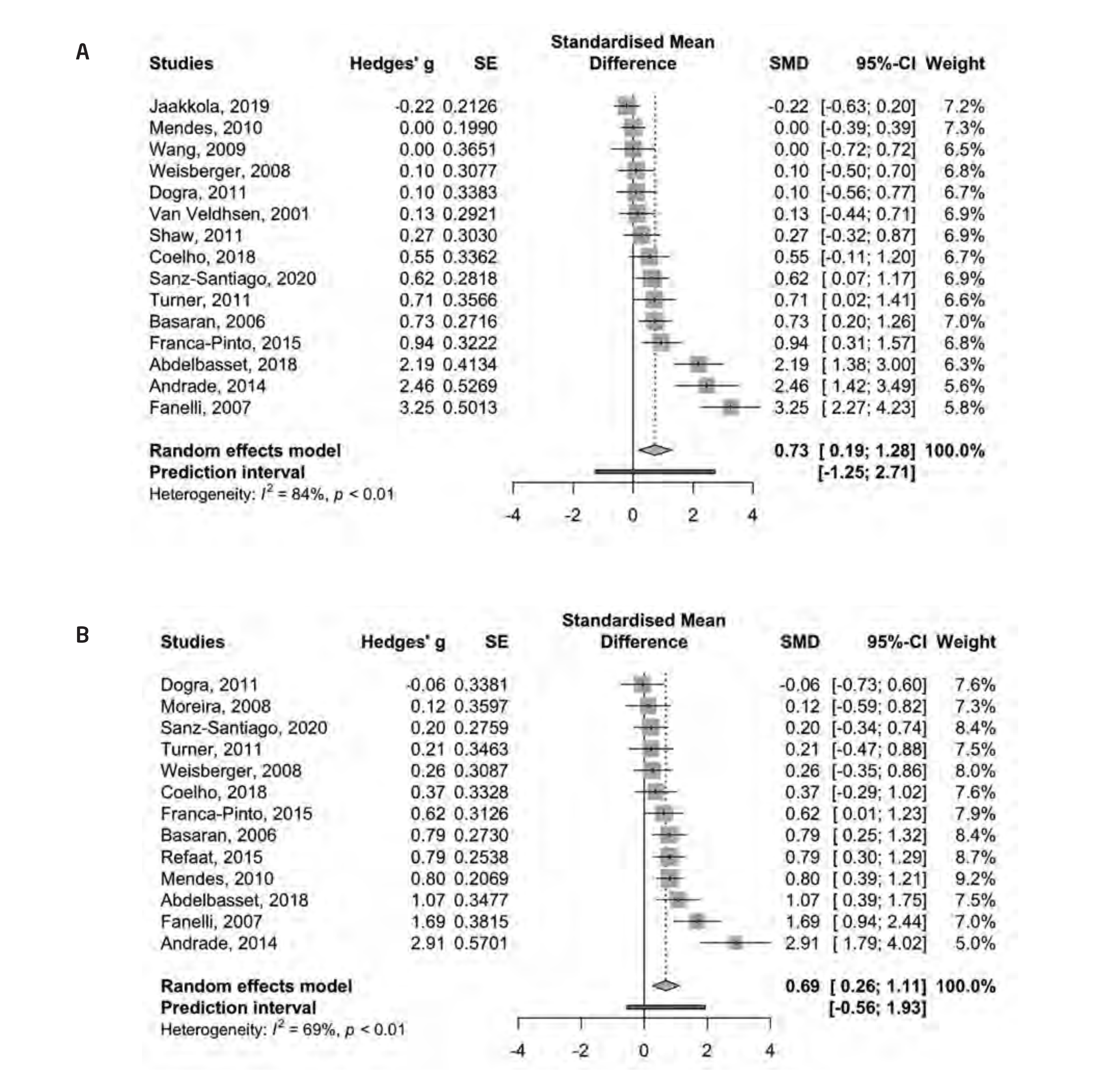
HR_{max}: Maximal Heart Rate; 6-MWT: 6-Minutes Walking Test; PAQLQ: Pediatric Asthma Quality of Life Questionnaire; AQLQ: Asthma Quality of Life Questionnaire.

Table 2. PEDro scale scores of the included studies.

Study	Eligibility criteria*	Random allocation	Concealed allocation	Baseline comparison	Blinded subjects	Blinded therapists	Blinded assessors	Adequate follow -up	Intention to-treat analysis	Between group comparison	Point estimates and variability	Overall
Abdelbasset, 2018	Yes	Yes	Yes	Yes	No	No	Yes	Yes	No	Yes	Yes	7
Andrade, 2014	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	6
Basaran, 2006	No	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Coelho, 2018	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	7
Dogra, 2011	Yes	Yes	Yes	Yes	No	No	No	No	No	Yes	Yes	5
Fanelli, 2007	Yes	Yes	No	Yes	No	No	Yes	No	No	Yes	Yes	5
França-Pinto, 2015	Yes	Yes	Yes	Yes	No	No	No	No	No	Yes	Yes	5
Jaakkola, 2019	Yes	Yes	No	Yes	No	No	No	No	No	Yes	Yes	4
Mendes, 2010	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Moreira, 2008	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	7
Refaat, 2015	Yes	Yes	No	Yes	No	No	No	No	No	Yes	Yes	4
Sanz-Santiago, 2020	No	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	6
Shaw, 2011	No	Yes	Yes	Yes	No	No	No	Yes	No	Yes	Yes	6
Turner, 2011	No	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Van Veldhoven, 2001	Yes	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Wang, 2009	No	Yes	No	Yes	No	No	No	Yes	No	Yes	Yes	5
Weisgerber, 2008	Yes	Yes	No	Yes	No	No	No	No	No	No	No	2

*Invalid criterion for final score.

Figure 2. Effect sizes for exercise on study outcomes. Studies are ordered according to their effect sizes. A) Aerobic capacity; B) Quality of life.



Methodological quality of included studies

We found that 6 studies[31,35,38,41–43] presented a good methodological quality, 10 studies[8,28–30,33,34,36,37,39,40] obtained a fair methodological quality score and only 1 study[32] presented a poor methodological quality. In summary, we can determine the methodological quality of our study as fair-good. All scores of the included studies are presented in Table 2.

Publication bias analysis

Eggers' test does not indicate the presence of funnel asymmetry (Table 3). After performing sensitivity analysis with the Pustejovsky-Rodges approach, our results also did not show the presence of funnel asymmetry, which indicates data consistency. To visualize the funnel symmetry, the funnel plots of both outcomes are illustrated in Figure 4.

Figure 3. Effect sizes and confidence ellipses of both outcomes. The diamonds near the axes are the estimates of the effect size of our variables and the black arrows represent their 95% CI. The diamond in the center is the combined effect for both variables. The red ellipse represents the 95% CI ellipse of our combined effect size. The black ellipse is 95% PI for all effects of all studies under a random-effects model. Each point represents a study and the dashed line its 95% CI.

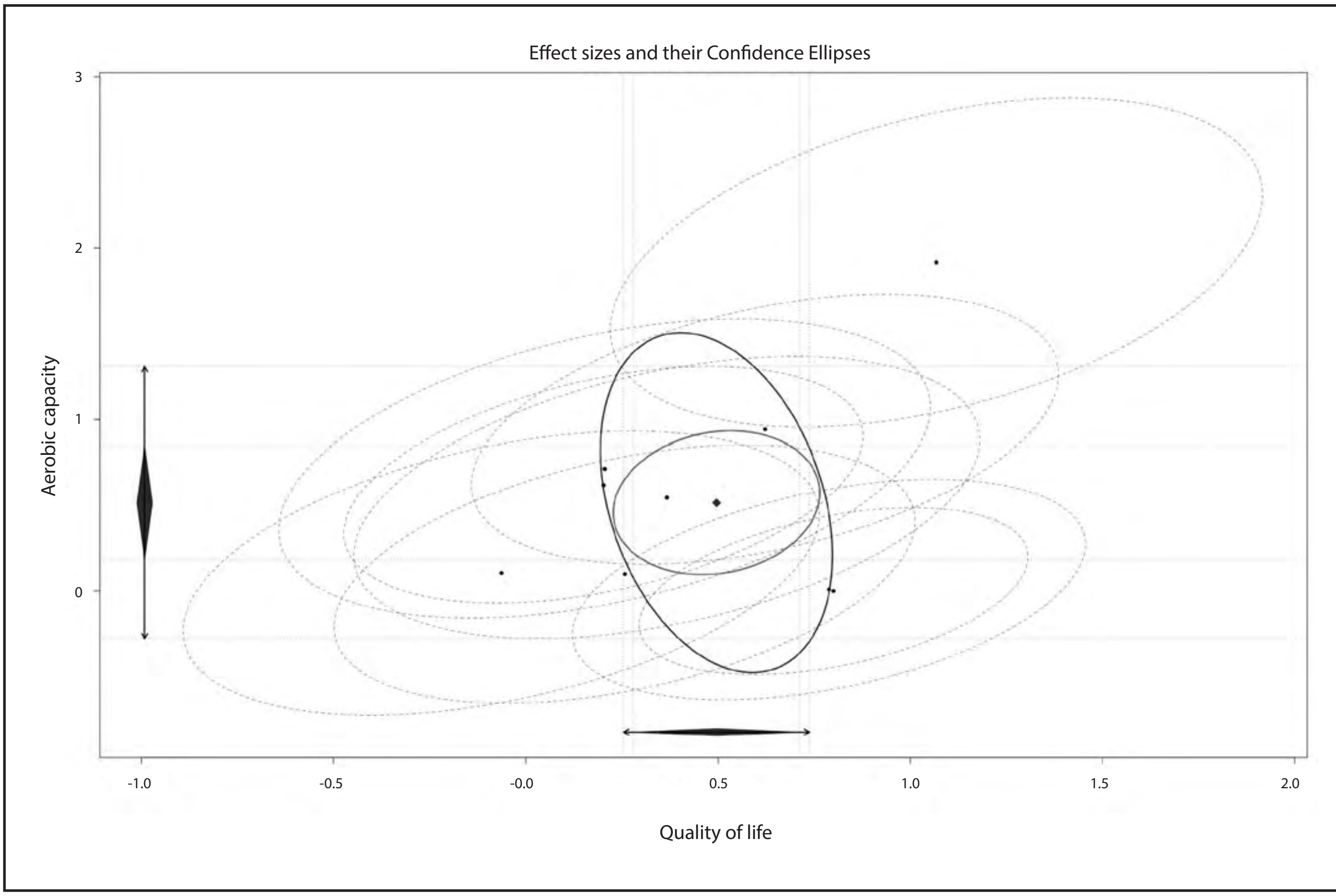


Figure 4. Contour-Enhanced Funnel Plots.

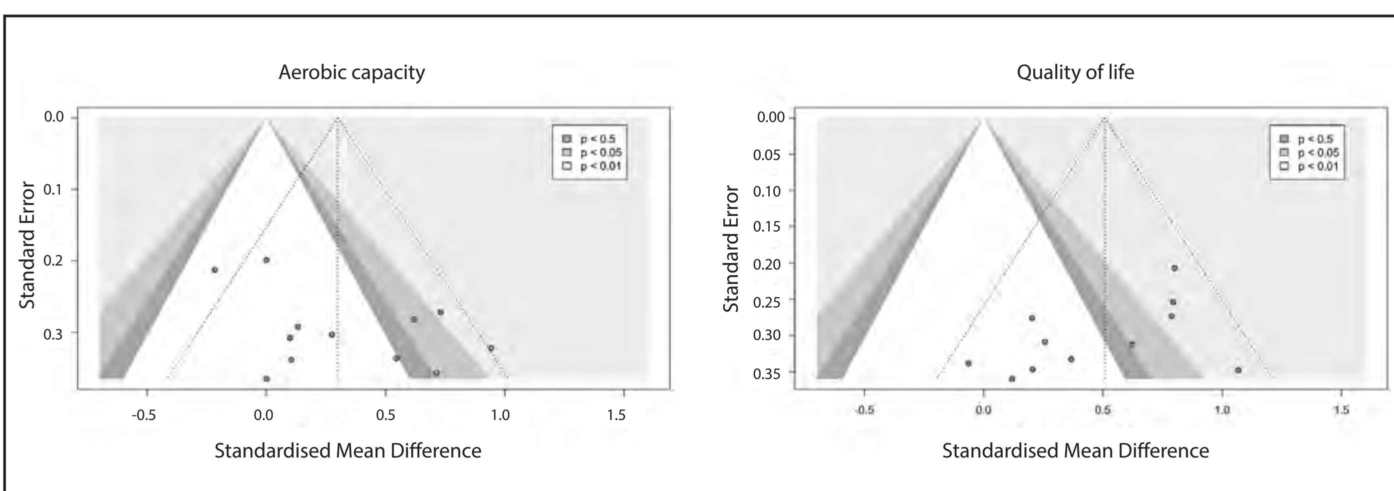


Figure 5. Leave-One-Out Meta-Analysis to identify the individual contribution to the heterogeneity and effect size. A) Aerobic capacity; B) Quality of life.

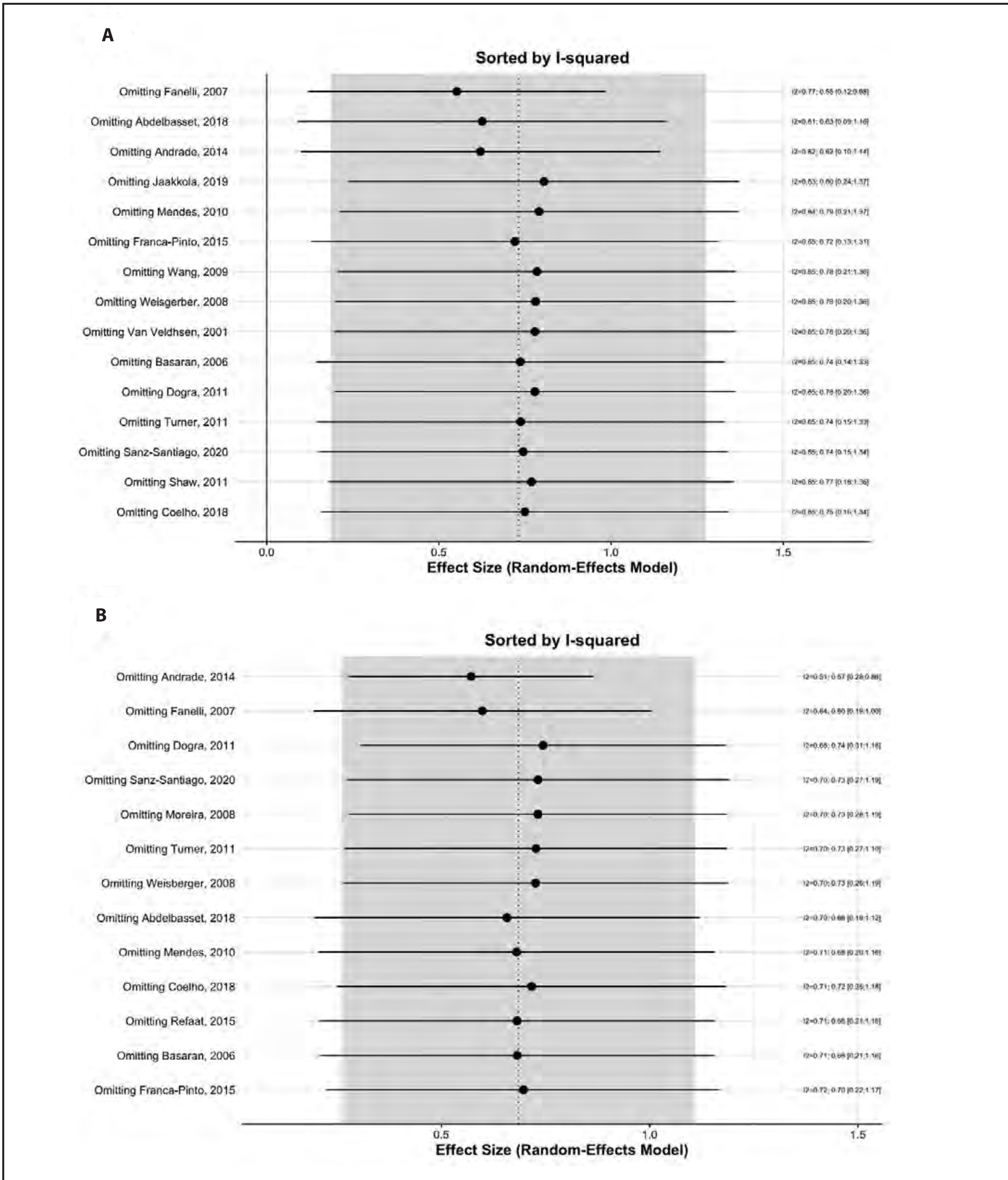


Table 3. Publication bias analysis results.

Method	Intercept	95% CI	t-value	p
Egger	–3.49	–7.10 – 0.12	–1.896	0.0904
Pustejovsky-Rodges	–1.28	–4.12 – 3.13	0.95	0.366

Sensitivity analysis

Observing the variance in effect sizes and heterogeneity through leave-one-out meta-analysis method, we detected 3 studies[30,38,41] for aerobic capacity outcome and 2 studies[30,38] for quality of life outcome that could have influenced the pooled effects. The individual contributions to the effect size and heterogeneity are illustrated in Figure 5. Removing the observed influential studies, the pooled effects of both outcomes decreased, but we obtained a significant reduction in the heterogeneity level and more accurate confidence and prediction intervals, suggesting significant positive effects of physical exercise on quality of life of these patients. All data referred to sensitivity analysis appeared in Table 4.

Discussion

To our knowledge, our meta-analysis, with a final representation of 1,329 patients with asthma (17 studies; 29 effect sizes), was the first-ever in reporting a significant correlation between aerobic capacity and quality of life effects in patients diagnosed with asthma. Furthermore, we found significant positive effects of physical exercise on aerobic capacity and quality of life in these patients. A point we must consider is that prediction intervals of both outcomes included zero in our main analyses. However, when we removed the influential studies, we obtained clear improvements on aerobic capacity and quality of life (i.e., prediction intervals did not include zero), a significant decrease in the heterogeneity levels, and more accurate intervals (i.e., confidence and prediction). In contrast, we also observed an effect size shrinking in that process. Lastly, we found a moderate positive correlation between both outcomes, suggesting that beneficial effects on quality of life may have been caused by benefits on aerobic capacity.

The results obtained in our meta-analysis are in line with other reviews[6,8–10], supporting the beneficial effects of exercise in asthmatic patients. Asthma is an inflammatory disease, and exercise and/or physical activity can play an important role in controlling its symptoms: improving the aerobic capacity of these patients may provide a reduction in exercise-induced bronchoconstriction (i.e., airway muscles contraction)[44], which is the main cause of the notorious sedentary behavior of people diagnosed with asthma[45], and a better physical exercise tolerance[46]. Hence, these benefits could be reflected on the overall quality of life of people with asthma, since the greater impact on any asthma symptom, the better their quality of life[47], which may partially explain the found correlation between both outcomes.

This research adds consistent evidence on the usefulness of physical exercise in the management and treatment of asthma. Considering our data and the current evidence[48], we hypothesize that physical exercise could improve some pathologies which share symptoms with asthma disease such as the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), from common symptoms (e.g., cough) to severe ones (e.g., difficulty breathing, shortness of breath, or loss of movement), taken in account all pathology symptoms, the context, and patient status. However, in order to transfer this knowledge to clinical practice, we need to fill in the existing gaps in the literature about the optimal type and dose for these patients[49]. International organizations recommend keeping a healthy and active life, encouraging people with asthma to engage in regular physical activity[49], at least 30 minutes of moderately intense physical activity or structured physical exercise every day[49], resulting in global recommendations, not specifications. In order to establish optimal physical exercise for these people, there is limited evidence which suggests that aquatic activities (e.g., swimming) are more beneficial by reducing the airborne particles exposure[47], and that moderate-vigorous intensity activities could result in greater benefits[47]. This information scarcity could explain that we do not detect moderation effects differentiating by type of physical exercise (i.e., aerobic vs. multicomponent), although significant interactions could be hidden by lack of available data.

In this point, we can identify several key strengths to our study. Our meta-analysis is the first one that has been able to explain part of the benefits caused on quality of life by aerobic capacity improvements. Sensitivity analyses allow us to explain large amounts of heterogeneity given in the main analyses. Included studies presented a fair-good methodological quality. Additional analysis did not show the presence of publication bias. Conversely, we also detected some limitations. We have only focused on exercise, but future meta-analyses should include different types of physical activities (e.g., body-mind or aquatic activities).

Table 4. Sensitivity analysis results

Outcome	Analysis	Hedges' g	95% CI	p	95% PI	I^2	95% CI
Aerobic capacity	Main Analysis	0.73	0.16 - 1.28	0.01	–1.25 - 2.71	84%	75 - 90
	Infl. Cases Removed	0.30	0.06 - 0.54	0.002	–0.31 - 0.91	43%*	13 - 72
Quality of life	Main Analysis	0.69	0.26 - 1.11	0.004	–0.56 - 1.93	69%	45 - 82
	Infl. Cases Removed	0.51	0.27 - 0.74	< 0.001	0.03 - 0.98*	28%*	0 - 64

[1]Removed as outliers: Abdelbasset, 2018; Andrade, 2014; Franelli, 2007
[2]Removed as outliers: Andrade, 2014; Franelli, 2007
*Significanrt changes between models

Moreover, we had a low number of studies to observe moderation subgroup effects (e.g., evidence support that children may benefit more from physical exercise than older adults[50], and we did not detect it), which limits the differentiation on the effects.

Conclusions

This work contributes to broadening the horizon in the management and treatment of asthma, proposing physical exercise as a non-pharmacological treatment to improve the aerobic capacity and, consequently, the quality of life of people with asthma. Our meta-analysis has demonstrated that physical exercise is an intervention which deserves further analysis to lay the foundations for specific and efficient recommendations (i.e., optimal type and dose of physical activity) to improve the lives of these patients who suffer a disease that currently has no cure.

Conflict of interest

The authors do not declare a conflict of interest.

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La dirección de Archivos de Medicina el Deporte desea agradecer a todos su desinteresada colaboración.

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All authors that sign the articles accept the responsibility defined by the World Association of Medical Editors.

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For the performance of controlled clinic essays the CONSORT normative shall be followed, available at http://www.consort-statement.org/

Campaña de aptitud física, deporte y salud

La **Sociedad Española de Medicina del Deporte**, en su incesante labor de expansión y consolidación de la Medicina del Deporte y, consciente de su vocación médica de preservar la salud de todas las personas, viene realizando diversas actuaciones en este ámbito desde los últimos años.

Se ha considerado el momento oportuno de lanzar la campaña de gran alcance, denominada **CAMPAÑA DE APTITUD FÍSICA, DEPORTE Y SALUD** relacionada con la promoción de la actividad física y deportiva para toda la población y que tendrá como lema **SALUD – DEPORTE – DISFRÚTALOS**, que aúna de la forma más clara y directa los tres pilares que se promueven desde la Medicina del Deporte que son el practicar deporte, con objetivos de salud y para la mejora de la aptitud física y de tal forma que se incorpore como un hábito permanente, y disfrutando, es la mejor manera de conseguirlo.

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