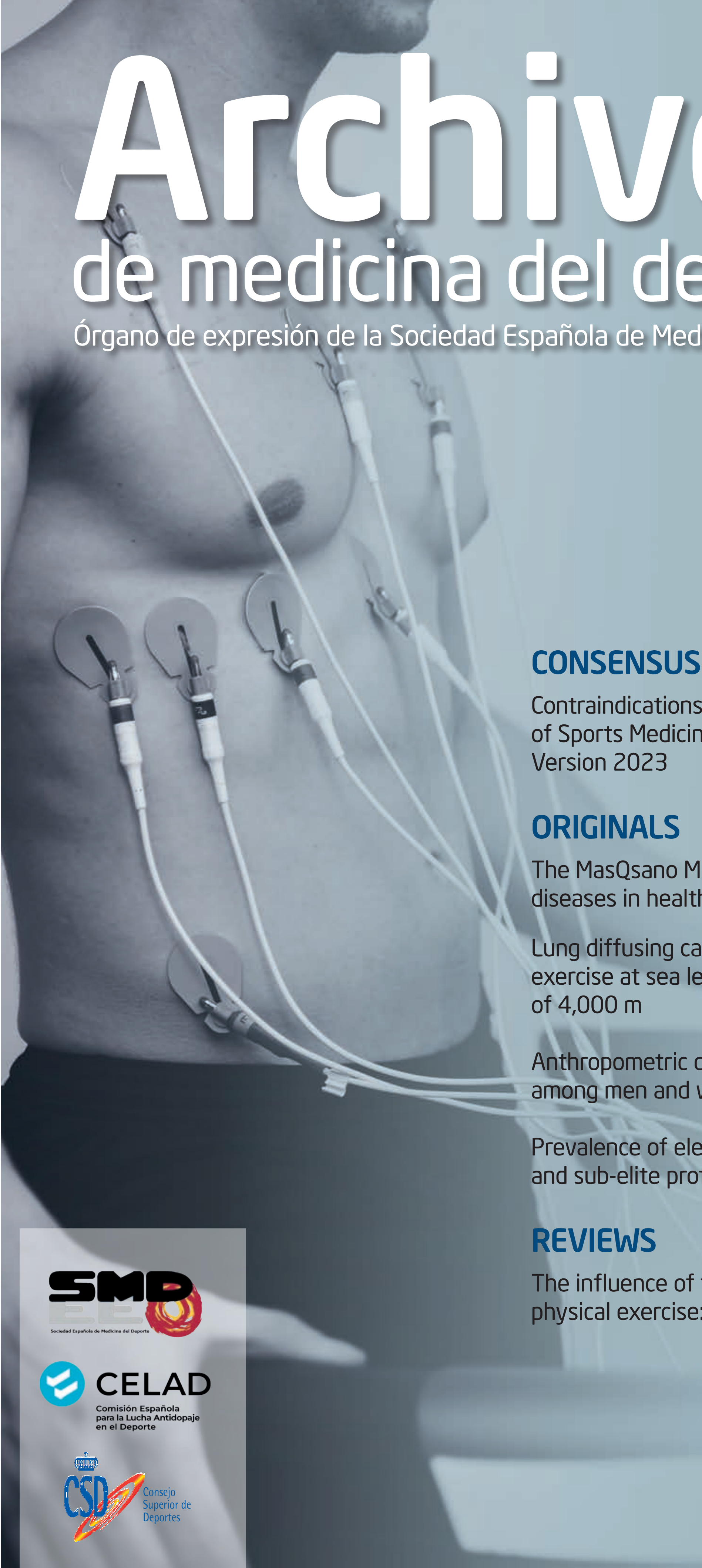

ISSN: 0212-8799

217

Volumen 40 (5)

September-October 2023

Archivos de medicina del deporte

Órgano de expresión de la Sociedad Española de Medicina del Deporte

ARCHIVOS DE MEDICINA DEL DEPORTE

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CONSENSUS DOCUMENT

Contraindications to sports participation. Spanish Society of Sports Medicine (SEMED) Consensus Document. Version 2023

ORIGINALS

The MasQsano Method. Detection of unknown cardiac diseases in health screening for athletes

Lung diffusing capacity after different modalities of exercise at sea level and hypobaric simulated altitude of 4,000 m

Anthropometric differences and maximal aerobic power among men and women in racing-boat rowing

Prevalence of electrocardiographic abnormalities in elite and sub-elite professional athletes

REVIEWS

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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

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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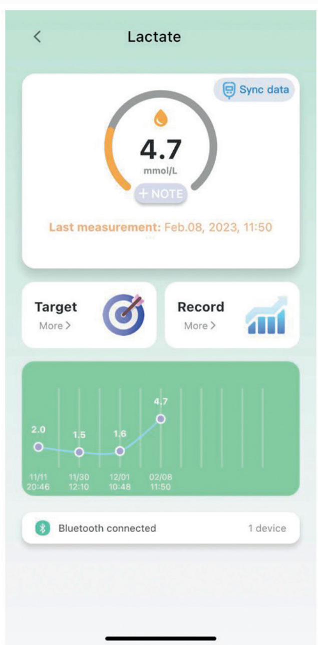

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Archivos
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Volumen 40(5) - Núm 217. September - October 2023 / *Septiembre - Octubre 2023*

Summary / Sumario

"Doctor... I feel fine now, it doesn't hurt any more"

"Doctor ... ya estoy bien, no me duele"

Ana V. Cintron Rodríguez

Puerto Rico Sports Medicine Federation
President – COPAMEDE
Elected Member- FIMS Executive Committee

doi: 10.18176/archmeddeporte.00141

"Doctor... I feel fine now, it doesn't hurt any more". How often do we hear that from our athletes? How often do our athletes return to the field prematurely after a sports injury without the necessary approval from their medical team? I suspect that many of you might be thinking to yourself "too often". How do we make not only our athletes but also certain healthcare providers understand that the absence of pain does not necessarily mean that someone has fully recovered from a sports injury? There is plenty of literature to show that incomplete rehabilitation is, time and again, one of the main causes of recurring sports injuries.

Rehabilitation from sports injuries has evolved over recent decades through treatment methods and exercise protocols that have gradually changed as new scientific evidence emerges, but two things remain unchanged: a medical background check and a comprehensive physical examination. These will vary depending on the characteristics of the individual being treated; i.e. whether they are an adult or a child, a man or a woman, whether the injury is acute or chronic, traumatic or caused by overexertion. The preliminary evaluation should also identify both intrinsic risk factors (e.g. static and/or dynamic anatomical alignment issues, muscle contracture and/or imbalance, etc.) and extrinsic risk factors (training errors, unsuitable equipment or technique, etc.).

It should be stressed at this point that a proper knowledge of the sport in question is also essential for achieving effective rehabilitation of an athlete. By studying the biomechanics of movement, it is possible to identify muscle and joint groups that will be at greater risk of injury and those that may be indirectly affected as part of that continuous movement chain known as the kinetic chain. Knowledge and understanding of why the injuries associated with a particular sport occur enables an effective rehabilitation plan to be created that not only treats painful tissues but also those that have been affected by replacing or compensating for the originally injured tissues. This is why we not only evaluate the shoulder that hurts but also the core and lower extremities that we know provide more than 50% of the force generated by a pitcher, looking for that "hidden" biomechanical deficit that affects movement in that shoulder. Only then can a suitable rehabilitation plan be created and effective recovery achieved. That knowledge is also the basis on which at-risk tissues can be trained in order to prevent injuries in a particular sport.

Despite the existence of numerous rehabilitation protocols, each athlete recovers at their own pace. For that reason, rehabilitation plans should be personalised and modified according to the needs of each case. A multidisciplinary team is fundamental and should include a physical therapist, an athletic therapist, an exercise physiologist and a sports nutritionist, among others, as well as the essential sports psychologist.

Rehabilitation from sports injuries has been split into stages and those stages are often associated with the stages of recovery in the affected tissue. Those stages of rehabilitation can be summarised as follows:

- Stage I: Acute or Recovery - this begins at diagnosis to work on the inflammatory phase in the tissue. It is an essential stage during which the body begins the recovery process and during which rehabilitation seeks symptomatic relief from the pain, to prevent excess oedema and to protect the injured area while also encouraging the movement arc. In some cases and depending on the severity of the injury, a light load can be used during early rehabilitation.
- Stage II: Readaptation - this coincides with the tissue repair stage in which the affected tissue is replaced by a collagen matrix through the proliferation of fibroblast cells. It is during this stage that rehabilitation is focused on recovery of the movement arc, strength and neuromuscular function, including proprioception. It includes

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alternative training sessions to prevent the loss of aerobic capacity. This is the stage at which we frequently "lose" our athletes due to the absence of pain.

– Stage III: Functional or Retraining Stage - this is associated with the tissue maturing or remodelling process, in which work continues on readaptation skills and the athlete is retrained on the movements and techniques required to deal with the specific demands of their sport.

The goal of any rehabilitation process is to achieve a safe return to the sport, whether competitive or recreational. Hence the importance of educating our athletes so they understand that rehabilitation is not only about eliminating the pain but also about restoring the movement arc, strength, neuromuscular function and, above all, the entire series of movements that are specific to the demands of their sport. This will not only enable an effective return to the sport but will also minimise the chances of a repeat injury. That decision should be taken following input from the multidisciplinary team while not only considering clinical and biological factors of the athlete but also the psychological and social factors that might impact their involvement in the sport.

We have a responsibility to educate our athletes, their coaches and families on the important process of rehabilitation and the possible consequences of incomplete rehabilitation. Education is essential to that process!

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Contraindications to sports participation. Spanish Society of Sports Medicine (SEMED) Consensus Document. Version 2023

Pedro Manonelles Marqueta, Emilio Luengo Fernández, Luis Franco Bonafonte (coordinators), Helena Álvarez-Garrido, Miguel Archanco Olcese, Carmen Arnaudas Roy, Rafael Arriaza Loureda, Montserrat Bellver Vives, Raquel Blasco Redondo, Araceli Boraita Pérez, Daniel Brotons Cuixart, Josep Brugada Terradellas, Juan Calatayud Pérez, Aridane Cárdenes León, Gonzalo María Correa González, Miguel Chiacchio Sieira, Miguel Del Valle Soto, Vicente Elías Ruiz, Vicente Ferrer López, Bernardo J. Galmés Sureda, Pedro García Zapico, Teresa Gaztañaga Aurrekoetxea, Luis González Lago, Gonzalo Grazioli, Fernando Gutiérrez Ortega, Fernando Jiménez Díaz, Ricardo Jiménez Mangas, Kepa Lizarraga Sainz, Jeroni Llorca Garnero, Begoña Manuz González, Ignacio Martínez González-Moro, Silvia Monserrat, Zigor Montalvo Zenarruzabeitia, Juan Miguel Morillas Martínez, Elena Muñoz Farjas, Fernando Novella María-Fernández, Concepción Ocejo Viñals, José Luis Orizaola Paz, Nieves Palacios Gil de Antuñano, Javier Pérez Ansón, Francisco Javier Rubio Pérez, Fernando Salom Portella, José Sánchez Martínez, Ángel Sánchez Ramos, Luis Segura Casado, Nicolás Terrados Cepeda, José Luis Terreros Blanco

doi: 10.18176/archmeddeporte.00142

Contraindications to sports participation. Spanish Society of Sports Medicine (SEMED) Consensus Document. Version 2023

Summary

Main purpose of sports medicine is reaching the health care of the athlete, not only from the point of view of treatment, but also from the point of view of prevention. The performance of preparticipation medical sports evaluation, one of the main attributions of this specialty, is aimed at the discovery of pathologies, diseases or alterations that may affect health. They might range from situations that can trigger deadly incidents, to those without putting life at risk, can affect the health or performance of the athlete. Adequate implementation of preparticipation medical sports evaluation implies the diagnosis of medical problems that must be analyzed, from other points of view such as the perspective of fitness for sport practice. In addition, the doctor in charge must have a guide for clearance for sports practice. In case of non-authorization, time for non-sports activities must be recommended in order to decrease injury risks. Cardiovascular pathologies are the best-known contraindications in sport practice, treated extensively in the literature. However, there are also contraindications secondary to problems or issues of the rest of apparatus organs and systems of the organism, knowing that the athlete represents an entity in which physical exercise affects all their sets. This document highlights those contraindications already discussed above and analyzes the legal aspects of sports practice contraindications. Medical professionals are responsible for managing the pre-participation medical sports evaluation as well as the documentary aspects that support it.

Key words:
Contraindication. Preparticipation medical sports evaluation. Ineligibility. Sports fitness. Consensus. Sports Medicine.

Resumen

La función principal de la medicina del deporte es el cuidado de la salud del deportista, no solo desde el punto de vista del tratamiento, sino también desde el de la prevención. Los reconocimientos médicos para la aptitud deportiva, una de las atribuciones principales de esta especialidad, están destinados a descubrir patologías, enfermedades o alteraciones que pueden afectar a la salud, y abarcan desde las situaciones que pueden desencadenar incidentes mortales hasta las que, sin poner en riesgo la vida, pueden afectar la salud o el rendimiento del deportista. La realización adecuada de reconocimientos para el deporte implica el diagnóstico de problemas médicos que deben analizarse, entre otros puntos de vista, desde la óptica de la aptitud para la práctica deportiva, y el médico encargado debe disponer de una guía que le oriente sobre la decisión de autorizar o no la práctica de deporte, y en caso de no autorización, la temporalidad de esta y el riesgo asumible de participación en algunos deportes. Las contraindicaciones para la práctica deportiva mejor conocidas son las de origen cardiovascular, tratadas extensamente en la literatura, pero también existen contraindicaciones del resto de aparatos y sistemas del organismo, entendiendo que el deportista es un ser completo y que el ejercicio físico afecta a todo su conjunto. Este documento, además de recoger dichas contraindicaciones, analiza los aspectos legales que afectan a los profesionales en los que recae la responsabilidad de realizar los reconocimientos y los aspectos documentales que les son propios.

Palabras clave:
Contraindicación. Reconocimiento médico deportivo. Exclusión. Aptitud deportiva. Consenso. Medicina del deporte.

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Introduction

Doing sport in today's society is not only an increasingly widespread fact of great social importance which involves more than half of the Spanish population, but it is also strongly recommended by the health authorities and scientific societies as a tool to combat sedentary lifestyles and chronic disease[1-3]. However, it is necessary to do sport in safe conditions to avoid the associated risks and make it as satisfactory as possible. There are risks inherent in sport that are difficult to avoid, such as those arising from accidents or overloading. However, it is possible to prevent many cases of sudden death (SD) or problems which are a consequence of medical conditions, alterations or diseases the athlete suffers. Pre-participation physical evaluations (PPE) serve to prevent these risks[4].

Proper medical evaluations detect conditions which, in some cases, may constitute some kind of risk for the athlete. Hence the concept of suitability for sports activity, that is, the criterion which, after carrying out a medical examination which, in this case, is called a pre-participation physical evaluation, determines the suitability of the athlete or his or her unsuitability for medical reasons.

Determining unsuitability for sports activity means that it is necessary to set objective, established criteria to create a catalogue of contraindications so that decisions do not have to be based solely on the doctor's own criteria. Although, ultimately, it is the doctor who assumes the responsibility of authorising sports activity, there needs to be a document on which the doctor confirming the athlete's eligibility can base him or herself to establish this criterion.

The Spanish Society of Sports Medicine (SEMED) took on the task of drafting a consensus document on contraindications to sports participation in 2018[5]. This document was ground-breaking, because it included contraindications concerning systems which went beyond the cardiological systems which have commonly been used.

The development of knowledge and experience has made it necessary to write up a new consensus document of contraindications to sports participation which contains two significant modifications with respect to the previous one. Firstly, the contraindications by systems other than the cardiovascular system have been thoroughly revised and, secondly, the cardiovascular contraindications have been significantly readdressed in such a way that contraindications for conditions according to the cardiovascular demands that sport places on each athlete evaluated are included.

The aim of this document is to serve as a useful guide for the doctor who has to make the decision about the sports participation of people with some type of condition discovered in their pre-participation physical evaluation or previously known.

Although the fundamental purpose of pre-participation physical evaluations is to prevent SD, hence the significant content in the document on cardiovascular contraindications[6], given that the athlete constitutes a unit of organs and systems, and sports activity affects the entire body, it also covers diseases relevant to other systems which can be significantly affected by physical exercise in order to avoid aggravation or decompensation.

Despite the fact that this document is intended to address recommended contraindications to competitive sport (federated athletes of any level, including school and university), it should not be forgotten that many amateur athletes, outside regulated competition, do similar and sometimes even more intense training and engage in their sport with a highly competitive spirit. In this sense, and always at the discretion of the most responsible doctor, these recommendations also apply to this type of athlete and other physically active people. Therefore, it is possible to selectively apply the principles contained in this document to certain sports activities that do not meet the exact definition of 'competitive', although always bearing in mind that excessive and unnecessary restrictions can lead to physical and psychological problems (especially in childhood)[7].

Although the document focuses mainly on contraindication standards for competitive athletes, especially federated ones, these guidelines may also be useful for physically active people in other circumstances, for example, police officers, firefighters and pilots[8], as well as those who take part in certain recreational sports activities and other physically active people.

Some of the criteria used are based on the opinion and experience of the authors of the document, and some are based on solid scientific evidence, but many others are presented in the knowledge that there is a lack of experience in the subject and that further studies are needed which should be taken into account in future editions of the document. In all events, it is a guide that should be used in the context of each medical condition and each specific patient, and it is up to the doctor to make the most appropriate decision in each case.

The indications and contraindications included in this guide provide decision support for sports doctors, who must reach their conclusions on the basis of the clinical data provided by the athlete or the clinical tests carried out. In no way should they replace correct clinical criteria based on the experience of the doctor and an appropriate, personalised medical act for the athlete or patient and the special circumstances at play in each situation.

Definitions

There now follows a list of exact definitions of some of the terms used in this consensus.

Competitive athlete. An athlete who participates in an organised team or individual sport which requires regular competition against others as a core component, attaches great importance to excellence and achievement, and requires some form of systematic and generally intense training[9].

Pre-participation physical evaluation[4]. An evaluation or examination carried out by a doctor on an athlete in order to determine if the latter is eligible for sports activity or if such activity is contraindicated for them.

Contraindications to sports participation[4]. Indicating that sports activity can, in certain cases, be harmful. Such contraindications establish the existence of a state or condition, especially pathological ones, which render sports inappropriate or dangerous. The diagnosis of any contraindication leads to recommending the limitation or impossibility of doing sport, and denying, where appropriate, the issuance of the relevant sports licence.

Medical certificate[10]. Written statement from a doctor attesting to a person's state of health at any given time.

Most responsible doctor[10]. Professional in charge of coordinating the information and health care of the patient or user, acting as their main contact in everything related to attention and information during the healthcare process, without prejudice to the obligations of other professionals who participate in the actions.

Patient[10]. A person who requires health care and is subject to professional care for the maintenance or recovery of their health.

User[10]. Person who uses health education and promotion, disease prevention and medical information services.

Medical-legal considerations

From the recognition of the right to health protection and the responsibility of the public authorities to organise and protect public health through preventive measures, among other things, as indicated in the Spanish Constitution[11], stem various rules to develop application.

The General Health Act[12] regulates all those actions aimed to fulfil the right to health protection for all Spaniards and foreign citizens who have established their residence in the country. The General Public Health Act[13] addresses the preventive aspect and health protection and promotion, regulating ways to encourage, protect and promote people's health, including physical exercise.

The Health Protection Act[14] establishes a framework for health prevention in the field of sports of general application, understanding as 'health protection in the field of sport the set of actions that the Public Authorities demand, drive or carry out, according to their respective fields of competence, to ensure that sports are performed in the best conditions for the health of athletes and to prevent any harmful consequences which may arise as a result of sports activity, especially in top-level sport'.

The law includes, as a specific minimum measure to protect the health of athletes, the performance of medical evaluations prior to the issuance of federation licenses in those sports where it is considered necessary to better prevent risks to the health of the athletes involved.

The priority objective of pre-participation physical evaluations is not only to reduce the incidence of SD in athletes but also to prevent health problems and, clearly, to determine the absolute or relative, permanent or temporary medical contraindications to sports participation, barring those individuals who are at risk[4].

It is, therefore, essential to know which conditions can affect, to a greater or lesser extent, the health of an athlete and establish the applicable contraindications.

Because cardiovascular disease is the most important cause of SD in athletes[15,16], there is a large body of work establishing cardiovascular contraindications to sports participation[17-30].

There is much less literature available regarding the other diseases and conditions which should be taken into consideration from the health protection perspective[18,31-37].

From a medical point of view, it is important to have a suitable guide covering contraindications of all kinds and that such a guide is, as a matter of course, revised according to the knowledge gained of the repercussions that sport and physical exercise can have on the health of athletes. Furthermore, and by no means less importantly, this guide should serve to support medical decisions regarding the specification of contraindications from a legal and judicial point of view, as indicated in the system of physical evaluations proposed by the Higher Sports Council[18,31].

Athletes, as individuals with health-related rights, have a series of rights safeguarded by law aimed at protecting their health both as patients, when they suffer a pathological process which requires health care, and as users, when they need health services aimed at prevention. These include the right to information about their health endorsed by the most responsible doctor[10].

Therefore, the doctor, within his/her obligations to play an active role to benefit the health and well-being of people in health and disease situations, especially in the field of prevention[38] and information, must warn them of the relevant or significant consequences and risks of, and contraindications to sports participation.

The professionals who decide contraindications

The contraindication to sports participation must be made by a doctor who has the appropriate knowledge, experience and responsibility. It is clear that the professionals with these characteristics are doctors who specialise in Physical Education and Sports Medicine. However, other doctors may point out contraindications if they meet the indicated requirements.

To issue the decision of participation or contraindication of any kind, the doctor should use as a guide the classic sports classification39 (Appendix 1), based on the varying intensities of dynamic and static demands (low, medium, high), the one based on the possibility of contact or risk of body collision (Appendix 2) and the risk to life in the event of syncope (Appendix 3). However, it should be remembered that the demands of training and competition can vary between sports and also within the same sport, that the intensity of training can be greater than that of competition and that different levels of physical activity can affect underlying (and unsuspected) cardiovascular diseases and other diseases unpredictably and in different ways. Furthermore, it is difficult to accurately evaluate or take into account exercise intensity in several sports due to a variety of factors, particularly motivational attitudes.

Sports participation recommendations or decisions should be based on probable or confirmed diagnostic tests and not involve ambiguous, possible or dubitable diagnoses.

In many cases it is necessary to consult a specialist in a specific area, with whose help the most responsible doctor makes the contraindication or who establishes it him/herself.

The importance of establishing a contraindication, especially an absolute contraindication, calls for the exercise of great responsibility by the doctor who makes it, who must spare no effort to make the decision in the most objective and appropriate way, based on the criteria described in this document.

Justification for the consensus

The Spanish Society of Sports Medicine adopted various initiatives as a means of preventing SD and protecting the health of athletes, including the recently published consensus document on pre-participation physical evaluations[4].

One possible consequence of health research, even when focussing on athletes, is the discovery of alterations, conditions or diseases which imply a declaration of unfitness for sports participation. This implies the existence of some type of contraindication to sports participation. When the consensus document on evaluations was drafted, the need to create a list of contraindications was recognised and it was decided that they should be independent documents so that they would not be so difficult to handle and could be updated separately when required.

The justification for this consensus document, an update of the previously published document[5], is the establishment of a guide to help the most responsible doctor make the appropriate decisions on participation in or contraindication to sports and to serve as legal protection, insofar as possible, for decision-making in their professional practice. This new consensus includes an update on all the conditions reviewed in the previous one with the modifications discussed above.

Documentation

The performance of a pre-participation physical evaluation should lead to two types of documents[4]: a medical report and a PPE report.

Medical report

Confidential report for the athlete only (or his/her father, mother, guardian or legal representative if he/she is a minor), it should be handed over personally. It should include:

- Personal details of the athlete.
- Sports details.
- Description of tests carried out and protocols applied.
- Results obtained in these tests.
- Evaluation of the results.
- Copy of the PPE report.
- Documentation on the contraindications in the PPE report (cause, future requirements to lift a contraindication, any necessary complementary studies or reports which need to be provided).
- Other contraindications other than those of the sport and speciality requested.
- Medical-sports advice for the participation in his/her sport in the best conditions of health and safety.

Any other information that the doctor wishes to give the athlete.

PPE report

Document to be submitted by the interested party to the relevant sports federation or requesting entity. This report will only express:

- Degree of fitness for sport, indicating very briefly:
  - Eligibility for the specific sport and speciality in question.
  - Existing contraindications to the specific sport and the speciality in question (stating whether these are definitive or temporary, and in the latter case the expected period of contraindication).
- Time for the next sports medical (SM), which by default is 2 years, but may be shortened by the doctor performing the medical.

This document should avoid including all types of medical information: diagnosis, complementary studies, advice, treatments, etc.

Contraindications to sports participation

The following types of contraindications exist:

- Absolute and definitive: definitive contraindication to participation in any sport or sport modality.
- Absolute and temporary: temporary contraindication to participation in any sport or sport modality. In this case, the period of contraindication or requirements for the contraindication to be lifted in the future should be specified in the final SM report. The period of contraindication should also be reflected in the PPE report.
- Relative and definitive: definitive contraindication to participation in a specific sport or modality. In this case, the contraindicated sports or modalities should be specified in the final sports medical (SM) report and on the fitness for sports certificate (FSC).
- Relative and temporary: temporary contraindication to participation in a specific sport or modality. In this case, both the contraindicated sports or modalities should be specified, together with the period of contraindication, (all in the final SM report and on the FSC), or the requirements for the contraindication to be lifted in the future (only in the final SM report).

Below are the contraindications to sports participation. Cardiovascular contraindications are discussed in various sections because there is a lot of experience in the subject and documentation on them, and they require more extensive treatment.

There are significant descriptions of other contraindications by systems after that.

Cardiovascular contraindications

General note on the use of the cardiovascular contraindications table.

The tables of contraindications presented below provide an adequate and reasonable guide for decision-making regarding the declaration of fitness to do a sport, complementing and guiding the good judgment and reasoned clinical judgment of the examining doctor.

A colour system has been used to more easily identify eligibility under each condition (Table 1).

Valvular heart disease

The incidence of valvular disease is still relevant due to non-rheumatic degenerative aetiologies and congenital valvular diseases[40]. In these diseases, exertion acts as a trigger and limiting factor for many of the symptoms, so it is important to define the criteria for sports activity and its contraindication[19,20]. Symptomatology is very helpful in deciding the management of these patients and four stages of valvular disease have been defined which can be useful in establishing recommendations and limitations on sports participation[39].

- Stage A: asymptomatic patients at risk of developing valvular stenosis or major valvular insufficiency. These patients have symptoms typical of their condition, such as murmurs, but do not have a malfunctioning valve.
- Stage B: asymptomatic patients with mild or moderate valvular disease and normal left systolic ventricular function.
- Stage C: asymptomatic patients with severe valvular disease, with evidence of preserved systolic ventricular function (stage C1) or left ventricular dysfunction (C2).
- Stage D: symptomatic patients with severe valvular disease, with or without left ventricular dysfunction.

This classification is of interest from the point of view of contraindications because patients in stages A, B and C, while asymptomatic, can participate in physical and sports activity, while those in stage D, symptomatic, cannot do so and must receive surgical treatment.

Table 2 describes the contraindications for valvular diseases and their degrees of application.

Table 1. Eligibility indication classes: for the sport or sports speciality evaluated for competitive activity in a federation context.

Class	Colour	Description	Details
RED	R	INELIGIBLE	Cardiovascular demand is evaluated taking into account the dynamic and static component of the sport/speciality evaluated, together with the exercise associated with training and physical preparation in terms of intensity, duration and type. Likewise, the load that the competitive component implies for the subject in the sport and, possibly, in the evaluation test.
ORANGE	O	ELIGIBLE for sports with low cardiovascular demand	
YELLOW	Y	ELIGIBLE for sports with up to moderate cardiovascular demand	
GREEN	G	ELIGIBLE	

Table 2. Cardiovascular contraindications. Valvular heart diseases[17-20, 42,43].

Condition	Level of severity	Details	Class	Follow-up needed
Aortic valve stenosis	Severe	With or without symptoms Group selected with EF >50%	R	SI or 6 months
	Moderate	WITH marker of severity: - EF<50% LV ejection fraction - Stress test with symptoms, poor FC or lowering BP - ARR complex ventricular arrhythmia	O	Referral for evaluation by HT
		NO marker of severity	G	1 year
	Mild	NO symptoms	G	1 year
	Bicuspid	NO severe stenosis and NO aortic dilatation	G	1 year

(continued)

Table 2. Cardiovascular contraindications. Valvular heart diseases17-20, 42,43 (continuation).

Condition	Level of severity	Details	Class	Follow-up needed
Aortic insufficiency	Severe	With symptoms	R	SI
		NO symptoms + WITH marker of severity - EF≤50% LV ejection fraction - LVESV >25 mm/m² or LVESD >50 mm - ARR complex ventricular arrhythmia - Abnormal stress test	R	SI
		NO symptoms + NO marker of severity	G	6 months
	Moderate	WITH marker of severity:	Y	6 months
		NO marker of severity	G	1 year
	Mild.		G	
Mitral stenosis	Severe		R	
	Moderate	WITH pulmonary hypertension PAPs >40 mm Hg (rest/exercise)	R	
		WITHOUT pulmonary hypertension PAPs <40 mm Hg and without symptoms (rest/exercise)	O	1 year
	Mild.	WITHOUT pulmonary hypertension PAPs <40 mm Hg (rest/exercise)	G	
Mitral insufficiency	Severe	WITH symptoms	R	
		NO symptoms + WITH marker of severity - EF <60% LV ejection fraction - LVEDD ≥60 mm, LVEDV ≥35.3 mm/m² H, ≥40 mm/m² M. - Abnormal stress test - PAPs at rest ≥50 mmHg	R	
		NO symptoms + NO marker of severity	O	6 months
	Moderate	WITH symptoms	R	
		NO symptoms + WITH marker of severity - EF <60% LV ejection fraction - LVEDD ≥60 mm, LVEDV ≥35.3 mm/m² H, ≥40 mm/m² M. - Abnormal stress test - PAPs at rest ≥50 mmHg	R	
		NO symptoms + NO marker of severity	G	6 months
	Mild.		G	1 year
Mitral valve prolapse		Reference will be made to the MI presented by the person evaluated		
Tricuspid stenosis	Moderate-severe	WITH symptoms, IVC dilatation without respiratory variation, severe dilatation of the right atrium	R	6 months
		NO symptoms	O	6 months
	Mild (mean gradient <5 mm Hg)	NO symptoms	G	1 year
Tricuspid insufficiency	Severe	WITH pulmonary hypertension and RA Pressure >20 mmHg	R	
		WITH pulmonary hypertension and (rest/exercise) >50 mmHg	O	6 months
		NO pulmonary hypertension	Y	6 months
	Mild-Moderate	NO pulmonary hypertension and normal RV	G	1 year
Multivalve		At least the most severe of the valve heart diseases or at least the one that involves the highest degree limitation for fitness in this case will be evaluated. Evaluate exercise echocardiogram		
Anticoagulated		For sports with RISK OF FALLING, CONTACT, COLLISION	R	
Heart transplants			O	1 year

Congenital heart diseases

All the great advances in knowledge and treatment of congenital heart diseases have led to an improvement in the physical condition of children with heart disease, allowing them to perform a greater number of physical activities, including participation in sport[44].

Recommendations on the participation of patients with heart disease in physical or sports activities are difficult due to the difficulties in quantifying myocardial exertion during exercise, which depends on the type of activity and the congenital heart disease involved[19,20].

In congenital heart disease, it is important to take into account its severity and possible symptoms, and evaluate the functional situation through a stress test (ST). In general, in most cases some type of exercise is allowed, although contraindications and recommendations must be established on an individual basis.

Table 3 describes the contraindications for congenital heart diseases and their degrees of application.

Table 3. Cardiovascular contraindications. Congenital heart diseases[18,21,45-48].

Condition	Level of severity	Details	Class	Follow-up needed
ASD VSD APVD PDA following closure of any defect Avoid underwater diving pre-closure, avoid high altitudes with pulmonary hypertension or cyanosis	Symptoms (syncope, chest pain, palpitations, dyspnoea) or any of the following 1. RV dysfunction (for ASD and APVD) or with LV dysfunction (for VSD or PDA) EF <45% 2. Tricuspid insufficiency >3.5 m/s suspected (right catheterisation PAP m >20 mm Hg or PVR >3 wu) 3. Dilation of aorta 4. Arrhythmias: Uncontrolled AF or AFL, ventricular ARR, NSVT, PVC with exercise, or AVB2 or AVB3 5. Baseline or exercise desaturation (<95%)		R	Evaluate treatment and 3-6 months after closure
	Only mild RV or LV dysfunction EF 45-50%		O	6 months
	Only tricuspid insufficiency 2.8-3.5 m/s and no RV dysfunction (for ASD and AVDP) or LV (for VSD or PDA) with right catheterization PAP >20 mmHg or PVR (pulmonary vascular resistance) >3 WU (Wood Units)		Y	6 months
	Only controlled atrial arrhythmias (AF or AFL), or only PVC >500 h/24 h, doublets that disappear with exercise		Y	6 months
	All normal (No symptoms or arrhythmias, TrI < 2.8m/s and no RV (for ASD and AVDP) or VI dysfunction (for VSD or PDA))		G	1 year
AV canal repaired	Same as ASD, AVDP, VSD or PDA, and depending on residual valve injury (MI or MS, TI or TS), see valvular heart diseases		G	
Right ventricular outflow tract obstruction	Severe	Severe: Transpulmonary gradient >60 mm Hg, or maximum velocity >4 m/s (severe)	R	6 months (if moderate TI progression, RV dysfunction, R-L shunt or SI symptoms)
	Moderate	Moderate: Transpulmonary gradient 40-60 mmHg or maximum velocity 3-4 m/s	O	6 months
	Mild.	Transpulmonary gradient <40 mm Hg or maximum velocity <3 m/s	G	1 year
Tetralogy of Fallot Rule out fibrosis with NMR, and if risk criteria for sudden death, perform EPS	Symptoms: Syncope or palpitations or any of the following 1. RV or LV dysfunction with EF <45% or severe RV dilatation (>160 ml/m^2) with severe PI 2. Right ventricular hypertension (>50% of systemic pressure) 3. Severe ascending aortopathy >50 mm 4. Uncontrolled atrial or ventricular arrhythmia, QRS ≥180 msec, fractionated QRS, QT scatter, extensive fibrosis in NMR, NSVT on Holter or VT induction in EPS. 5. Baseline or exercise desaturation <90% Other risk criteria: long-lasting palliative shunts, repair at older age, LV end-diastolic pressure >12 mm Hg, coronary anomalies		R	Evaluate treatment
	Only one of the following: - Severe pulmonary insufficiency with slightly dilated RV and RV EF >55% - Moderate RVOT obstruction - Aorta 45-50 mm - Baseline or exercise desaturation 90-95%		O	6 months
	Only one of the following: - RV or LV EF 45-50% - Moderate pulmonary insufficiency. - Aorta 40-45 mm - Controlled atrial or ventricular arrhythmia		Y	1 year

(continued)

Table 3. Cardiovascular contraindications. Congenital heart diseases[18,21,45-48] (continuation).

Condition	Level of severity / Details	Class	Follow-up needed
Tetralogy of Fallot Rule out fibrosis with NMR, and if risk criteria for sudden death, perform EPS	Asymptomatic and without risk criteria: 1. LV and RV EF >50% and RV size normal or slightly increased or mild PI 2. No or mild RVOT obstruction 3. No aortopathy. Aorta <40 mm 4. No arrhythmia on Holter, normal stress test and no significant fibrosis in NMR. 5. Baseline or exercise desaturation Sat O2 >95%	G	1 year
Cyanotic heart disease without surgery	Symptomatic for cardiac insufficiency	R	
	Asymptomatic. Sat O2 90-95% without risk criteria	O	
Transposition of the great arteries, atrial switch procedure (Mustard and Senning: DO not do sports with high static component (III)) or congenitally corrected	Risk criteria: 1. Systemic RV EF <40-45% 2. Right ventricular hypertension (>50% of systemic pressure) 3. Severe ascending aortopathy >50 mm 4. Recurrent or uncontrolled atrial or ventricular arrhythmia, VT on Holter or stress test or significant fibrosis in NMR. 5. Sat O2 <90% Other risk criteria: Previous VSD, QRS >180 msec, fractionated QRS, CI, ischaemia, coronary abnormalities.	R	
	Atrial switch: No risk criteria and normal stress test	O	
	CCTGA : No risk criteria and normal stress test	O	
Operated transposition of great arteries (anatomical correction – Jatene arterial switch) Coronary CT angiography: Rule out coronary stenosis or angulation	Only one of the following: - Myocardial ischaemia in stress - Ventricular dysfunction EF <45% - Severe neo-aortic insufficiency with dilated LV and LV EF <55% - Severe pulmonary stenosis	R	
	Only one of the following: - Severe neo-aortic insufficiency with dilated LV and LV EF >55% - Moderate pulmonary stenosis	O	
	Only one of the following: - Moderate-severe neo-aortic insufficiency. - Mild ventricular dysfunction EF 45-50% with normal stress test	Y	
	Asymptomatic. Mild neo-aortic insufficiency, mild pulmonary stenosis 1. LV and RV EF >50% 2. No or mild RVOT obstruction 3. No aortopathy. 4. No arrhythmia on Holter, normal stress test 5. No residual short circuit	G	
Total cavo-pulmonary shunt – Fontan rocedure	Symptoms of CI or risk criteria	R	6 months
	Asymptomatic for cardiac insufficiency and without risk criteria: 1. LV and RV EF >50% 2. No or mild RVOT obstruction 3. No aortopathy. 4. No arrhythmia on Holter, normal stress test 5. No residual short circuit Sat O2 >95% Normal stress test (no ischaemia or arrhythmias or arterial hypotension)	O	6 months
Ebstein's anomaly	Severe TI with symptoms or any of the following: 1. Moderate-severe RV and/or LV dysfunction EF <45% or RV moderately-severely dilated 2. Right ventricular hypertension (>50% of systemic pressure) 3. Dilation of aorta >50 mm 4. Uncontrolled atrial arrhythmias or malignant ventricular arrhythmias 5. Baseline or exercise desaturation <90%	R	Evaluate treatment
	Severe TI with only mild RV and/or LV dysfunction EF 45-55% and non-significant or non-malignant arrhythmias (infrequent isolated PVCs) Severe tricuspid insufficiency with mildly dilated RV and RV EF >55%	O	Evaluate treatment (stress test with gas and proBNP)

(continued)

Tabla 3. Contraindicaciones cardiovasculares. Cardiopatías congénitas[18,21,45-48] (continuation)

Condition	Level of severity / Details	Class	Follow-up needed
	Mild, moderate, severe TI without symptoms 1. No RV and/or LV dysfunction, with RV not dilated 2. No arterial hypertension 3. No dilation of aorta 4. No arrhythmias 5. No baseline or exercise desaturation	G	
Untreated coarctation of the aorta (avoid isometric exercise)	1. Aortic dilatation score ≤3.0 2. Systolic blood pressure gradient between right upper and lower limbs < 20 mm Hg 3. Systolic blood pressure peak <95th percentile predictable by age (stress test with BP <220 in men and <200 mm Hg, in women)	G	1 year
	Exceed any of the 3 items above	R	6 months
Coarctation of the aorta treated with stenting or surgical repair (avoid isometric exercise)	After 3 months when all these points are presented: 1. Aortic dilatation z score ≤3.0 2. Systolic blood pressure gradient between right upper and lower limbs <20 mm Hg 3. Peak systolic blood pressure <95th percentile predictable by age 4. No aneurysm associated with the coarctation 5. No aortic valvular disease that contraindicates it N.B. Evaluate association with bicuspid valve which could be [Y]	G	1 year
	Aortic dilatation z score >3 With aneurysm associated with the coarctation N.B. Evaluate association with bicuspid valve which could be [O]	Y	6 months
Turner syndrome	ASI >25 mm/m^2	R	Evaluate SI (bicuspid, elongated transverse aortic arch, CoA , and/or arterial hypertension)
	ASI (aortic size index) 20-25 mm/m^2	O	6 months
	Non-dilated aorta	G	1 year
Anomalous origin of coronary arteries	Course between aorta-pulmonary and origin with acute angle (particularly common trunk from right coronary sinus), including incidental detection and other coronary anomalies with symptoms (angina, or syncope or sudden death) or exercise echocardiogram positive for ischaemia or arrhythmias	R	Evaluate SI
	Coronary artery from the pulmonary artery (except when previous infarction or pending surgery) with rest normal RC from left coronary sinus with rest normal, individualise	O	1 year
	No previous criteria 3 months after successful SI without ischaemia or arrhythmias	G	1 year

Myocardial and pericardial diseases

Myocardial diseases have a high probability of causing SD, especially hypertrophic cardiomyopathy, the most frequent cause of SD in young athletes in the United States15 and the second most frequent in Spain[16].

Table 4 describes the contraindications for myocardial diseases and their degrees of application.

Arrhythmias and conduction disorders

A wide range of heart rates and rhythms, specific arrhythmias and atrioventricular and intraventricular conduction disorders can be observed in athletes.

Arrhythmias and cardiac conduction disorders should be considered in a global context when they are discovered in an athlete due to the important relationships between physical exercise and the cardiovascular system.

In general, arrhythmias can be classified as benign, paraphysiological or malignant[19,20].

They are considered benign when they do not present an arrhythmogenic substrate, do not have haemodynamic consequences when they appear during sports activity and do not constitute a vital risk for the athlete. The hypoactive arrhythmias typical of athletes are called paraphysiological arrhythmias (sinus bradycardia, wandering pacemaker, type I second degree atrioventricular block, junctional rhythms, etc.), which appear mainly during situations of vagal predominance and usually disappear with exertion, physical activity and emotions. Finally, arrhythmias with serious haemodynamic consequences during physical activity are considered malignant, can put the athlete's life at risk and are indicative of arrhythmogenic heart disease.

Table 5 describes the contraindications for arrhythmias and cardiac conduction disorders, and their degrees of application

Table 4. Cardiovascular contraindications. Myocardial and pericardial diseases[18-22].

Condition	Level of severity	Details	Class	Follow-up needed
Pericarditis	Acute	Until full resolution of signs and symptoms	R	Temporary until control
	Recurrent	Until full resolution of signs and symptoms	R	Temporary until control
		NO marker of severity	G	1 year
	Chronic constrictive		O	1 year
	Chronic pericardial effusion	MODERATE or SEVERE or WITH haemodynamic impact	R	
		MILD or MODERATE or SEVERE and WITHOUT haemodynamic impact	G	
Myocarditis (Myopericarditis)	Acute	Until end of acute symptoms	R	
	3 months after acute symptoms	NO symptoms or marker of severity - LV dysfunction of any kind - Persistent pericardial effusion - ARR complex (ventricular) arrhythmia - ECG not normalised	R	3 months
		NO symptoms + NO marker of severity	G	
Hypertrophic cardiomyopathy	Reasons for suspicion	- Certain family history of hypertrophic cardiomyopathy - Syncopes (with no identified cause) - Unexplained chest pain - Palpitations - ECG with indicative or suspicious alterations		Referral to specialised HT evaluation
	1 or more criteria...	- Syncope studied and with no identified cause - ARR complex ventricular arrhythmia - LVH severe ventricular hypertrophy, with tissue confirmation of risk - Intolerance or poor haemodynamic response to exercise - Presence of any mutation involving risk	R	
	If the subject only meets one of the above criteria, and NOT severely, and only in sports that do not pose a personal risk to the athlete or to third parties		G	6 months (failure to pass is cause for non-fitness)
Dilated cardiomyopathy	1 or more criteria...	- EF <50% LV ejection fraction - LV end-systolic diameter >35mm/m^2 - ARR complex ventricular arrhythmia	R	
	If the subject only meets one of the above criteria, and NOT severely, and only in sports that do not pose a personal risk to the athlete or to third parties		G	6 months (failure to pass is cause for non-fitness)
Arrhythmogenic dysplasia	With correct clinical diagnosis		R	

Table 5. Cardiovascular contraindications. Arrhythmias and conduction disorders[18-22].

Condition	Level of severity	Details	Class	Follow-up needed
Bradyarrhythmia	- Sinus - 1AVB - 2-1 AVB Wenckebach - 2-2 AVB Mobitz	- Asymptomatic at rest and during exercise - No underlying structural disease - With adequate exercise-induced tachycardisation	G	
	- Any bradyarrhythmia: symptomatic, with structural disease, with poor tachycardisation - High grade 2AVB - 3AVB - High grade sinoatrial block		R	Until appropriate treatment
Bundle branch block or fascicular block	Incomplete RBBB to QRS <120ms		G	
	- RBBB QRS >120 ms, LBBB, AFB , PFB - Any combination of branch blocks		R	Until heart disease is ruled out

(continued)

Table 5. Cardiovascular contraindications. Arrhythmias and conduction disorders[18-22] (continuation).

Condition	Level of severity	Details		Class	Follow-up needed
Ventricular extrasystole	-- No heart disease - No channelopathy - Non-exercise induced			G	Once heart disease is ruled out
	- Severe/complex - Exercise induced			R	Until heart disease is ruled out
	N.B. The degree of fitness will depend on the underlying heart disease, if discovered				
Atrial fibrillation	WITH structural disease		Refer to underlying structural heart disease		
	NO disease	Adrenergic	Exercise-induced AF in young athlete	R	Until diagnosis
		Others	With poor HR control with exercise	Y	
			With good HR control with exercise	G	
		N.B. The limitation induced by possible anticoagulation must be evaluated *(vide retro)*			
Atrial flutter				R	Diagnosis and treatment
Supraventricular tachycardia	Due to nodal re-entry	Detected or symptomatic	Until electrophysiological study (EPS) and successful ablation (ABL) after that: [G], other heart disease ruled out	R	
		Asymptomatic	Chance finding Commitment to electrophysio-logical study/ ablation within 6 months, which if it not done will lead to loss of eligibility for the specific sport	G	Before 6m: EPS/ABL or... INELIGIBILITY
Channelopathies	Properly defined with genotype and phenotype	Brugada Syndrome	WITH increased repolarisation alterations typical with/after exercise, or extreme endurance sports or high ambient temperature risk	R	
			NO previous data	G	
		Catecholamine-induced VT		R	
		Prolonged QT		R	
	Other channelopathies: there are no data at present to be able to provide adequate information in athletes				
Ventricular tachycardia	NO underlying heart disease	Until effective treatment		R	
		AFTER treatment		G	
	WITH structural heart disease			R	
Pre-excitation	Pre-excitation NO demonstrable or inducible SVTs and no risk criteria (fast AV conduction pathway) in electrophysiological study			G	
	WITH demonstrable or inducible SVTs and with risk criteria (fast AV conduction pathway) in electrophysiological study			R	Until solution of pre-excitation by ablation
Implanted devices	AID or PPM	NO underlying heart disease	EXCEPT: [R], for contact sports, with risk of collision, integrity hazard for the device, cables, or athlete	G	
		WITH structural heart disease	Evaluation of underlying structural heart disease		
Syncope	Related to physical exercise (with, during or after)			R	Until diagnosis and treatment
	Unrelated to physical exercise	EXCEPT: [R], for sports with integrity hazards for the		G	
		athlete or third parties		G	

Arterial Hypertension

High blood pressure (HBP) is the most prevalent cardiovascular disease in the general population, and the most common cardiovascular risk factor. Although it fundamentally affects the middle-aged and elderly population, it is estimated that in Spain 35% of adults have blood pressure (BP) figures ≥140/90 mmHg[49] and in the United States of America 11.6% of subjects aged 20-39 years have high BP figures and 11.0% of children and adolescents aged 8 to 17 years old have HBP (systolic BP [SBP] or diastolic BP [DBP] in the 95th percentile or higher) or borderline HBP (SBP or DBP in the 90-95th percentile, or BP of 120/80 mmHg or higher, but below the 95th percentile[50]). This means that a significant number of people, even very young people, have high blood pressure.

Although HBP has been associated with an increased risk of complex ventricular arrhythmias and SD, this cardiovascular risk factor per se has not been indicated as a cause of SD in young athletes[51]. Furthermore, certain types of physical activity cause BP to decrease, also occurring in hypertensive patients[52], so sports can be beneficial when suffering from this condition.

Table 6 describes the contraindications for arterial hypertension and their degrees of application.

Aortic diseases – Marfan syndrome

Several aortic conditions, such as aortic dissection or rupture in Marfan syndrome, are important causes of SD in athletes[15]. The increase in BP and strain on the aorta during exertion cause an enormous risk of rupture, dissection or acceleration of an aneurysm formation in the first sections of the artery[25].

Given the small number of patients with these conditions, there is not a lot of experience in their participation in physical and sports activity, and although active lifestyles should be favoured to improve health and avoid the stigmatisation of these patients at young ages, we must bear in mind the great risk they present of suffering catastrophic incidents.

Table 7 describes the contraindications for aortic diseases and Marfan syndrome, and their degrees of application.

Table 6. Cardiovascular contraindications. Arterial hypertension[18,24,27].

Condition	Level of severity	Details	Class	Follow-up needed
Systemic arterial hypertension.	Untreated	With baseline values of >180 and/or >110 mmHg	R	
	Controlled	With extreme response to physical exercise: ≥230 mmHg SBP and ≥110 mmHg DBP	O	Temporary until control
		With adequate response to physical exercise:	G	
	N.B. In sports with high isometric upper body demands, the BP evaluation must be performed on an individual basis			

Table 7. Cardiovascular contraindications. Aortic diseases and Marfan syndrome[25,53].

Condition	Level of severity	Details	Class	Follow-up needed
Bicuspid valve	See AORTIC VALVE STENOSIS or AORTIC INSUFFICIENCY			
	Dilation Evaluate with echocardiogram and CT angiography or NMR angiography	≥55 mm	R	SI
		≥50 mm or if there are risk factors: - SI - Family history of aortic dissection - Pregnancy desired - HBP - Growth of >3 mm/year	R	
		≥45-50 mm or Z-score ≥4	O	6 months
		≥40-45 mm or Z–score 3-4	Y	6 months
		≥35-40 or Z-score 2-3	G	1 year
		≤35	G	1 year
	After successful aortic surgery		Y	1 year
	N.B. In SPORTS with HIGH ISOMETRIC UPPER BODY DEMANDS (power sports, car racing), the evaluation must be performed individually if the aorta is ≥40-45 mm or Z–score 3-4. Non-contact sports if ≥45-50 mm or Z-score ≥4			
Marfan Syndrome	Dilation of aorta	45-50 mm o Z-score ≥4	R	If risk factors or >50: SI
		40-45 mm o Z-score 3-4	R	
	Mitral or aortic valve heart disease	Severe to moderate grade	R	
	Well-defined MARFAN WITHOUT EITHER of the above two components		Y	6 months
	After successful aortic surgery		O	6 months
	N.B. Evaluate the risk of valve or isthmic rupture, or dissection in contact sports, avoid competition, contact and isometric exercise			

Ischaemic heart disease

Ischaemic heart disease (atherosclerotic coronary artery disease) is the leading cause of SD[16,51] and myocardial infarction in adult athletes[54]. Although physical exercise performed for health purposes (low-moderate intensity) is highly beneficial and facilitates the prevention of coronary episodes[55], it is unquestionable that intense exercise, performed in an acute and transient manner, increases the risk of triggering SD or a myocardial infarction even in apparently healthy people[55].

Table 8 describes the contraindications for ischaemic heart disease and their degrees of application.

Table 8. Cardiovascular contraindications. Ischaemic heart disease[18,26,27].

Condition	Level of severity	Details	Class	Follow-up needed
Ischaemic heart disease	Severe or unstable	- Acute Coronary Syndrome, before at least 1 month has passed - ECHO Ejection fraction <50% - At least 1 coronary lesion with at least 70% ischaemic obstruction Ischaemia with exercise - ARR complex/severe arrhythmia in stress	R	
	Chronic	Revascularisation (by any procedure) without severe ischaemia or ARR with exercise	G	
		Coronary heart disease without severe lesions, or without severe ischaemia or ARR with exercise	G	
	Other situations	Muscle bridging or milking with good response to medical treatment, without associated ARR	Y	
		Coronary spasm	Y	
		Coronary microvascular disease	Y	

Supplementary note common to the tables of contraindications and limitations on sports eligibility

In the event of conditions or clinical situations not covered in the foregoing tables, the athlete should be referred to a centre or professional specialised in cardiology, from which/whom a reasoned report should be obtained on the suitability of the athlete for participation in the specific sport or speciality for which the evaluation is required. The eligibility of the athlete will be determined in consideration this report.

The abbreviations, initials and acronyms used in the cardiovascular contraindications are described in Table 9.

Table 9. Initials / abbreviations / acronyms.

Initials	Explanation
ABL	Ablation in electrophysiological study of the mechanisms responsible for arrhythmia
ARR	Arrhythmia (usually severe, complex, progressive with exercise) (usually ventricular)
ASI	Aortic size index
1-2-3AVB	1st-, 2nd-, 3rd-degree atrioventricular block
BNP (proBNP)	(N-terminal fragment) of brain (pro-) natriuretic peptide
RBBB, LBBB	Right bundle branch block, Left bundle branch block
AFB, PFB	Left anterior or posterior fascicular block
FC	Functional capacity, ability to perform physical activity without symptoms or signs interpretable as representing a medical condition
ASD	Atrial septal defect
APVD	Anomalous pulmonary venous drainage
VSD	Ventricular septal defect
PDA	Patent ductus arteriosus
LVEDD- LVESD	Left ventricular end-diastolic or end-systolic diameters
LVEDV - LVESV	Left ventricular end-diastolic or end-systolic volumes
AS	Aortic valve stenosis
ECG	Resting electrocardiogram (classic12 leads)
EPS	Electrophysiological study
MS	Mitral stenosis
PS	Pulmonary valve stenosis
TS	Tricuspid stenosis
PVC	Premature ventricular contraction
AF	Atrial fibrillation
EF	Ejection fraction (two-dimensional echocardiography, or equivalent and comparable validated method)
AFL	Atrial flutter
HT	Heart team, evaluation by, referral for (re)evaluation
AI	Aortic valve insufficiency/regurgitation
MI	Mitral insufficiency/regurgitation
PI	Pulmonary valve insufficiency/regurgitation
TI	Tricuspid valve insufficiency/regurgitation
SI	Surgical intervention, indication thereof
PAP	Pulmonary artery (systolic) pressure
QT, QTc	ECG QT interval, corrected QT interval (by Bazertt formula)
NMR	Cardiac (nuclear) magnetic resonance
PVR	Pulmonary vascular resistance
SBP	(Systemic) Systolic arterial blood pressure
NSVT	Non-sustained ventricular tachycardia
LV	Left ventricle/ ventricular

Contraindications for respiratory system diseases

Table 10 describes the contraindications for respiratory system diseases and their degrees of application.

Table 10. Contraindications for respiratory system diseases[18-31].

Condition	Level of severity	Contraindication
Asthma	Difficult-to-control asthma	Only participation in low-intensity sports (class IA) is allowed Absolute contraindication to contact sports or with risk of body collision, mountaineering in conditions of environmental hypoxia or at low temperatures. Absolute contraindication to life-threatening sports in the event of syncope
Chronic bronchial conditions	Symptomatic and poorly controlled with treatment	Only participation in low-intensity sports (class IA) is allowed
Respiratory insufficiency	With poor arterial O2 saturation: a) Baseline saturation <90% with normal haemoglobin b) Progressive desaturation with exercise	Only participation in low-intensity sports (class IA) is allowed Absolute contraindication to contact sports or with risk of body collision, underwater diving and mountaineering in conditions of environmental hypoxia or at low temperatures.
Spontaneous pneumothorax	Treated conservatively if there is no reversal	Only participation in low-intensity sports (class IA) is allowed. Absolute contraindication to contact sports or with risk of body collision, underwater diving and mountaineering in conditions of environmental hypoxia or at low temperatures.
	Surgically treated	Temporary absolute contraindication 1 month
	Treated surgically and with recurrence	Absolute contraindication to contact sports or sports with risk of body collision and underwater diving.
Pulmonary thromboembolism	Up to 3 months after resolution of signs and symptoms N.B. See anticoagulant and antiplatelet medication	Temporary absolute contraindication
Interstitial lung disease	Symptomatic and poorly controlled with treatment	Absolute contraindication
Thoracic surgery	Until declared fit	Absolute contraindication to underwater diving

Contraindications for endocrine-metabolic and nutritional diseases

Table 11 describes the contraindications for endocrine-metabolic and nutritional diseases, and their degrees of application.

Table 11. Contraindications for endocrine-metabolic and nutritional diseases[18,56].

Condition	Level of severity	Contraindication
Hyperthyroidism	Not controlled with treatment	Absolute contraindication
Familial hypercholesterolemia	Homozygous variety. Adequately treated, with reasonable cholesterol levels and no evidence of cardiovascular disease	Static, low dynamic intensity sports (class IA) are allowed
	If the above criteria are not met	Absolute contraindication
Obesity	IBMI>40 kg/m^2, until beneath this index	Absolute contraindication
	BMI>35-39,9 kg/m^2, until beneath this index	Only participation in low-intensity sports (class IA) is allowed.
Diabetes mellitus	Poorly controlled with treatment, with blood glucose >250 mg/dl, with frequent hypoglycaemia, difficult to control during exertion, or inability of the patient to control and monitor their blood glucose	Only participation in low-intensity sports (class IA) is allowed. Absolute contraindication to sports that involve driving a vehicle, underwater diving, sailing and mountaineering in cold and hypoxia conditions
Alterations in amino acid and fatty acid metabolism		Relative contraindication. Each case should be individualised, but in general only static intensity and low dynamic sports (classes IA and IB) should be allowed
Alterations of purine and pyrimidine metabolism		Relative contraindication. Each case should be individualised, but in general only static intensity and low dynamic sports (classes IA and IB) should be allowed
Glycogen storage disease and other alterations of carbohydrate metabolism		Relative contraindication. Each case should be individualised, but in general only static intensity and low dynamic sports (classes IA and IB) should be allowed

BMI: body mass index.

Contraindications for infectious diseases

Table 12 describes the contraindications for infectious diseases and their degrees of application.

Table 12. Contraindications for infectious diseases[18,31,57].

Condition	Level of severity	Contraindication
Tuberculosis	Active	Absolute contraindication
Infectious mononucleosis	Until the normalisation of the test markers and the return to normal spleen size is observed	Only participation in low-intensity sports (class IA) is allowed
	With normal blood test results and observation of the return to normal spleen size	Temporary absolute contraindication 1 week more for contact sports or sports with risk of body collision
Acute febrile illness	Until the end of fever and accompanying symptoms	Temporary absolute contraindication
Human immunodeficiency virus infection	In symptomatic phase with marked immunodeficiency	Temporary absolute contraindication
Any infection	Until resolution	Temporary absolute contraindication
Long COVID	Until resolution of major disease	Temporary relative contraindication

Contraindications for nephro-urological diseases

Table 13 describes the contraindications for nephro-urological diseases and their degrees of application.

Tabla 13. Contraindicaciones por enfermedades nefrourológicas[18,31].

Condition	Level of severity	Contraindication
Renal insufficiency	Active	Absolute contraindication
Glomerulonephritis	Up to 3 months after episode	Temporary absolute contraindication
Single kidney		Absolute contraindication to contact sports or sports with risk of body collision
	Adults and adolescents over 14 years of age	Absolute contraindication to contact sports or sports with risk of body collision
	Children, up to 14 years old, with normal single kidney, with recent images confirming the normal position and anatomy of the single kidney and no evidence of renal insufficiency, hypertension or proteinuria. Inform that when they pass that age they will not be able to participate in the chosen sport	No contraindication.
	Children, up to 14 years old, with a single kidney who do not meet all the above criteria	Sports participation decision by the appropriate specialist doctor (nephrologist, urologist, oncologist
Myoglobinuria and organic haematuria		Absolute contraindication
Permanent lesional proteinuria		Absolute contraindication
Varicocele	Until resolution	Temporary absolute contraindication
Hydrocele	Until resolution	Temporary absolute contraindication
Cryptorchidism	Until resolution	Temporary absolute contraindication
Testicular torsion	Until resolution	Temporary absolute contraindication
Orchitis	Until resolution	Temporary absolute contraindication
Epididymitis	Until resolution	Temporary absolute contraindication
Testicular neoplasm	Until resolution	Temporary absolute contraindication
Prostate disease	Chronic	Absolute contraindication to sports that involve driving a vehicle, including cycling
	If corrected by treatment (prostate cancer, etc.)	Temporary absolute contraindication
Kidney, liver, heart and marrow transplantation		Absolute contraindication to contact sports or sports with risk of body collision and sports that involve driving a vehicle

Contraindications for ophthalmological diseases

Table 14 describes the contraindications for ophthalmological diseases and their degrees of application.

Table 14. Contraindications for ophthalmological diseases[18,58].

Condition	Level of severity	Contraindication
Retinal detachment	Including surgically operated	Only participation in low-intensity sports (class IA) is allowed unless authorised by an ophthalmologist
Retinal, choroidal or pupillary condition		Absolute contraindication to underwater diving and boxing
Myopia	Advanced (decimal visual acuity <0.5)	CAbsolute contraindication to underwater diving, skydiving and mountain sports above 1200 m (risk of retinal detachment)
	>3 dioptres	Absolute contraindication to underwater diving, boxing and martial arts in which all types of contact are allowed and there is no facial protection
Other visual acuity alterations (1)	Visual acuity <9/10 in each eye, unless corrected (10/10 in one eye and 8/10 in the other is acceptable). Abnormal binocular vision Decreased visual field. Abnormal stereopsis Macular degeneration	Temporary absolute contraindication until correction to sports that involve driving a vehicle and skydiving
Glaucoma	Angle-closure glaucoma	Absolute contraindication to underwater diving
	Initial, moderate or advanced stage, due to the decrease in peripheral vision	Only sports with low static and dynamic components (class IA) are allowed.
Conjunctiva disease	Until resolution of signs and symptoms	Absolute contraindication to snow sports, swimming and contact sports
Radial keratotomy		Absolute contraindication to boxing and contact sports
Single eye or monocular vision		Absolute contraindication to underwater diving. Evaluate absolute contraindication to contact sports or sports with risk of body collision. Absolute contraindication to sports that involve driving a vehicle
Eye prosthesis or hollow implant		Absolute contraindication to underwater diving. Evaluate absolute contraindication to contact sports or sports with risk of body collision
Hyphaema	Until full resolution	Temporary absolute contraindication
Colour blindness		Absolute contraindication to air sports and skydiving. Consider the legal restrictions and regulations specific to sports that involve driving vehicles and boats
Cataracts		Temporary contraindication until resolution of the condition
Trauma of the eye	With moderate or high myopia, due to the risk of detachment. Increased risk when underwater diving and doing mountain sports above 1200 m	Temporary contraindication until declared fit by an ophthalmologist
Previous eye surgery (2)		Contraindication to combat and collision sports

1. If glasses are worn, they must be shatterproof.
2. Eye protection is required.

Contraindications for digestive system diseases

Table 15 describes the contraindications for digestive system diseases and their degrees of application.

Table 15. Contraindications for digestive system diseases[18,31].

Condition	Level of severity	Contraindication
Splenomegaly	Palpable	Only participation in low-intensity sports (class IA) is allowed. Absolute contraindication to contact sports or sports with risk of body collision
Abdominal hernia	Large and with symptoms	Only participation in low-intensity sports (class IA) is allowed
	Abdominal wall hernia without surgery	Absolute contraindication to skydiving and sports requiring isometric strength (such as weightlifting). Relative contraindication to combat and collision sports
Hepatomegaly		Absolute contraindication to contact sports or sports with risk of body collision
Inflammatory bowel disease	Flare-up	Temporary absolute contraindication
Hepatitis	Viral. Until normalisation of symptoms and analysis	Temporary absolute contraindication
	Chronic B and C with cirrhosis	Absolute contraindication
	Chronic B and C, no cirrhosis, with good response to treatment	Temporary absolute contraindication
Haemorrhoids	Significantly affected, until evaluation of surgical correction	Temporary absolute contraindication to weightlifting and maximal strength sports
Diarrhoea	Significantly clinically affected or risk of dehydration, until the signs and symptoms are normalised	Temporary absolute contraindication

Contraindications for musculoskeletal system diseases

Table 16 describes the contraindications for musculoskeletal system diseases and their degrees of application.

Table 16. Contraindications for musculoskeletal system diseases[18,31-36,59-65].

Condition	Level of severity	Contraindication
Spondylolysis	Symptomatic or unstable, until the cessation of symptoms in all sports that involve an increase in lumbar lordosis or repetitive trunk twists, maintaining trunk hyperextension, such as golf, canoeing and kayaking, artistic, rhythmic and acrobatic gymnastics, swimming in breaststroke and butterfly style, synchronised swimming, high jump, diving, wrestling, judo, horseback riding, skydiving, motocross, rowing. Congenital lyses. Until confirmation of no instability	Temporary absolute contraindication until resolution when traumatic. Relative contraindication in congenital lyses
	After surgery, up to 6-12 months	Absolute contraindication
Spondylolisthesis	Symptomatic (contracture, pain) and/or with vertebral slippage <25%, until the symptoms cease and stability is verified	Temporary absolute contraindication. Absolute contraindication to activities involving extension or hyperextension of the rachis
	With vertebral slippage ≥25%, or with any degree of listhesis with neurological compromise	Absolute contraindication to contact sports or sports with risk of body collision, rhythmic and artistic gymnastics, diving, skydiving, equestrian sports, motocross, high jump in Fosbury style, swimming in breaststroke or butterfly styles, synchronised swimming, judo, wrestling/Greco-Roman wrestling, sailing in trapeze positions, weightlifting
Cervical instability	Post-traumatic or post-surgical. Until resolution and between 6-12 months asymptomatic	Absolute contraindication to contact sports or sports with risk of body collision. Absolute contraindication to life-threatening sports in the event of syncope
Cervical canal stenosis	Asymptomatic	No contraindication.
	Symptomatic. Until resolution, and liberation and stability have been checked for 6/12 months	Absolute contraindication to contact sports or sports with risk of body collision. Absolute contraindication to life-threatening sports in the event of syncope
Odontoid alterations	Agenesis, odontoid hypoplasia and os odontoideum	Absolute contraindication to contact sports or sports with risk of body collision
Spina bifida	Occulta	No contraindication.
Atlanto-occipital assimilation		Absolute contraindication to contact sports or sports with risk of body collision
Klippel–Feil syndrome	Type I: Massive fusion of the upper cervical and thoracic vertebrae	Absolute contraindication to contact sports or sports with risk of body collision
	Type II: fusion of only one or two intervening spaces in C3 and below with full range of cervical movement and no occipitocervical abnormalities, instability, disc disease or degenerative changes	No contraindication.
Disc hernia	Symptomatic, with compression of the medullary or nerve root canal	Absolute contraindication to contact sports or sports with a risk of body collision, skydiving, windsurfing, horse riding, weightlifting and sports with significant axial loads and sudden bending of the trunk
Vertebral hyperkyphosis	Severe (>40°)	Absolute contraindication to butterfly-style swimming, cycling and equestrian sports
Lumbar vertebral hyperlordosis	Severe or symptomatic	Absolute contraindication to rhythmic gymnastics and judo. Similar to description for spondylolisthesis in terms of sports until symptom resolution

(continued)

Table 16. Contraindications for musculoskeletal system diseases[18,31-36,59-65] (continuation).

Condition	Level of severity	Contraindication
Vertebral scoliosis	With Cobb angle ≤20°, asymptomatic	No contraindication.
	When treated with fixation or immobilisation systems that pose a risk to others in contact sports	Absolute contraindication to contact sports or sports with risk of body collision
	With Cobb angle 20-30°, asymptomatic	Relative contraindication to weightlifting and butterfly-style swimming. Relative contraindication to unilateral sports such as racket sports, throwing sports, golf, etc
	With Cobb angle of 30-50°, or with progression of 5° in 6 months, asymptomatic	Absolute contraindication to butterfly-style swimming and weightlifting, and for unilateral sports such as racket sports, throwing sports, golf, etc.
	With Cobb angle >50°, asymptomatic	Absolute contraindication, except swimming, cycling and long-distance running
	Post-surgical vertebral scoliosis, 1 year after surgery with complete consolidation	No contraindication, except to sports with axial and rotational loads (ball sports, tennis, downhill skiing, diving, ski jumping, throwing and jumping in athletics, gymnastics, contact sports and motorcycling)
Spinal arthrodesis	Post-surgery 6-12 months	Temporary absolute contraindication
		Absolute contraindication to contact sports or sports with risk of body collision
Spondylarthrosis	With poor tolerance or neurological deficit	Absolute contraindication to equestrian sports
Osgood–Schlatter disease	Severe, until control of signs and symptoms	Temporary absolute contraindication to jumping sports
Perthes' disease	Until resolution of symptoms	Temporary absolute contraindication Relative for long-distance running
Other diseases that present with bone necrosis and epiphysitis: Sinding-Larsen Johansson, Panner, Freiberg, etc.	With severe symptoms, until control of signs and symptoms	Temporary absolute contraindication
Flat feet	Severe and symptomatic, until surgical correction	Absolute contraindication, except to sports in which the feet do not support body weight and standing sports with low axial loads which do not trigger symptoms
Pes cavus	Severe and symptomatic, until surgical correction	Absolute contraindication, except to sports in which the feet do not support body weight and standing sports with low axial loads which do not trigger symptoms
Recurrent shoulder instability	Due to surgical contraindication, delay or failure of surgery	Absolute contraindication to combat sports, solo sailing, surfing, climbing and diving
Fractures	Uncomplicated, until resolution and disappearance of symptoms	Temporary absolute contraindication if the sport involves the affected area
	Joint or unstable, not properly stabilised which may entail a delay in consolidation, malunion or may lead to sequelae or functional limitations	Absolute contraindication
	Significant sequelae in lower limbs with deformities or alteration of axes	Absolute contraindication to skydiving, jumping and running sports
Stress fractures	Until resolution	Temporary absolute contraindication
Dislocations	Until resolution	Temporary absolute contraindication
Tendon tears.	Until recovery after treatment	Temporary absolute contraindication
Muscle tears	Until recovery after treatment	Temporary absolute contraindication
Ligament tears	Until recovery after treatment	Temporary absolute contraindication
Rheumatic diseases	Significant symptoms	Temporary absolute contraindication
	Chronic or subacute, in joints of lower limbs	Absolute contraindication to skydiving and jumping activities with intense axial loads
	With atlantoaxial instability	Absolute contraindication to contact and collision sports

(continued)

Table 16. Contraindications for musculoskeletal system diseases[18,31-36,59-65] (continuation).

Condition	Level of severity	Contraindication
Functional limitation of joint mobility	Hand joints >50%	Absolute contraindication to sports that involve driving a vehicle
	Large joints >50%	Absolute contraindication to sports that involve driving a vehicle
	Abnormal mobility of the first finger and at least two of the other fingers on the hand	Absolute contraindication to motorcycling
	Knee, ankle, hip or shoulder joint ankylosis	Absolute contraindication to skydiving, running, jumping and sports that involve pivoting action
Amputations	Except for fingers if grip is retained	Absolute contraindication to sports that involve driving a vehicle
	Of a limb below the knee, even with prostheses	Absolute contraindication to motorcycling
	Of the two lower limbs	Absolute contraindication to motorcycling
	Segment of a limb	Absolute contraindication to skydiving
Joint prostheses or replacements	Evaluate individually	There may be absolute contraindication to sports that involve driving a vehicle and relative contraindication to sports in which the joint affected is used a lot
	Upper limb prostheses	Absolute contraindication to motorcycling
Spinal instability		Absolute contraindication to sports involving the possibility of head/neck trauma (motorcycling, combat sports, rugby, climbing, jumps in gymnastics, diving, weightlifting and golf) Similar to listhesis
Severe limitation of spinal mobility	Cervical or thoracolumbar	Absolute contraindication to sports involving the possibility of head/neck trauma (motorcycling, combat sports, rugby, climbing, jumps in gymnastics, diving, weightlifting and golf)
Repeat Lumbosciatica	Hyperalgic phase	Absolute contraindication to motorcycling, weightlifting, equestrian sports, sports that involve twisting the trunk (gymnastics, golf, etc.) and marked flexion of the spine (long jump...) until diagnosis and effective treatment
Rhabdomyolysis	Until the normalisation of liver enzymes and creatine kinase, disappearance of symptoms and images of severity	Temporary absolute contraindication

Contraindications for neurological, neurosurgical and psychiatric diseases

Table 17 describes the contraindications for neurological, neurosurgical and psychiatric diseases, and their degrees of application.

Table 17. Contraindications for neurological, neurosurgical and psychiatric diseases[18,31,66,67].

Condition	Level of severity	Contraindication
Epilepsy and seizures of different aetiology	Poorly controlled with treatment	Absolute contraindication to contact sports or sports with risk of body collision. Absolute contraindication to life-threatening sports in the event of syncope. Absolute contraindication to sports that involve driving a vehicle and doing sports alone
	Even controlled with treatment	Absolute contraindication to boxing and other combat sports in which KOs may exist
	Seizures with loss of consciousness during the last year	Absolute contraindication to sports that involve driving a vehicle, air sports, underwater diving and mountaineering. After 1 year with no crisis: no contraindication
	Seizures or with loss of consciousness during sleep. It should be confirmed that 1 year has passed with only crises of this kind and only during sleep	Absolute contraindication to sports that involve driving a vehicle, air sports, underwater diving and mountaineering. After 1 year with no crisis: no contraindication
	Repeated epileptic or convulsive seizures with no influence on consciousness or the ability to act. It should be confirmed that 1 year has passed with only crises of this kind	Absolute contraindication to sports that involve driving a vehicle, air sports, underwater diving and mountaineering. After 1 year with no crisis: no contraindication
	With epileptic or convulsive seizures caused by an identifiable causative factor, a favourable neurological report must be provided confirming a seizure-free period of 6 months	Absolute contraindication to sports that involve driving a vehicle, air sports, underwater diving and mountaineering. After 6 months with no crisis: no contraindication
	In the event of a first or single unprovoked crisis, a crisis-free period of 6 months must be confirmed by a neurological report	Absolute contraindication to sports that involve driving a vehicle, air sports, underwater diving and mountaineering. After 6 months with no crisis: no contraindication
	If a seizure or loss of consciousness occurs during a change or withdrawal of medication, 1 seizure-free year must be confirmed once anti-epileptic treatment has been restored. On the basis of neurological criteria, driving may be forbidden from the start of the withdrawal of treatment and for 6 months after cessation	Absolute contraindication to sports that involve driving a vehicle, air sports, underwater diving and mountaineering. After 1 year with no crisis: no contraindication
Traumatic brain injury	Until the total disappearance of psychological, cognitive, affective and sensory-motor symptoms	Temporary absolute contraindication
Multiple sclerosis	In symptomatic outbreaks	Temporary absolute contraindication
Myopathies	In symptomatic phase	Temporary absolute contraindication
Peripheral neuropathy	In symptomatic phase	Temporary absolute contraindication
Psychiatric condition	Suicide risk	Solo sports are not allowed
	History and established condition	Absolute contraindication to boxing and other contact sports, and underwater diving
Headaches	Intense, with exertion or with little response to treatment	Temporary absolute contraindication

(contined)

Table 17. Contraindications for neurological, neurosurgical and psychiatric diseases[18,31,66,67] (continuation).

Condition	Level of severity	Contraindication
Chiari malformation, type 1 (1)	Symptomatic by compression of the brainstem, herniation of the tonsils or cerebrospinal fluid circulation disorders (pulsatile headache, severe cervical pain, caused by coughing, sneezing, strain, change of posture or physical exertion, which can cause an increase in intracranial pressure)	Absolute contraindication to contact sports or sports with risk of body collision and sports that involve intense Valsalva manoeuvre (e.g. weightlifting)
	Asymptomatic patients in whom the abnormality was discovered after a diagnostic evaluation for concussion	Absolute contraindication to contact sports or sports with risk of body collision
	Asymptomatic patients, after the chance finding of the abnormality and with authorisation from a neurosurgeon	No contraindication.
Permanent treatment with psychotropics	While treatment lasts	Absolute contraindication to sports that involve driving a vehicle, air sports, Olympic shooting, archery and combat sports

Contraindications for dermatological diseases

Table 18 describes the contraindications for dermatological diseases and their degrees of application.

Table 18. Contraindications for dermatological diseases[18,68,-75].

Condition	Level of severity	Contraindication
Human papilloma virus (HPV) infections (warts)	Until resolution of signs and symptoms	Temporary absolute contraindication to sports that use mats.
Impetigo	Until 72 hours after antibiotic treatment, 48 hours without new lesions and no exudation	Temporary absolute contraindication
Mycosis	If the affected area cannot be isolated completely to avoid contact with other people and while the lesions are active	Temporary absolute contraindication until cured to contact sports or sports with a risk of body collision, and to sports that use mats.
Folliculitis, boils, anthrax, abscesses, cellulitis, erysipelas	Until 72 hours after antibiotic treatment, 48 hours without new lesions and no exudation. In the event of Pseudomonas infection, recommendations should be individualised due to the possibility of skin-to-skin contact (contact sports or sports with a risk of body collision, and for sports that use mats)	Temporary absolute contraindication
Wounds	Symptomatic and risk of poor cicatrisation while active or bleeding	Temporary absolute contraindication
Cuts and abrasions	If they cannot be covered or until resolution	Temporary absolute contraindication to contact sports
Molluscum contagiosum	Depending on location, as long as the lesions are active	Temporary absolute contraindication to contact sports and sports that use mats.
Pediculosis	In the event of active infestation and until resolution	Temporary absolute contraindication
Urticaria and angioedema (cholinergic, cold, pressure, aquagenic, sunlight, exercise-induced anaphylaxis)	Depending on the degree of control	Relative contraindication
Hereditary angioedema	Depending on the degree of control	Relative contraindication
Atopic dermatitis	Depending on the degree of control	Relative contraindication for water sports
Oral retinoid treatment	Depending on the symptoms (fatigue, arthralgia, photosensitivity, staphylococcus colonisation, CPK elevation)	Relative contraindication

Contraindications for haematological diseases

Table 19 describes the contraindications for haematological diseases and their degrees of application.

Table 19. Contraindications for haematological diseases[18,31,33,36,76].

Condition	Level of severity	Contraindication
Coagulation disorders (haemophilia, von Willebrand disease and other severe coagulopathies) (1)	No prophylactic treatment	Absolute contraindication to contact sports or sports with risk of body collision
	With prophylactic treatment, evaluation of participation in sports theoretically contraindicated by haematologist (1)	Possible participation in non-contact sports without risk of collision or falling, when permitted by the haematologist
Platelet diseases (thrombocytopenia or thrombopathies)	Risk of bleeding, especially with platelet counts <50,000	Absolute contraindication to sports with risk of injury and contact sports, with risk of body collision or falling
Anticoagulant and antiplatelet medication		Absolute contraindication to sports with risk of injury and contact sports, with risk of body collision or falling
Haemoglobinopathies	Heterozygous alterations or thalassaemic features (thalassaemia minor) without anaemia	No contraindication.
	Heterozygous alterations or thalassaemic features (thalassaemia minor) with anaemia (Hb <10 gr/dl) and thalassaemia	Absolute contraindication to high dynamic intensity sports (classes CI, CII and CIII)
	Sickle cell anaemia or sickle cell disease	Absolute contraindication to high-intensity sports, underwater diving and sport in extreme temperature conditions. Children should be encouraged to participate in sports activities to the best of their ability and physical tolerance, with more frequent periods of rest and greater hydration
	Sickle cell trait (carrier) The diagnosis is not in itself a justification for ineligibility for competitive sport, but the following preventive strategies must be taken: a) Adequate rest and hydration to minimise the likelihood of an event occurring on the sports field b) Familiarity with the medical strategies for acute emergencies if a medical incident occurs c) Special care with athletes competing or training in high temperature or ambient humidity conditions or at extreme altitude	Possible absolute contraindication to high dynamic intensity sports (classes IC, IIC and IIIC)
Deficiency anaemias (iron deficiency, vitamin B12 deficiency, folic acid deficiency, etc.)	Symptomatic, of any nature, until recovery to normality	Temporary absolute contraindication (while Hb <10 gr/dl)
Oncohaematology (acute leukaemias, lymphomas and myelomas)		Absolute contraindication to high and medium intensity exercise

1. Before organising any sports programme, risk situations and protocols for action in case of emergency must be assessed.

Contraindications for other syndromes, diseases and cases

Table 20 describes the contraindications for other syndromes and diseases, and their degrees of application.

Table 20. Contraindications for other syndromes, diseases and cases[18,31,33].

Condition	Level of severity	Contraindication
Alteration of ion concentrations in the blood	Hypernatraemia, hyponatraemia, hyperkalaemia, hypokalaemia, hypercalcaemia, hypocalcaemia, hyperphosphoraemia, hypophosphoraemia, hypermagnesaemia, hypomagnesaemia, until normalisation of figures	Temporary absolute contraindication
Any surgery	Not specifically described elsewhere	Temporary absolute contraindication, until full recovery
Neurosensory hypoacusis		Absolute contraindication to shooting and underwater diving sports
Otosclerosis and otospongiosis		Absolute contraindication to underwater diving
Loss or absence of organ of hearing, deafness	Loss or absence of an organ of hearing	Absolute contraindication to shooting
	Total unilateral deafness	Absolute contraindication to underwater diving
Alterations of the middle ear		Absolute contraindication to skydiving and air sports
Blocked eustachian tube	Permanent	Absolute contraindication to skydiving, underwater diving and air sports
Mastoiditis	Operated	Absolute contraindication to underwater diving
Tracheotomy	Permanent	Absolute contraindication to underwater diving
Congenital laryngocele		Absolute contraindication to underwater diving
Balance alteration	If permanent	Absolute contraindication to motorcycling, skydiving, gliding, figure skating, underwater diving, cycling, climbing and mountaineering
Malformed or affected oral cavity	Severe	Absolute contraindication to skydiving
Malformed or affected upper airways	Severe	Absolute contraindication to skydiving
Cold urticaria		Absolute contraindication to windsurfing and winter sports
Acrocyanosis, Raynaud's phenomenon	Severe	Absolute contraindication to windsurfing and for sports in which it is not possible to maintain sufficient hand temperature
Dupuytren's contracture		Absolute contraindication to windsurfing and hand pelota
Drug addiction		Absolute contraindication
Alcoholism		Absolute contraindication
Taking medication that causes drowsiness	While treatment lasts	Absolute contraindication to life-threatening sports in the event of syncope
Acute symptoms	Diarrhoea, vomiting, dizziness, fatigue, dyspnoea, etc., depending on the degree affected and with the need to study until diagnosis	Temporary absolute contraindication
Heat stroke	With risk of recurrence and after evaluation of risks and trigger factors	Relative absolute contraindication in hot and humid conditions
Hypoglycaemia	Repeated, with syncope or impairment of degree of consciousness	Absolute contraindication to sports that involve driving a vehicle, air sports, underwater diving and mountaineering
Polymyositis/dermatomyositis		Only participation in low-intensity sports (class IA) is allowed

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APPENDIX 1. Classification of sports according to their static and dynamic demands, and as contact sports or sports with risk of body collision, or life-threatening sports in the event of syncope[39].

	A. Low dynamic component	B. Moderate dynamic component	C. High dynamic component
I. Low static component	Billiards Bowling Cricket Curling Golf Boules Olympic Shooting[b]	Baseball Softball Basque pelota Doubles tennis Table tennis Volleyball Fencing	Long-distance running Race walking Badminton Cross-country skiing (classic technique)[a,b] Football[a] Field hockey[a] Orienteering[b] Padel Squash[a] Tennis
II. Moderate static component	Auto racing[a,b] Underwater diving[b] Equestrian sports[a,b] Motorcycling[a,b] Archery[b] Aeronautical sports[a,b]	Field events (jumping) Running (sprint) American football[a] Rhythmic gymnastics Synchronised swimming[b] Figure skating[a] Rugby[a] Surfing[a,b]	Running (middle-distance) Basketball[a] Handball Cross-country skiing (skating technique) Ice hockey[a] Lacrosse[a] Swimming
III: High static component	Field events (throwing)[b] Martial arts[a] Bobsledding[a,b] Rock climbing[a,b] Waterskiing[a,b] Weightlifting[b] Artistic gymnastics[a,b] Luge[a,b] Ski jumping[a,b] Sailing Windsurfing[a,b]	Bodybuilding Downhill skiing[a,b] Wrestling[a] Skateboarding[a,b] Snowboarding[a,b]	Combined track and field events[b] Boxing[a,b] Cycling[a,b] Ski mountaineering[a,b] Speed skating[a,b] Kayaking[b] Sailing[b] Triathlon[a,b] Waterpolo[a,b]

[a] Contact sports or sports with risk of body collision.
[b] Life-threatening sports in the event of syncope.

APPENDIX 2. Contact sports or sports with risk of body collision[18].

• Martial arts • Auto racing • Boxing • Cycling • Rock climbing • Downhill skiing • Waterskiing • Cross-country skiing • Ski mountaineering	• Football • American football • Artistic gymnastics • Wrestling • Equestrian • Field hockey • Ice hockey • Motorcycling • Figure skating	• Speed skating • Rugby • Ski jumping • Snowboarding • Squash • Surfing • Waterpolo • Windsurfing

APPENDIX 3. Life-threatening sports in the event of syncope[18].

• Field events (throwing) • Combined track and field events • Auto racing • Boxing • Underwater diving • Cycling • Rock climbing • Waterskiing • Downhill skiing • Cross-country skiing	• Ski mountaineering • Artistic gymnastics • Weightlifting • Equestrian sports • Motorcycling • Swimming • Synchronised swimming • Orienteering • Speed skating • Kayaking	• Sailing • Ski jumping • Snowboarding • Surfing • Archery • Olympic Shooting • Sailing • Waterpolo • Windsurfing

The MasQsano Method. Detection of unknown cardiac diseases in health screening for athletes

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doi: 10.18176/archmeddeporte.00143

Received: 26/10/2022
Accepted: 06/03/2023

Summary

The sports medical examination is considered a starting point for any athlete before taking up physical or sporting activity. Its main objective is to detect pathologies that could put your life at risk and those that, once corrected, can enhance physical performance. This is why it must be carried out by a multidisciplinary health team with expertise in the area. In this way, it is important to review the scientific evidence and learn directly about the health status of a group of adult and child athletes, their incidence of cardiovascular diseases and the role of nursing in their application. This study evaluated a sample of 7340 athletes aged between 3 and 17 years, composed of 1693 females and 5647 males, who underwent a sports medical examination, according to a registered and previously established protocol in sports clubs in 2 Spanish provinces with the support of nursing staff during the year 2021. Of these, a total of 112 cases of cardiac pathologies were obtained, of which 54% were known to have a cardiac pathology and 64% were unknown. Of this group of unknown cardiac pathologies, 5.9% of the cases required surgical intervention, 21.1% are under review and 73% were discharged. The total number of cases with unknown cardiac pathologies represents 0.70% of the sample. The fundamental role of nursing in the application of this protocol was also determined.

Key words:
Sudden death. Electrocardiography. Physical examination. Athletic perfomance. Disease prevention.

Método MasQsano. Detección de enfermedades cardiacas no conocidas en reconocimientos médicos deportivos

Resumen

El reconocimiento médico deportivo es considerado como un punto de partida para cualquier deportista antes de incorporarse a la actividad física o deportiva. Su objetivo principal es la detección de patologías que pudieran poner en riesgo su vida y aquellas que una vez corregidas pueden potenciar el rendimiento físico. Es por ello por lo que debe realizarse por un equipo de salud multidisciplinario experto en el área. De esta manera, resulta importante revisar la evidencia científica y conocer directamente el estado de salud de un grupo de adultos y niños deportistas, su incidencia de enfermedades cardiovasculares y el rol de la enfermería en su aplicación. Este estudio, evaluó una muestra de 7.340 deportistas con edades comprendidas entre los 3 y 17 años, compuesta de 1.693 femeninos y 5.647 masculinos, a los cuales se les realizó el reconocimiento médico deportivo, de acuerdo con un protocolo registrado y establecido previamente en los clubes deportivos de 2 provincias españolas con el apoyo del personal de enfermería durante el año 2021. De estos, se obtuvo un total de 112 casos de patologías cardiacas, de los cuales el 54% tenía conocimiento de patología cardiaca y el 64% no era conocido. De este grupo de patologías cardíacas no conocidas, el 5,9% de los casos requirió intervención quirúrgica, el 21,1% se encuentra en revisión y el 73% fue dado de alta. El total de casos con patologías cardíacas no conocida representa un 0,70% de la muestra. Así mismo, se determinó el rol fundamental de enfermería en la aplicación de este protocolo.

Palabras clave:
Muerte súbita. Electrocardiografía. Examen físico. Rendimiento atlético. Prevención de enfermedades.

2nd Second Prize SEMED Research Awards 2022

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Introduction

There are numerous benefits to be gained from participating in sports. When approaching the topic in terms of population health, a surprising improvement can be seen over time; not only at a cardiovascular, respiratory or organic level but also mentally and socially[1]. Athletes are considered a paradigm of health and wellbeing, the ultimate reflection of maximum performance and unwavering health, except in those cases of acute or sports injuries and those caused by overexertion[2]. For that reason, health screening for athletes is viewed as a great first step for any athlete intending to resume physical activity or sport. Its main goal is to detect pathologies that could potentially jeopardise the health of the athlete and those that could enhance physical performance[3] once corrected. Health screening for athletes is currently regulated in Spain under Spanish Royal Decree 41/2009. This Commission rules on the need for health screening in those sports where it is deemed necessary for improved prevention of the risks to athletes based on the characteristics of the sport in question, the effort required and other physical and environmental conditions. Currently in Andalusia, those sports are football, basketball, handball and volleyball.

Current European and Spanish guidelines recommend the use of electrocardiograms during health screening in sport prior to participation because they offer a high detection rate for cardiac diseases[4-6]. These cardiac diseases can lead to the sudden death of an athlete if not detected in time. However, due to the similarity between certain findings from an electrocardiogram associated with physiological adaptation to physical training and certain cardiac disorders, interpreting an electrocardiogram in athletes is usually quite a challenge[7]. Cases of sudden death in athletes are uncommon but have such a strong impact on the sports and medical communities, as well as on spectators and relatives obviously, that the main strategy is to prevent them through health screening for athletes[3].

The main purpose of this article is to identify the prevalence of cardiac irregularities in athletes aged 3-17 in the provinces of Granada and Almería in 2021. The secondary goals are to assess the overall health of athletes in general, to monitor those athletes with cardiac pathologies and to determine the characteristics of those pathologies.

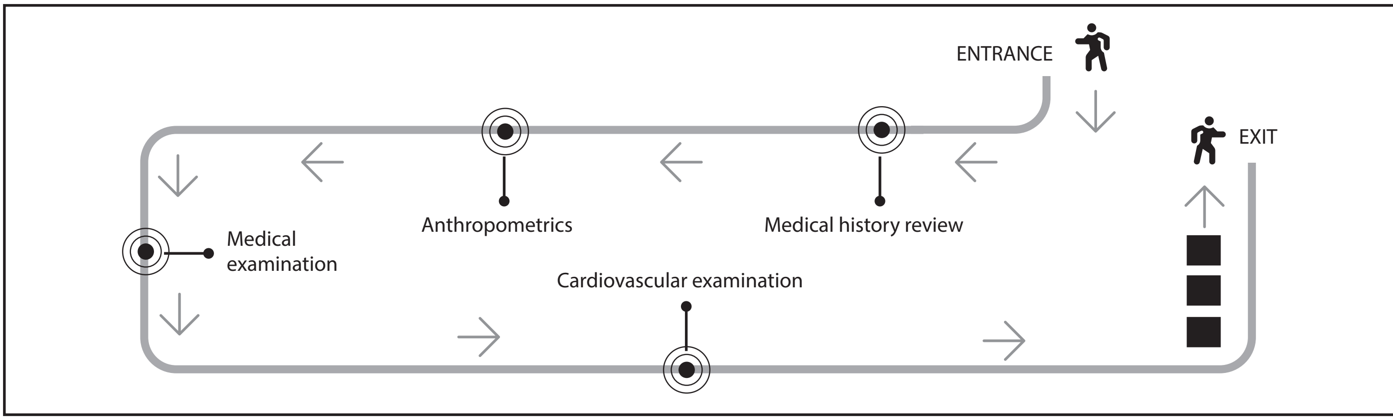
Material and method

A descriptive observational study of a group of athletes subject to pre-competition compulsory health screening for athletes at a sports medical examination company, MasQsano Salud y Deporte S.L.P. The sample consisted of 7,340 athletes aged between 3 and 17, inclusive, from clubs in Almería and Granada. The sports in question were football, basketball, athletics, indoor football, handball, volleyball, rugby and swimming. The clubs ranged from municipal sports academies that introduce children to sport to clubs engaged in advanced or technical training for semi-professional athletes competing at regional or national levels. The criteria for inclusion in the study were: athletes aged 3-17 who received health screening for athletes at MásQsano between June and November 2021. The criteria for exclusion were: Athletes aged 3-17 who received health screening for athletes at MásQsano between June and November not suffering from a prior cardiac pathology and athletes aged 3-17 who received health screening for athletes at MásQsano between June and November suffering from a prior cardiac pathology. The main variables for the study are: presence of previous cardiac diseases, known family history, irregularities defined in the international criteria for the interpretation of electrocardiograms on athletes and the presence of anomalies in the cardiac auscultation. The secondary variables are: sex, age, heart rate, blood pressure and sport.

The method used begins by sending each athlete a form to fill in, which must be checked and signed by an adult. These forms provide information on data protection. The examination circuit consists of four stations, with a different professional at each one. The first station reviews the clinical history of the athlete, with a particular focus on personal and family backgrounds. This is conducted by nursing staff. The athlete then undergoes an anthropometric assessment, with measurements of weight, height, body mass, abdominal circumference, upper limb girth, upper and lower limb segments. A static footprint analysis is also performed using a podoscope, and the ankles, knees and back are examined. Finally, visual acuity is assessed using the Snellen[8] chart. The tests at this station can be performed by a physiotherapist or nursing staff. The third station involves a complete medical examination. It encompasses osteoarticular assessment, cardiopulmonary auscultation, neurological assessment, peripheral pulse palpation, dermatology and general assessment of all the organs. The tests at this station are exclusively performed by a doctor specialising in sports medicine. Finally, a cardiovascular examination is performed at the fourth station using a digital electrocardiogram and by monitoring vital signs (Figure 1). The medical history review, the anthropometric assessment and cardiovascular examination are all performed by nursing staff. Their role is therefore essential in the health screening process because these professionals are responsible for conducting an educational interview regarding the various pathologies detected, providing advice on the practise of sport and following up with those athletes who require assessment by other specialists. The electrocardiogram (ECG) is checked by a sports medicine doctor or, otherwise, a community medicine doctor with experience in sports health screening. Furthermore, the 2017 international criteria for electrocardiographic interpretation in athletes[9] were applied. Any ECG results revealing a discrepancy are assessed by an independent cardiologist and were resolved with a consensual reading. Athletes in whom a previously unknown cardiac pathology is detected are contacted by the nursing staff, who recommend to the athlete – or to the parents or legal guardians in the case of a minor – that they be seen by a cardiologist via the public health system. The approximate wait before being seen by a cardiologist can vary between two to four weeks.

The method is based on guidelines from the European Society of Cardiology (ESC), which recommends a method that includes a review

Figure 1. The MasQsano medical health screenings for athletes method.



of the medical history, a physical examination and an electrocardiogram at rest[3]. A search was therefore performed in the online PubMed, Web of Science, Scopus and Google Scholar databases, up to June 2022. The study was approved by the provincial ethical research committee of Almería.

The results are presented as the average + standard deviation for the normally distributed continuous variables and as percentages for the categorical variables. The quantitative variables were analysed using the Student's t-test for normal distribution or the Mann–Whitney U test for non-normal distribution. The level of significance was set at $p < 0.05$. The statistical analyses were conducted in SPSS Statistics 24.0.

Results

The results from this assessment revealed 52 cases of cardiac pathologies that were previously unknown to the athlete in question (0.69% of the sample), with an average age of 10.8 + 4.2 standard deviation. The median was 11 years old and the mode was 17 years old, as shown in Table 1. The most common gender among the athletes in whom cardiac pathologies were found was male (71.4%), the rest being women (28.6%), as shown in Table 2.

The most commonly practised sport among the athletes with cardiac pathology was football, which was also the most common among all the athletes included in the study (Tables 3 and 4).

Furthermore, there were 60 cases of cardiac pathologies that were already known to the athletes in question (0.82% of the sample); i.e. they were already aware of their diagnosis (repolarisation disorder in 9.2%, heart murmurs in 75.4% and left ventricular hypertrophy in 15.4%).

Of the group with previously unknown cardiac pathologies (n = 52), 5.7% of the cases (n = 3) required surgical intervention, 21.1% are undergoing regular monitoring (n = 11) and 73% (n = 38) were discharged (Figure 2).

Nonetheless, and despite the main objective for this research being to identify the prevalence of cardiac pathologies in adult and

Table 1. Age of the athletes in whom a cardiac pathology was detected.

N Valid	56
Average	10.8
Median	11
Mode	17
Standard deviation	4.206

Table 2. Gender of the athletes in whom a cardiac pathology was detected.

	Frequency	Percentage	Valid percentage	Cumulative percentage
Female	16	28.6	28.6	28.6
Male	40	71.4	71.4	100
Total	56	100	100	

Table 3. Sports practised by the athletes with detected cardiac pathology.

	Frequency	Percentage	Valid percentage	Cumulative
Football	38	67.9	67.9	67.9
Basketball	12	21.4	21.4	89.3
Handball	2	3.6	3.6	92.9
Volleyball	1	1.8	1.8	94.6
Rugby	1	1.8	1.8	96.4
Athletics	1	1.8	1.8	98.2
Swimming	1	1.8	1.8	100
Indoor football	0	0	0	100
Total	56	100	100	

child athletes, the total number of cases with cardiac pathologies only represents 1.52% of the total sample: athletes with previously known and unknown cardiac pathologies. A total of 8,268 referrals were made, with the same athlete potentially being referred to several specialists. The largest number of referrals was to nutrition (38.47%, n = 3,220), followed by podiatry (29.04%, n = 2,431), physiotherapy (20.58%, n = 1,723), ophthalmology (5.72%, n = 479), dermatology (3.62%, n = 303) and

Table 4. Total number of health screenings conducted per sport.

	Number of health checks	Percentage	Valid percentage	Accumulative percentage
Football	3,667	49.95	49.95	49.95
Basketball	1,439	19.6	19.6	69.55
Handball	790	10.76	10.76	80.31
Volleyball	695	9.46	9.46	89.77
Rugby	370	5.04	5.04	94.81
Athletics	150	2.04	2.04	96.85
Swimming	130	1.77	1.77	98.66
Indoor football	99	1.34	1.34	99.96
Total	7,340	100	100	

Figure 2. Trend in detected cardiac pathologies.

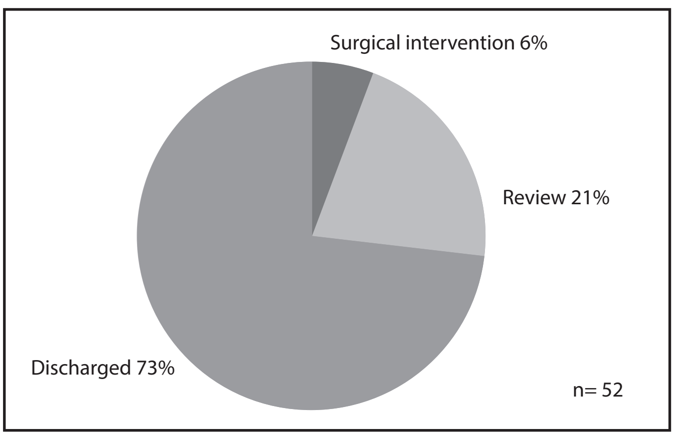
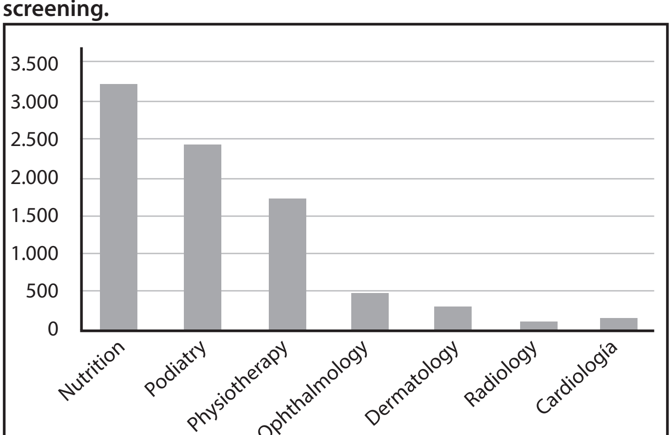


Figure 3. Referral to specialists of athletes subject to the health screening.



radiology (1.21% n = 102), as well as those already known cardiology cases (1.33%, n = 112) (Figure 3).

Under the 2017 international criteria for electrocardiographic interpretation in athletes[9], cases of previously unknown pathologies were referred to cardiology, revealing T wave inversion in 43%, ventricular pre-excitation in 21%, ventricular extrasystoles in 22%, supraventricular tachycardia in 7% and right bundle branch block in 7% (Figure 4).

Furthermore, this health screening for athletes enabled a decision on whether or not to suspend sports activity in the sample subject to study. As a result, among the sample referred to cardiology for a previously unknown pathology (n = 52), 61% continued practising their sports activity after being discharged by cardiology, 22% had to suspend the practise of sport temporarily until studies could be completed and subsequently resumed the practise of sport, and 17% had to permanently stop practising the sport for which the screening was conducted.

It was also possible to further define the characteristics of the group (n = 112) that was referred to cardiology specialists. It was found that 83.92% consisted of male athletes and 16.07% female athletes, with the largest age group being that of 0-5 years (20.1%), followed by over-18s (15.17%), 8-9 years (12.5%), 14-15 years (11.6%) and 16-18 years (9.82%). Of this sample, 92.22% are right-handed and 7.78% left-handed.

For the anthropometric assessment, the Body Mass Index was used to classify nutritional condition. To classify said weight problems in the athletes from the total sample (n = 7,430), the base cut-off point criteria proposed by the WHO International Obesity Task Force (IOTF) were used for the various weight situations in children and teenagers by age and gender from 5 to 19 years, with such cut-off points as (<18.5 kg/m^2 (underweight); 18.5 kg/m^2 (normal); 25 kg/m^2 (overweight) and 30 kg/m^2 (obese) in adults10. The average for the sample overall was 17.64 ± 1.51 kg/m^2.

Figure 4. Classification of the athletes according to the 2017 international criteria for electrocardiographic interpretation in athletes.

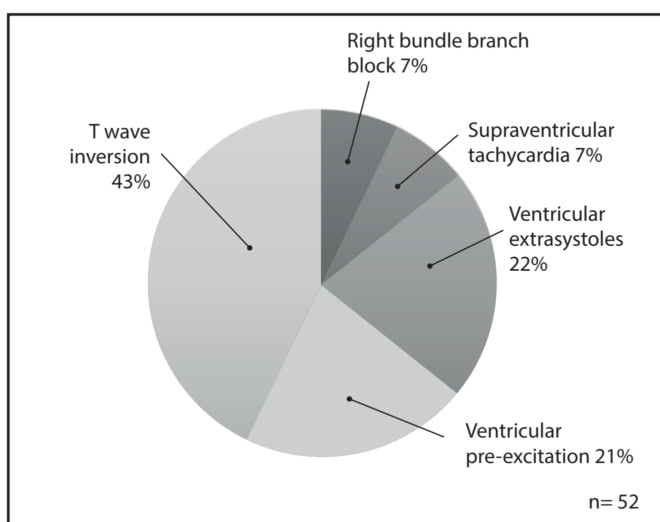
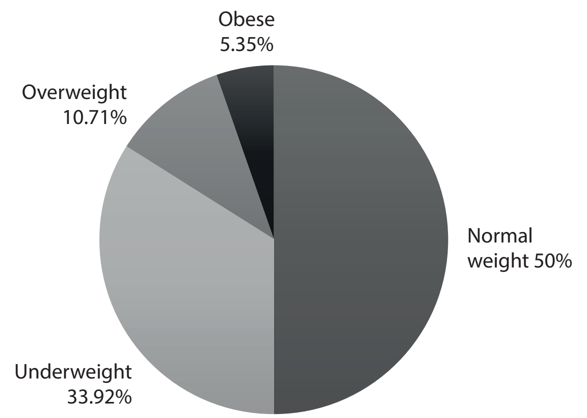


Figure 5. Classification of the BMI of the athletes subject to the health screening.



From the assessment, 50% appeared to be within normal ranges, 33.92% underweight, 10.71% overweight and only 5.35% obese (Figure 5).

Discussion

EThis study was conducted using the MasQsano health screening for athletes method, which can be said to follow the guidelines from the European Society of Cardiology (ESC), which recommends a method that includes a review of the medical history, a physical examination and an ECG at rest[3]. This was adapted to the population being assessed given that, in the case of assessments on groups or teams of athletes, Moreno[11] states that this can be organised into a series of stations with other professionals, such as nursing staff and physiotherapists, among others, lending support to create a method that is entirely valid for the detection of cardiac risks and pathologies in athletes that can contribute to Sudden Cardiac Death (SCD).

Asif and Drezner[12] believe that health screening for athletes that includes an ECG offers an additional benefit of being better able to identify diseases, and the modern ECG interpretation standards specifically applicable to athletes that are used by experienced doctors provide low false positive rates, thus improving profitability and preserving sensitivity. The ECG has shown itself to be a key tool for detecting the main cause of SCD: hypertrophic cardiomyopathy. However, it can be costly for many countries and is therefore not considered a compulsory part of the preventive protocol[13].

Evidence has shown that, if athletes are assessed using these advanced protocols, they can potentially improve their health and safety during sports events and that they should be considered best practice in high-risk athletes whenever sports cardiology supervision and infrastructure are easily available[14].

A low percentage of athletes with cardiac pathologies was found during the course of this research, highlighting the importance of this type of assessment given that it represents a challenge for public health, the league or club, the athlete and their relatives. The majority of these anomalies are treatable hereditary cardiac disorders, but ones that can give the athlete a certain predisposition to SCD, mainly via ventricular arrhythmia[13]. With that in mind, the Spanish Sports Medicine Society (FEMEDE) highlights the need for health screening that can help to determine sports aptitude prior to commencing the practise of sport in all kinds of athletes, especially those with a history of having suffered from a disease, regardless of the level of impact[3].

Furthermore, this corroborates the statements by Moreno[13] on the possible scenarios in health screening for athletes in which there may be an absence of pathologies, the presence of minor or moderate irregularities potentially giving the athlete a predisposition to future injuries or that pose a risk, pathologies that restrict the practise of sport because they pose a risk to life although not requiring the immediate suspension of physical activity and the presence of pathologies that recommend against all forms of physical activity either temporarily or permanently. However, factors may be found in the assessments that might appear to be a cardiac problem but are actually various structural and functional adaptations within the heart that enable the generation of a large and sustained increase in cardiac output and/or a blood pressure increase. The scope to which these physiological remodelling markers manifest in the surface ECG is governed by various factors and certain athletes show electrical and structural changes that overlay those observed in the cardiomyopathy and ion channel diseases, which are recognised causes of sudden cardiac death in young and adult athletes[14].

A limitation was encountered in the poor availability of clinical studies demonstrating the effectiveness of health screening for athletes, as well as studies focused on the pathologies found when conducting these assessments.

Similarly, the important work of both medical and nursing healthcare professionals should be recognised in the detection of cardiac pathologies and in the prevention of SCD given that their role in these procedures ranges from the educational to supervising the equipment, proper organisation for conducting the assessment and offering the necessary advice to athletes[12]. Furthermore, in the presence of already diagnosed pathologies[15], they must guide athletes on the precautionary measures to apply during training and competition, and on switching to a different sport if necessary[14].

In conclusion, this study found a 1.52% prevalence of cardiac pathologies in a sample of 7,430 athletes aged 3-17 in the provinces of Granada and Almería in 2021, but only 0.69% of the total from the sample were previously unknown. This allows us to conclude that the MasQsano method applied to conduct the health screening for athletes at an early age is effective at assessing health conditions and determining the presence of cardiac pathologies.

Furthermore, a general health assessment was also conducted on the athletes. Those athletes with cardiac pathologies were monitored to reveal their development over time and the characteristics of those athletes who were referred to cardiology were defined.

Conducting European-style health screening for athletes that includes ECG assessment complements the medical evaluation and facilitates the detection of cardiac pathologies that may require anything between regular medical attention and the definitive or permanent suspension of sports activity depending on the level of risk posed to the life of the athlete.

Conflict of interest

The authors declare no conflict of interest whatsoever.

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Lung diffusing capacity after different modalities of exercise at sea level and hypobaric simulated altitude of 4,000 m

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doi: 10.18176/archmeddeporte.00144

Received: 09/06/2022
Accepted: 28/04/2023

Summary

Introduction: Lung diffusion capacity of carbon monoxide (DL_{CO}) provides a measure of gas transfer in the lungs, which increase in relation to exercise and decrease in the presence of lung interstitial disease. The aim of this study is to evaluate the changes in lung diffusion after anaerobic and aerobic exercise in a cycle ergometer.
Material and method: The participants were 9 healthy active subjects, including six females and three males (age: 24.3 ± 3.1 years). Lung diffusion capacity for carbon monoxide (DL_{CO}) was studied under two different protocols: In the first day, DL_{CO} was measured at SL at rest (SL-R), after 30-s maximal exercise (SL-ANA), and after 15-min moderate continuous exercise (SL-AER). In the second day, DL_{CO} was evaluated at rest at SL, and then at HA (4,000 m) at rest (HA-R) and after 30-min of moderate interval exercise (HA-AER).
Results: There was an increase in DL_{CO} from rest to after SL-ANA (32.5 ± 6.4 to 40.3 ± 11.6 mL·min^{-1}·mmHg^{-1}, $P = 0.027$). In the second day, DL_{CO} was evaluated at rest at SL, and then at HA (4,000 m) at rest (HA-R) and after 30-min of moderate interval exercise (HA-AER). During HA exposure, there was no changes in DL_{CO}, either at HA-R, or after HA-AER.
Conclusions: Lung diffusion capacity largely increased after 30-s maximal exercise in a cycle ergometer, although the O_2-dependence is small during this type of anaerobic exercise. Thus, exercise intensity may be a key modulator of the changes in lung diffusing capacity in relation to exercise.

Key words:
Diffusing capacity. Intermittent hypoxic exercise. High-altitude pulmonary edema. Hypobaric hypoxia.

Capacidad de difusión pulmonar bajo diferentes modalidades de ejercicio a nivel del mar y en hipoxia hipobárica simulada de 4.000 m

Resumen

Introducción: La difusión pulmonar para el monóxido de carbono (DL_{CO}) proporciona una medida de la transferencia de gas en los pulmones, que aumenta con relación al ejercicio y disminuye en presencia de una lesión intersticial pulmonar. El objetivo de este estudio es fue evaluar los cambios en la difusión pulmonar después de un ejercicio aeróbico y anaeróbico en cicloergómetro.
Material y método: Los participantes fueron 9 sujetos físicamente activos, incluyendo seis mujeres (edad: 24,6 ± 3,6 años) y tres hombres (edad: 23,7 ± 1,5 años). La DL_{CO} se estudió bajo dos protocolos diferentes: El primer día, la DL_{CO} fue medida a nivel del mar en reposo (SL-R), después de un esfuerzo máximo de 30 segundos (SL-ANA), y después de un ejercicio moderado continuo de 15-min (SL-AER). El segundo día, la DL_{CO} fue evaluada a nivel del mar en reposo (SL-R, y luego en altitud (4.000 m) en reposo (HA-R) y después de un ejercicio interválico de 30 minutos (HA-AER).
Resultados: Se produjo un aumento de la DL_{CO} de la SL-R a la SL-ANA (32,5 ± 6,4 a 40,3 ± 11,6 mL·min^{-1}·mmHg^{-1}, p = 0,027). En el segundo día, la DL_{CO} no se modificó después de la exposición en altitud, ya sea en reposo a 4.000 m (HA-R) o después del ejercicio interválico moderado a dicha intensidad (HA-AER).
Conclusiones: La difusión pulmonar aumentó ampliamente después de un esfuerzo máximo de 30 segundos en cicloergómetro, aunque la dependencia del oxígeno en este tipo de esfuerzos es pequeña. La intensidad del esfuerzo es un modulador determinante en las modificaciones de la difusión pulmonar con relación al ejercicio.

Palabras clave:
Capacidad de difusión pulmonar. Ejercicio intermitente en hipoxia. Edema pulmonar de altura. Hipoxia hipobárica.

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Introduction

The physiological benefits of exercise training have long been studied, including cardiac remodelling, increase in capillary density, and improvement of muscle oxidative capacity among others with continuous and interval exercise training[1-3]. However, pulmonary structural and functional capabilities seem to do not significantly change in response to anaerobic nor aerobic training in healthy subjects[4], except in aquatic sports such as swimming[5] or artistic swimming[6].

Different exercise modalities have been largely utilized to improve exercise performance and health. During last years, evidence is amounting regarding the positive effect of exercise, from sport high performance to clinical rehabilitation, both in elite athletes and subjects with chronic pathologies[7,8]. However, it remains unknown whether there are acute changes in the structural or functional properties of the lungs in response to anaerobic and aerobic exercise.

Measures of carbon monoxide diffusing capacity of the lungs (DL_{CO}) are widely utilized to evaluate the gas conductance from the alveoli to the blood[9]. Acute changes in DL_{CO} have been already described in relation to exercise. Lung diffusion capacity increase with exercise to meet the demand of O_2 by means of an expansion of the pulmonary capillary network due to the increase in cardiac output and pulmonary perfusion pressure at sea level[10,11]. Then, from rest to peak exercise, DL_{CO} may increase up to 150%[12]. Consequently, aerobic performance[13], maximal oxygen uptake (VO_{2max})[14], and quality of life[15] has been correlated with DL_{CO} values. However, in some cases the permeability of the alveolar-capillary barrier has been impaired after exercise[16], possibly due to pulmonary hypertension and capillary wall stress failure in the lungs[17].

High-altitude exposure also provokes changes in DL_{CO} although there is no consensus about the conditions needed to provoke changes in DL_{CO} in relation to exercise at high-altitude, with some studies describing slightly decrease or increase and other studies finding no changes in DL_{CO}[18-21]. Although intermittent hypoxic exercise is becoming popular, to the best of our knowledge it remains unclear how lung function cope with this exercise modality.

In this study, we aimed to evaluate the acute changes in DL_{CO} after different modalities of exercise, at SL and simulated HA under artificial hypobaric conditions. We evaluate DL_{CO} at SL, after a 30-s maximal intensity exercise (SL-ANA) and after moderate intensity continuous exercise (SL-AER). An additional aim is to analyse whether changes in DL_{CO} are correlated to power output (watts) performed in the (SL-ANA). Later, we evaluate DL_{CO} at 4,000 m of HA, at rest (HA-R) and after moderate intensity interval exercise (HA-AER).

Material and method

Participants

The participants were 9 healthy non-smoker subjects, including 6 females and 3 males (age: 24.3 ± 3.1 years, height: 167.9 ± 9.8 cm, body mass: 60.3 ± 8.7 kg) with no history of cardiovascular or respiratory abnormalities. All of them were physically active university students who performed on average 3 sessions of moderate exercise per week. None had asthma, recent upper respiratory tract infections or other respiratory conditions.

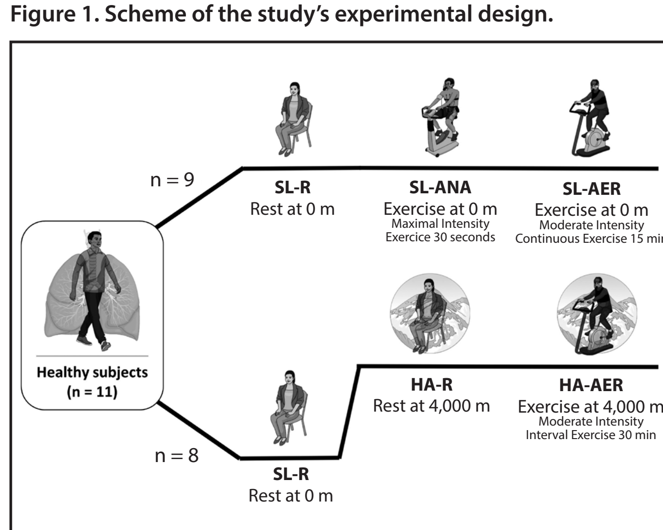
Experimental design

The participants performed two DL_{CO} measurements before the start of the study to become familiar with the procedure. A cycle ergometer (in aerobic test: Corival Lode BV, Groningen, Netherlands; in Wingate test: Excalibur Lode BV, Groningen, Netherlands) was used to do the exercise protocols, and a computerized spirometer (Easy One Pro, ndd Medical Technologies, Zurich Switzerland) was used to evaluate DL_{CO} and other pulmonary parameters.

The participants reported to the laboratory on two occasions. Figure 1 shows a schematic representation of the experimental design. The first day, measurements of lung diffusion capacity were performed at rest at sea level (SL), after 30-seconds maximal intensity exercise (Wingate test) (SL-ANA), and after 15-minutes of continuous aerobic exercise at 30% Watts (W) of the maximal W performed in the Wingate test (SL-AER). The second day, lung diffusing capacity was evaluated in relation to exercise during a short-term exposure to hypobaric HA at 4,000 m. The participants performed another basal measurement in resting condition at sea level (SL-R). Then, they reached the target barometric pressure of 462 torr (equivalent to 4,000 m of altitude) in the hypobaric chamber. After at least 30 minutes of reaching target barometric pressure, measurements were performed again in a resting condition (HA-R), and immediately after 30 minutes of moderate interval exercise at the same artificial high-altitude (HA-AER).

Due to the inability to sustain 15 minutes of continuous exercise at the intensity proposed at SL-AER, the exercise duration was separated in interval sets during HA-AER. The exercise interval protocol consisted of 5 sets with 3 minutes at moderate intensity (30% W of the maximal W performed in the Wingate test) interspersed with 3 minutes of active recovery (25 W). The computerized spirometer utilized to measure DLCO was placed inside the hypobaric chamber during the HA measurements. Measurements in the HA-AER condition was taken

Figure 1. Scheme of the study's experimental design.



between 1 to 2 h after hypoxic exposure. Exercise at HA was monitored by pulse oximeter oxygen saturation (S_pO_2) and heart rate (HR) to ensure an optimal health status during exercise. To ensure a safe HA exposure in the unacclimated subjects, there was no Wingate test at 4,000 m.

All the measures considered were "grade A" manoeuvres (>90% of VC_{IN} and VA within 0.2 L or 5% of largest VA from another acceptable manoeuvre)[22]. In addition, the haemoglobin (Hb) concentration was determined from a small blood sample obtained by venepuncture to adjust DL_{CO} to individual parameters before the beginning of the study.

Pulmonary function measurements

The procedure used to obtain diffusion lung capacity parameters was the single-breath method, for which a computerized spirometer was attached to a gas mixture cylinder. This method involves measuring the uptake of CO from the lungs over a short breath-holding period. The recommendations made in a recent joint statement by the American Thoracic Society (ATS) and the European Respiratory Society (ERS) were followed[22]. The participants were placed in a seated position, with a mouthpiece and nose-clip in place throughout the test procedure. The test started with tidal breathing for 2–4 breaths until the subject felt comfortable with the mouthpiece. Then the DL_{CO} manoeuvre began with an unforced exhalation to residual volume (RV). At residual volume (RV) the subject's mouthpiece was connected to the source of test gas, and the subject inhaled rapidly to maximal inspiration. After that, the participant was asked to hold their breath for 10 s and then exhale completely without interruption in fewer than 4 s and to continue with a tidal breath to finish the test. The test gases mixture used to calculate pulmonary function and diffusion capacity was composed of 0.3% of carbon monoxide (CO), 11% of a tracer inert gas (He) used to measure VA and the initial alveolar CO, a mixture of 20.9% of oxygen (O_2) and the remainder was nitrogen (N_2). In addition to DL_{CO} and VA, transfer coefficient of the lung for carbon monoxide (K_{CO}), total lung capacity (TLC), vital capacity inspired (VC_{IN}) and residual volume (RV) were calculated.

Ethics approval and consent to participate

The study was developed in accordance with the Helsinki Declaration concerning the ethical principles of human experimentation and approved by the Institutional Ethical Committee from the University of Barcelona (Institutional Review Board number IRB00003099), in accordance with current Spanish legislation. The participants were informed and familiarized with all the experimental procedures, as well as the risks and benefits of the study. They signed an informed consent form and were free to withdraw from the experimental protocol at any time.

Statistical analysis

Data are reported as mean values ± standard deviation (SD). Differences in pulmonary functional and structural parameters between conditions were analysed using a one-way repeated measures analysis of variance (ANOVA) respectively, and in case of detecting statistical effects (P <0.05), Bonferroni corrections were performed. Effect sizes as partial eta squared (η^2_p) values were employed to present the magnitude of differences and statistical power (sp) was also described. The analyses were performed using the SPSS v. 20 (IBM SPSS Statistics, Armonk, New York, USA).

Results

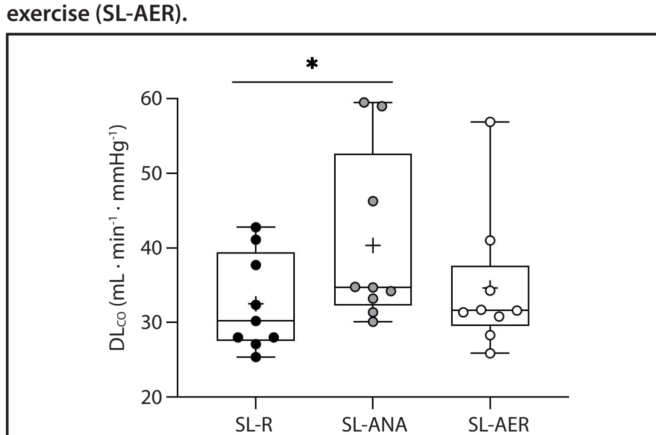
Table 1 shows the response in pulmonary functional and structural parameters to SL conditions. There was a significant interaction between changes in DL_{CO} and exercise conditions at SL (F = 7.82, P = 0.004, η^2_p = 0.49, sp = 0.905; Figure 2), including an increase in DL_{CO} from SL-R to SL-ANA (32.5 ± 6.4 to 40.3 ± 11.6 $mL \cdot min^{-1} \cdot mmHg^{-1}$, P = 0.027). However, there was no differences from SL-R to SL-AER (P = 0.873) or from SL-ANA to SL-AER (P = 0.058). In the case of K_{CO}, there was also a significant interaction between conditions at sea level and K_{CO} (F = 8.32, P = 0.003, η^2_p = 0.51, sp = 0.992), presenting a significant increase from SL-R to SL-ANA (P = 0.003).

Table 1. Pulmonary parameters response to the different conditions studied at sea level (SL): Basal (SL-R), after 30-seconds maximal intensity exercise (SL-ANA), and after moderate intensity continuous exercise (SL-AER).

	SL-R	SL-ANA	SL-AER
DL_{CO} ($mL \cdot min^{-1} \cdot mmHg^{-1}$)	32.5 ± 6.4	40.3 ± 11.6[a]	34.7 ± 9.3
DL_{CO} (%-predicted)	126 ± 11	154 ± 13	134 ± 13
K_{CO} ($mL \cdot min^{-1} \cdot mmHg^{-1} \cdot L^{-1}$)	6.02 ± 0.48	6.70 ± 0.64[a]	6.26 ± 0.71
K_{CO} (%-predicted)	124 ± 10	138 ± 10	129 ± 11
VA (L)	5.39 ± 0.94	5.97 ± 1.33	5.58 ± 1.29
VA (%-predicted)	101 ± 8	111 ± 9	104 ± 11
TLC (L)	5.54 ± 0.94	6.13 ± 1.33	5.73 ± 1.29
TLC (%-predicted)	101 ± 8	111 ± 9	104 ± 11
VCIN (L)	4.01 ± 0.92	3.89 ± 0.89	3.84 ± 0.84
RV (L)	1.54 ± 0.50	2.23 ± 0.66[a]	1.91 ± 0.79

[a]Significantly higher than SL-R (***P*** <0.05).

Figure 2. Changes in DLCO from sea level at rest (SL-R), to after 30-s maximal exercise (SL-ANA), to after 15-min moderate continuous exercise (SL-AER).



*Significant differences between conditions (P < 0.05).

Regarding lung volumes, there were no significant differences in structural parameters along the SL conditions such as VA ($P = 0.115$), TLC ($P = 0.115$) or RV ($P = 0.095$).

Figure 3 shows the correlation between DL_{CO} at SL-R and average Watts (W) performed in the Wingate test (R = 0.95), in which the studied sample developed an average of 523 ± 166 W and 8.56 ± 1.65 W/Kg in the 30-s of exercise. It is also showed the correlation between the changes in DL_{CO} (ΔDL_{CO}) from basal to after SL-ANA and the Watts performed at the Wingate test (R = 0.63).

Table 2 shows the response in pulmonary functional and structural parameters to HA conditions. At the hypobaric chamber, there were no differences between SL-R, HA-R, and HA-AER in any of the main pulmonary parameters evaluated such as DL_{COadj} (DL_{CO} adjusted to barometric pressure) (Figure 4), K_{CO} and VA.

Figure 3. (A) Correlation between DL_{CO} at sea level at rest (SL-R) and the average watts (W) performed after 30-s maximal exercise (SL-ANA), and (B) correlation between the changes in DL_{CO} (ΔDL_{CO}) from SL-R to SL-ANA and the W performed at SL-ANA.

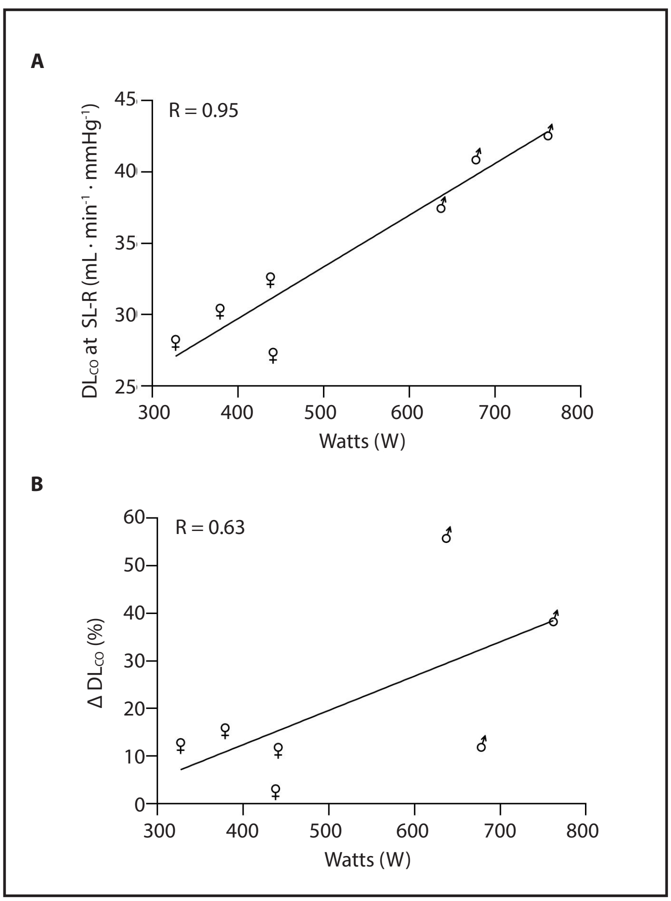
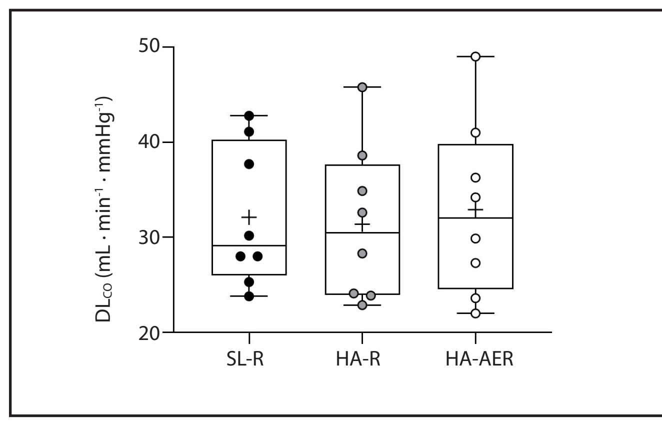


Table 2. Pulmonary parameters response to the different environmental and exercise conditions studied at 4,000 m high-altitude (HA): Sea level at rest (SL-R), simulated high-altitude at rest (HA-R) and simulated high-altitude immediately at the end of exercise (HA-AER).

	SL-R	HA-R	HA-AER
DL_{COadj} ($mL \cdot min^{-1} \cdot mmHg^{-1}$)	32.1 ± 6.7	31.4 ± 8.2	32.9 ± 9.1
DL_{COadj} (%-predicted)	121 ± 13	118 ± 14	125 ± 17
K_{COadj} ($mL \cdot min^{-1} \cdot mmHg^{-1} \cdot L^{-1}$)	5.93 ± 0.48	5.73 ± 0.85	6.09 ± 0.70
K_{COadj} (%-predicted)	122 ± 10	118 ± 16	128 ± 21
VA (L)	5.39 ± 0.95	5.51 ± 1.28	5.42 ± 1.43
VA (%-predicted)	99 ± 9	101 ± 15	98 ± 12
TLC (L)	5.54 ± 0.95	5.66 ± 1.28	5.57 ± 1.43
TLC (%-predicted)	99 ± 9	101 ± 15	99 ± 12
VCIN (L)	4.06 ± 0.88	3.83 ± 0.88	3.99 ± 0.94
RV (L)	1.48 ± 0.51	1.83 ± 0.51	1.59 ± 0.66

Figure 4. Changes in DL_{CO} from sea level at rest (SL-R), to simulate altitude at rest (HA-R), to after 30-min moderate interval exercise (HA-AER).



Discussion

The main finding of this study was the high increase in DL_{CO} (+24%) after 30-s maximal intensity exercise (Wingate test) in a cycle ergometer when compared to rest. However, after 15-min of moderate intensity exercise, DL_{CO} returned to resting levels, suggesting that exercise intensity may be a key modulator of pulmonary function in healthy subjects.

During HA exposure, there were no changes in any pulmonary parameter during the exposure to 4,000 m in the hypobaric chamber (HA-R and HA-AER), suggesting that pulmonary system of healthy subjects cope well with a short-term conditional exposure to exercise and high altitude.

Changes in DL_{CO} in relation to exercise at SL

The Wingate test is considered the most common test to evaluate anaerobic (sprint) cycling performance. In our study, lung diffusing capacity (DL_{CO} and K_{CO}) increased more in this short and explosive exercise compared to 15-min of moderate intensity continuous exercise.

To the best of our knowledge, this is the first study that evaluates acute changes in DL_{CO} after anaerobic exercise, although some studies have investigated the relationship between aerobic performance and DL_{CO} both in the short-term and long-term. Lalande *et al.*[23] showed that individuals with higher maximal aerobic capacity have a more distensible pulmonary circulation. The expansion of the pulmonary vasculature appeared not to reach a plateau during maximal aerobic exercise[14]. Interestingly, the changes in DL_{CO} found by Lalande *et al.*[23] were similar to our results, with an increase of 27 and 24% respectively. We probably did not find a similar DL_{CO} response after 15-min of moderate intensity exercise due to the lower intensity applied compared to the Wingate test and the maximal aerobic exercise utilized by Lalande *et al.*[23]. Therefore, exercise intensity seems to be an important factor to provoke a short-term increase in lung diffusion, ahead of oxygen requirements or exercise duration, and probably due to the increased requirements for CO_2 elimination.

During exercise, alveolar-capillary diffusion increases in proportion to the increase in metabolic rate, but there is no causal response between metabolic rate and hyperpnea, and the mechanisms involved in the increase in ventilation during exercise has not been fully elucidated[24]. Volitional exercise requires activation of the central nervous system (CNS), in which neural feed-forward (central command) mediate the exercise hyperpnea[24]. The rapid increase in DL_{CO} from our study probably take part of the same physiological mechanism. The entire organism tried to adjust the cardiovascular and ventilatory systems to maximal intensity exercise[25], despite 30-s anaerobic exercise barely relying on O_2-dependent energy production. This rapid response also makes sense since lung diffusion in the first limiting step of aerobic performance along the O_2 transport cascade and the increase in cardiac output has been shown to be faster than VO_2 kinetics[26].

Correlation DL_{CO} - Wingate

Anaerobic performance measured in Watts correlated closely with DL_{CO} at SL-R (R = 0.95; Figure 2), suggesting that central command-mediated intensity rather than O_2-dependent metabolism is the key in DL_{CO} changes. Figure 2 also shows how changes in DL_{CO} (Δ DL_{CO}) respond to Wingate test anaerobic power (R = 0.63). In this regard, DL_{CO} does not only correlates with VO_{2max} and aerobic performance[27], but also correlates with neuromuscular anaerobic power. Muscular strength has been already correlated with lung function in some studies[28] which may explain the close relationship between DL_{CO} and neuromuscular power.

Our results also suggest that lung volume (VA and TLC) tend to increase, but this change is not statistically significant, after maximal intensity exercise (SL-ANA). Changes in lung volumes also has been suggested to participate in DL_{CO} changes during exercise periods[28], but at the best of our knowledge there have not been described elsewhere. Potentially, we suggest that interval maximal work could induce sufficient mechanical and/or physiological stimulus to promote a long-term improvement in lung diffusion capacity (e.g., alveolar growth, increased permeability of the alveolar–capillary membrane) or lung growth[4].

Changes in DL_{CO} in relation to exercise at HA

In this study, there were no changes in lung diffusion upon arrival to 4,000 m at rest nor after exercise in a short-term HA exposure of 60 minutes, although some relevant risk factors to the development of pulmonary oedema were also induced in our experimental design such as rapid ascent rate, high-altitude and intervals of strenuous exercise. However, our data supports the idea that short-term exposures to HA seems to be in-sufficient to provoke capillary wall stress failure in the lungs[29].

During HA exposure, in some cases, an exacerbation in the permeability properties of the lung capillary endothelium can create an imbalance between pulmonary vascular leakage and alveolar fluid reabsorption[30,31], although a large inter-individual response has been described[32,33]. We suggest that the activity of the pulmonary lymphatics regulated the rate of fluid clearance from the interstitial space well under short-term severe hypoxic exposure in healthy subjects, avoiding significant changes in lung diffusing capacity. The appearance of pulmonary oedema under specific conditions of low PO_2 and high blood flow due to exercise may provoke diffusion unbalance[34,35], although in some cases an additional functional reserve can be recruited to improve membrane O_2 diffusing capacity during exercise in hypoxia[33,36].

The literature is unclear regarding the conditions needed to provoke changes in lung diffusing capacity. Senn *et al.* [37] found a slight decrease in DL_{CO} after a rapid ascent (3 h) to 4,559 m compared to baseline at 490 m. Agostoni *et al.*[38] also found a slight decrease in DL_{CO}, and an increase in ultrasound lung comets (ULCs) at 4,559 m after 36 h, suggesting that interstitial lung oedema can occur relatively rapid in healthy lowlanders. However, Snyder *et al.*[39] found that exercise in hypoxia increased DL_{CO} and reduced lung fluid accumulation due to acceleration in alveolar fluid clearance in a 17-h exposure to normobaric hypoxia (FIO_2 = 12.5%). Prolonged exposure to HA could be necessary to elicit changes in lung diffusion capacity, although the evidence is also unclear. In this regard, Clarenbach *et al.*[32] found 8 cases of HAPO in a group of 18 mountaineers, but DL_{CO} was only decreased after 3 days of exposure to 4,559 m. In turn, de Bisschop *et al.*[40] showed a post-exercise decrease in lung diffusing capacity for nitric oxide (DL_{NO}), but no changes in DL_{CO} after 7 days at 5,050 m. Nonetheless, Taylor *et al.*[41] found a significant increase in DL_{CO} after an 8-day hike and 5-day stay at 5,150 m in mountaineers. At the best of our knowledge, this is the first study assessing DL_{CO} changes during short-term altitude exposure with exercise. As it can been assumed after the results at sea level, exercise intensity seemed a relevant factor to induce DL_{CO} modifications. Therefore, the moderate intensity interval exercise proposed at high-altitude could have influenced the lack of DL_{CO} modifications during hypobaric hypoxic exercise. From a security point of view, the participants of this study were healthy subjects, but unaccustomed to strenuous exercise at high altitude neither highly trained athletes. As a result, a limitation in the exercise intensity performed at 4,000 m was not possible to elude.

We suggest that there was no decrease in DL_{CO} due to a pulmonary interstitial fluid fine balance between pulmonary capillary fluid leakage and the rate of fluid removal from the thoracic lymphatic ducts during short-term exposure to HA[12,42]. Also, the induced increase in interstitial lung fluid could be masked by an additional recruitment of the pulmonary vasculature during hypoxic exercise due to limitations in O_2 uptake in the lungs under low barometric pressure conditions[33].

Strengths and limitations

The duration and intensity of the exercise may be decisive to find an increase, no changes, or a decrease in DL_{CO}. Dynamics of lung diffusing equilibrium may change depending on these factors, and inter-individual physiological status.

Another concern is the use of indirect measurements of interstitial lung fluid. Although DL_{CO} has been consistently associated with an increase in extravascular lung water[32,39], the study of DL_{NO} is more sensitive to detect very mild interstitial fluid accumulation[43]. A combination of DL_{CO} and DL_{NO} would be more descriptive of changes in lung diffusion since DL_{NO} is minimally affected by haemoglobin and pulmonary blood volume (V_C). One relevant strength from this study is that all the DL_{CO} measurements were taken into the first minute after exercise. Most of the studies have assessed DL_{CO} 30 to 120 min after exercise suggesting that the potential decrease in $DL_{CO}$is due to blood volume redistribution to the peripheral organs after exercise, a hypothesis that may be dismissed in our study.

Acknowledgements

The authors would like to thank all participants for their time and commitment in undertaking this study. Also, we would like to thank Mr. Álvaro Sánchez–Nieva (Sanro Electromedicina) for kindly supplying the equipment needed to conduct this research. We are grateful to Mrs. Lynette Stewart for her help in the proofreading of the manuscript.

Conflicts of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Anthropometric differences and maximal aerobic power among men and women in racing-boat rowing

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doi: 10.18176/archmeddeporte.00145

Received: 09/06/2022
Accepted: 28/04/2023

Summary

Anthropometric, mechanical and performance differences have been observed in rowing between rowers from the same club competing in different categories. Maximal aerobic power has been defined as one of the best predictors of rowing performance. The aim was to observe differences between male and female rowers in anthropometric, physiological and aerobic power data. Weight (P), height (T), fat percentage (G), sum of seven folds (S7) and absolute and relative watts (W) (W/kg) of 55 subjects were assessed. Of the 55 subjects, 38 were male (26.95 ±7.0 years) and 17 were female (24.82 ±6.8 years). Cohen's d was used to calculate the effect size as standardised mean difference. In the results, sample means were obtained for the variables analysed in the different sexes (F: females and M: males). For F: [P: 77.25 (9.41) - T: 1.80 (0.07) - G: 12.77 (3.04) - S7: 72.23 (28.20) - W: 273.6 (52.88) - W/kg: 3.57 (0.67)] and for M: [P: 61.79 (6.85 - T: 1.67 (0.07) - G: 14.44 (2.47)- S7: 103.83 (28.64) - W: 171.35 (29.19) - W/kg: 2.78 (0.43)]. Finally, the results were as follows: P: 1.77 - T: 1.87 - G: 0.57 - S7: 1.11 - W: 2.17 - W/kg: 1.28. Showing significant differences and a large effect size between both sexes in all the variables analysed, except for the fat percentage variable.

Key words:
Water Sports. Rowing. Physiology. Body composition

Diferencias antropométricas y potencia aeróbica máxima entre hombres y mujeres en el remo de traineras

Resumen

En el remo de traineras se han observado diferencias antropométricas, mecánicas y de rendimiento entre remeros de un mismo club que competían en distintas categorías. La potencia aeróbica máxima se ha definido como uno de los mejores predictores del rendimiento en el remo. El objetivo fue observar diferencias entre de remeros y remeras en datos antropométricos, fisiológicos y de potencia aeróbica. Se evaluó el peso (P), la talla (T), el porcentaje graso (G), el sumatorio de siete pliegues (S7) y los vatios (W) absolutos y relativos (W/kg) de 55 sujetos. De los 55 sujetos, 38 fueron hombres (26,95 ±7,0 años) y 17 mujeres (24,82 años ±6,8). Para calcular el tamaño del efecto como diferencia de medias estandarizadas se utilizó la d de Cohen. En los resultados, se obtuvieron medias muestrales en las variables analizadas en los diferentes sexos (M: mujeres y H: hombres). Para H: [P: 77,25 (9,41) – T: 1,80 (0,07) – G: 12,77 (3,04) – S7: 72,23 (28,20) – W: 273,6 (52,88) – W/kg: 3,57 (0,67)] y para M: [P: 61,79 (6,85 - T: 1,67 (0,07) – G: 14,44 (2,47)- S7: 103,83 (28,64) – W: 171,35 (29,19) – W/kg: 2,78 (0,43)]. Finalmente los resultados fueron los siguientes: P: 1,77 – T: 1,87 – G: 0,57 – S7: 1,11 – W: 2,17 – W/kg: 1,28. Mostrando diferencias significativas y un tamaño del efecto grande entre ambos sexos en todas las variables analizadas, exceptuando la variable del porcentaje graso.

Palabras clave:
Deportes acuáticos. Remo. Fisiología. Composición corporal.

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Introduction

There are various competition modalities within fixed-seat rowing, depending on geographic location. On the one hand, along the coastline of the Bay of Biscay (French Basque Country, Spanish Basque Country, Cantabria, Asturias and Galicia) there are rowboats used for racing called batel, *trainerilla* and *trainera*,[1] while the Mediterranean regions have their own versions such as the *Falucho i*n the Valencian Community, the *Llagut* in Catalonia, the *Jábegas* in Andalusia and the *Llaüt* which unifies the competitions in the three Mediterranean modalities[2].

In the Bay of Biscay, men have been competing in *trainera* competitions for many years,[3,4] although women did not take part in official *trainera* regattas until 2008.[5] Female participation in *trainera* regattas grew from that moment on as reflected in the number of female federated rowers, setting up and consolidating sporting structures and the number of boats that compete[6,7].

Physical performance is the most researched aspect of *trainera* rowing. Specifically, the maximal aerobic power (MAP), defined as the work intensity when achieving VO_{2max},[8-10] was determined as one of the best predictors of rowing performance.[11-13] In addition, articles have been published recently which demonstrate performance differences between genders.[14-16] As demonstrated in other sports, this parameter is also useful in rowing due to the simplicity attributed to it when designing, controlling and performing the training[17-19].

Anthropometric and mechanical analysis was also carried out in this sport, as previous studies had determined them both as performance predictors,[13] even pinpointing differences between rowers in the same club who compete in different categories.[4,20] In addition, body mass has been shown to be performance-related.[20,21] Furthermore, regarding *trainera r*owing, physiological and anthropometric differences have been observed between the different categories in the Bay of Biscay *trainera* leagues[18] (Asociación de Clubes del Cantábrico (ACT), Asociación de Remo del Cantábrico (ARC1) and its subsidiary (ARC2).

Regarding female rowers, as far as we know, no study has analysed the physiological or performance aspects among the different categories in the *Liga Euskotren, Asociación de Traineras de Mujeres* (ETE) and *Liga Gallega de Traineras* (LGT) rowing leagues. However, there are studies which determine differences between genders in other rowing disciplines.[15,16] Therefore, it can be asserted that research into female trainera rowing has not accompanied increased participation in this sport[14].

Considering all the above, the aim of this paper was to analyse and compare MAP and anthropometric differences between the different categories and gender of *trainera* rowing.

Material and method

Design and participants

In the cross-sectional observational study, 55 subjects were recruited from Level 3 highly trained/national level,[22] 38 men (26.9 ± 7.0 years old) divided into two categories (ARC1 = 18; ARC2 = 21) and 17 women from the ETE category (24.8 ± 6.8 years old). The measurements were taken in the rowing club facilities during the months of the general preparatory phase before the *trainera* season. To be precise, the data was compiled in January, after 11 weeks of general strength training and aerobic work. The participants freely agreed to have measurements taken, as routine tests carried out during season preparation, so the subjects were familiar with the tests they were going to take.

The study was approved by the Ethics Committee of the Ramón Llull University (reference 1920005D) and each participant gave their informed consent in writing before it began.

Variables, measuring instruments and procedures

Body composition was defined by weight (P), height (T), fat percentage (G), body mass index (BMI) and the sum of seven skinfolds (S7). This was done by using a mechanical column scale with a height rod (Año Sayol SL 150 KGS- Medical Weighing Scales) and a Holtain skinfold calliper (HOL-98610ND - precision of 0.2 mm). These tests were carried out on all participants in the same time slot (4:00 to 7:00 pm), using the method from the International Society for the Advancement of Kinanthropometry[23] and always by the same trained, experienced person. To calculate the fat percentage, Faulkner's equation was used, derived from the Yuhasz's equation [% Fat Weight = 0.153*(Triceps fold + Subscapular fold + Suprailiac fold + Abdominal fold) + 5.783].[23] The S7 was obtained using the 7-site skinfold equation, which is determined by adding the following seven skinfolds: biceps, triceps, subscapular, suprailiac, abdominal, quadriceps and calf[24].

The mechanical parameters were defined by the absolute power (W) and power relative to the weight (W/kg). To do this, a test was performed lasting up to 4 minutes on a Concept 2 indoor rower (Model D, Morrisville, VT, USA) modified for fixed seat.[18,25] Before the maximal test, there was a prior warm-up lasting 20 minutes,[26,27] broken down into 4 x 4-minute sessions, increasing the power in each session simulating the total volume of the maximal test, with one minute's rest and total recovery before performing the last stage,[28] so that the system can fully recover before maximal effort. This last maximal 4-minute stage[29-33] determined the MAP, noting the average power. The resistance from the Drag Factor was 140 in men[34] and 120 in women, as women have less body mass, so the drag factor must be adjusted accordingly[35].

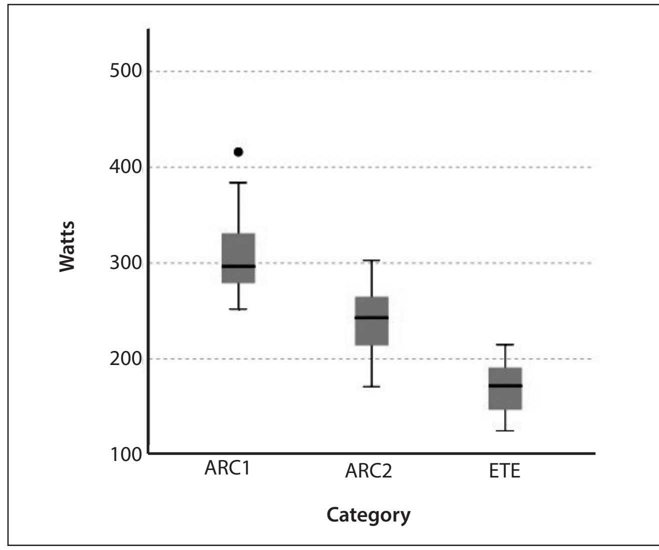
Statistical analysis

The IBM SPSS Statistics software (version 26) was used to analyse the variables. The quantitative variables are presented as means and standard deviation. Due to the small sample size and the high variance within the group, non-parametric tests were performed to analyse the data. The Mann-Whitney U test for independent samples was performed to analyse gender differences in the P, T, G, S7, W and W/kg variables. The Kruskal-Wallis test was used to analyse differences in the variables between the categories. Furthermore, Spearman correlations were made between the gender, category, P, T, S7, W and W/Kg variables. The size of the effect was calculated using Cohen's d to analyse the standardised mean difference (SMD); an effect size of 0.2-0.49 would be considered small, 0.5-0.79 moderate and 0.8 or above as high[36].

Results

Table 1 shows the descriptive data for the sample being analysed, with significant differences in the average Watts between categories (Figure 1). Significant differences are also seen between ARC1-ARC2 in absolute power (W) (p <0.00) and relative power (W/Kg) (p <0.00), between ARC1-ETE in absolute power (p 0.00) and relative power (p <0.00) and between ARC2-ETE in absolute power (p <0.00), on the contrary, ARC2-ETE did not show significant differences in relative power (p <0.07). Cohen's d demonstrates high differences between genders in all the variables analysed, excluding the G variable (P = 1.77; T = 1.87; G = -0.57; S7 = -1.11; W = 2.17 and W/Kg = 1.28) (Table 2).

Figure 1. Difference in Watts between categories



*p<0,05.

Discussion

This study analysed and compared the anthropometric profile and the body composition in male and female *trainera* rowers, and the role of these variables in predicting rowing performance. Our results concur with other researchers that variables such as T[24] and G are decisive for the MAP,[15,25] as this is a priority indicator for good results in this discipline.[6-26] On the other hand, like other authors, differences were seen in the MAP in different male categories[18] and between genders[16,37]. The differences in MAP production are similar to results obtained in the study by Penichet-Tomas et al. (2023), where the differences between male and female rowers was 105.5 W compared to 102.3 W, as observed in this study. Furthermore, it is well-known that morphological characteristics are just as decisive in success in this sport.[38,39] Our study seems to confirm this evidence, observing significant correlations for the power generated with the morphological variables analysed (T vs W/Kg = 0.31; T vs W = 0.67; P vs W = 0.60).

It is known that women have a higher fat percentage than men, even at birth.40 The results show a negative correlation between the fat percentage both in the W (r = -0.42) and in the W/Kg (r = -0.51)

Table 1. Average values per category.

Category	N	Weight	Height	Age	BMI	S7	Fat	W	W/Kg
ARC1 (1)	18	79.13 (9.65)	1.83 (0.07)[3]	31.00 (6.49)[2,3]	23.44 (1.59)	68.22 (15.68)[3]	12.53 (1.89)[3]	309.22 (42.95)[2,3]	3.93 (0.46)[2,3]
ARC2 (2)	21	75.55 (9.08)[3]	1.78 (0.05)[3]	23.30 (5.37)[1]	23.80 (2.58)	75.85 (36.06)[3]	12.99 (3.84)[3]	241.55 (38.87)[1,3]	3.25 (0.68)[1]
ETE (3)	17	61.79 (6.85)[2]	1.67 (0.07)	24.82 (6.83)	22.11 (2.29)	103.83 (28.64)	14.44 (2.47)	171.35 (29.19)[1,2]	2.78 (0.43)[1]

Data presented as means and standard deviation. [1-2-3]. Significant differences (p <0.05) between categories.

Table 2. Differences between genders.

	Men	Women	Differences	Cohen's *d*	*p*-value
Weight	77.25 (9.41)	61.79 (6.85)	15.46	1.77	<.001
Height	1.80 (0.07)	1.67 (0.07)	0.13	1.87	<.001
BMI	23.63 (2.15)	22.11 (2.29)	1.52	0.69	0.10
Fat percentage	12.77 (3.04)	14.44 (2.47)	-1.67	-0.57	0.01
S7	72.23 (28.2)	103.83 (28.4)	-31.60	-1.11	<.001
Watts	273.60 (52.88)	171.35 (29.19)	102.25	2.17	<.001
W/kg	3.57 (0.67)	2.78 (0.43)	0.79	1.28	<.001

Table 3. Correlations between variables.

Gender	Category	Weight (P)	Height (T)	Folds (S7)	Absolute (W)	Relative (W/Kg)	
Gender -							
Category	0.85**	-					
P	-0.64**	-0.61**	-				
T	-0.66**	-0.68**	0.78**	-			
S7	0.46**	0.44**	-0.00	0.40**	-		
W	-0.71**	-0.83**	0.60**	0.67**	-0.42**	-	
W/Kg	-0.51**	-0.65**	0.10	0.31*	-0.51**	0.84**	-

*Significance at p<0.05 - ** Significance at p <0.01

Table 4. Differences between genders.

Results	Men	Women	Differences	Cohen's *d*
Weight	77.25 (9.41)	61.79 (6.85)	15.46	1.90
Height	1.80 (0.07)	1.67 (0.07)	0.13	1.85
Fat percentage	12.77 (3.04)	14.44 (2.47)	-1.67	-0.60
S7	72.23 (28.2)	103.83 (28.4)	-31.60	-1.11
Watts	273.6 (52.88)	171.35 (29.19)	102.25	2.49
W/kg	3.57 (0.67)	2.78 (0.43)	0.79	1.43

(Table 3), so it seems that a low-fat percentage is beneficial to improve sporting performance.[38] These results in the anthropometric differences concur with other studies,[18] which conclude that controlling body mass in relation to the lean mass and the fat percentage could be decisive to achieve greater success in this sport, where there is inverse association between the evolution of anthropometric and physiological parameters.[15] In concordance with the study by Podstawki *et al*., (2022) significant differences were seen in anthropometric and mechanical characteristics (P, T, G, S7, W, W/kg <0.001).

This suggests new research on comparing different performance-related values and variables between men and women in the *trainera* rowing sport, as some studies have demonstrated differences in the kinematic parameters for the rowing technique.[41,42] Our results indicate a high effect size between men and women in the power and body composition variables (Table 4), so that male rowers seem to produce more power than female rowers in consonance with other studies.[2,42]

On the other hand, as might be expected,[4,18] significant differences can be seen when analysing the composition categories in the performance parameters, giving higher levels in the highest-level category (Table 1).

The gender-related differences observed in the fixed-seat sport[43] suggest the need to run an analysis which might improve the trainera design for women, as the physiological and anthropometric needs of female rowers seem to clearly differ from their male counterparts. If the distances, performance and body composition differ between genders, it is clear that the boat should be reviewed.

Conclusions

Traditional male rowers were significantly taller and heavier than their female counterparts, with higher values in absolute and relative power. Furthermore, women demonstrated a higher sum of skin folds, and a higher percentage of fat. Consequently, it is recommended to consider the training methodology and adjust boats to the sexual dimorphism noted between male and female rowers.

Conflicts of interest

The authors declare that there is no conflict of interest.

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Prevalence of electrocardiographic abnormalities in elite and sub-elite professional athletes

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doi: 10.18176/archmeddeporte.00146

Received: 07/11/2022
Accepted: 05/06/2023

Summary

Objective: The objective of this study is to determine the prevalence of electrocardiographic abnormalities that could endanger the lives of elite and sub-elite professional athletes based on normal, borderline, and abnormal findings described in international recommendations.
Material and method: This retrospective observational study was performed only on men elite football players, men elite baseball players, men elite basketball players, and men sub-elite football players (second division, third division, U-15, U-17, and U-20). Data were collected from pre-competition ECGs performed by team-affiliated physicians in the 2012 – 2019 preseasons of active-roster athletes and sub-elite players. The qualitative characteristics of each ECG were analyzed using the international recommendations for electrocardiographic interpretation in athletes to detect accepted training-related ECG findings and findings classified as borderline and abnormal.
Results: A total of 716 ECGs were included. Common training-related ECG changes were found in 63.1%; sinus bradycardia was the most prevalent training-related ECG change (47.2%). The prevalence of borderline ECG readings among all the participants was 3.9%; the most frequent change was right axis deviation. The prevalence of abnormal ECG findings overall was 4.2%.
Conclusion: Electrocardiographic changes in athletes are frequently seen; however, a constant review of changes within abnormal or borderline parameters is recommended. It is suggested that further research studies should study the electrocardiographic changes in elite and sub-elite athletes and compare these changes considering the biological sex of the athletes to see if there are any differences.

Key words:
Football. Baseball. Basketball. Electrocardiographic. Athletes.

Prevalencia de alteraciones electrocardiográficas en deportistas élite y sub-élite

Resumen

Objetivo: El objetivo del presente estudio es evaluar la prevalencia de anormalidades electrocardiográficas que puedan poner en peligro la vida de deportistas profesionales élite y sub-élite, a partir de hallazgos normales, limítrofes y anormales en el ECG descritas en consensos internacionales.
Material y método: Estudio retrospectivo y observacional donde se analizaron los ECGs de 12 derivaciones en reposo de jugadores de élite de fútbol, béisbol y baloncesto y jugadores sub-élite de fútbol, solamente del género masculino. Los datos se recopilaron de ECGs previos a la competencia realizados por médicos afiliados al equipo en las pretemporadas 2012-2019 en deportistas de la lista activa y jugadores sub-élite. Se utilizaron las recomendaciones internacionales para la interpretación electrocardiográfica de deportistas en las variables cuantitativas para conocer las alteraciones electrocardiográficas aceptadas y evaluar la detección de anormalidades en el trazo para clasificarlas en anormal o en el límite.
Resultados: Un total de 716 ECGs fueron incluidos. Se encontraron cambios comunes en el ECG relacionados con el entrenamiento en el 63,1%; la bradicardia sinusal fue el cambio en el ECG relacionado con el entrenamiento más frecuente (47,2%). La prevalencia de lecturas limítrofes de ECG entre todos los participantes fue del 3,9%; el cambio más frecuente fue la desviación del eje a la derecha. La prevalencia de hallazgos ECG anormales en general fue del 4,2%.
Conclusiones: Los cambios electrocardiográficos en los deportistas se ven con frecuencia, sin embargo, se recomienda constante revisión de cambios dentro de parámetros anormales o en limitrófes. Se sugiere que estudios de investigación estudien los cambios electrocardiográficos en deportistas élite y sub-élite y que se comparen estos cambios teniendo en cuenta el sexo biológico de los deportistas para ver si existen diferencias.

Palabras clave:
Fútbol. Beisbol. Baloncesto. Electrocardiográficas. Deportistas.

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Introduction

Sudden Death in Sports (MSD) is a rare, unexpected tragic event occurring in a healthy person during sports practice or one hour after. It is due to natural, non-traumatic or non-violent causes. MSD represents the leading cause of death in athletes during sports[1].

Over the past decade, ECG interpretation standards have undergone several modifications to improve the accuracy of detecting life-threatening heart conditions in young athletes while limiting false-positive results. In February 2015, an international group in Seattle, Washington, updated the current recommendations for interpreting the ECG in asymptomatic athletes aged 12 to 35 years[2]. The International Criteria for the interpretation of the electrocardiogram aimed at asymptomatic athletes between 12 and 35 years of age but also included specific considerations for adolescent athletes 12-16 years of age and for those ≥30 years of age who have a higher prevalence of coronary heart disease[3].

The European Society of Cardiology guidelines recommends pre-participation screening (PPS) in the medical examination before sports practice. Among the aspects that can influence the prevalence of some alterations in an athlete's ECG are age, sex, race, type and intensity of training, and sports history[2].

The objective of our study is to determine the prevalence of electrocardiographic abnormalities that could endanger the lives of elite and sub-elite professional athletes based on normal, borderline, and abnormal findings in the ECG of players described in International Recommendations[4].

Material and method

Data collection and study population

This retrospective observational study was performed only on men elite football players, men elite baseball players, men elite basketball players, and men sub-elite football players (second division, third division, U-15, U-17, and U-20). Data was collected from pre-competition ECGs performed by team-affiliated physicians in the 2012 – 2019 preseasons on active-roster athletes and sub-elite players. Weight, fat mass percentage, and fat-free mass were measured with a bioimpedance scale. The maximum oxygen consumption was measured indirectly from a test of incremental and intermittent maximum effort on a treadmill with the protocol described by Kindermann[5], starting at 6 km/h with an incline of 5%. Each stage lasted 3 minutes with a passive rest of 30 seconds between each, and speed was increased by 2 km/h between each stage until volitional fatigue. Oxygen consumption was estimated with the formula described by Pugh[6], including the time spent during the last stage reached.

ECG Analysis

The resting 12-lead ECGs were recorded at a 10 mm/mV voltage and a paper speed of 25 mm/s. Quantitative ECG data were obtained with manual measurements by the investigators. The P-wave, PR interval, and QRS duration were measured to the nearest 2 ms from the averaged PQRST complex in lead II. If the PR interval was <120 ms in lead II, all leads were measured. The PR interval was categorized as short if <120 ms in all leads. The *R*- and *S*-wave amplitudes were measured to the nearest 1 μV as the mean of the highest amplitude in the QRS complexes. The maximum P-wave amplitude was measured in lead II. The QT intervals were corrected for heart rate (HR) (QTc) using Bazett's formula. The qualitative characteristics of each ECG were analyzed using the international recommendations for electrocardiographic interpretation in athletes[4] to detect accepted training-related ECG findings and findings classified as borderline and abnormal. The physiological cardiac adaptations to regular exercise consisted of increased QRS voltage for left ventricular hypertrophy (LVH) or right ventricular hypertrophy (RVH), incomplete right bundle branch block (RBBB), early repolarization, juvenile T-wave pattern, sinus bradycardia, sinus arrhythmia, ectopic atrial rhythm, junctional escape rhythm, first-degree atrioventricular block (AV) and Mobitz Type I second-degree AV block. For borderline electrocardiogram findings in athletes, left axis deviation, left atrial enlargement, right axis deviation, right atrial enlargement, and complete RBBB. The abnormal findings were *T* wave inversion, ST-segment depression, pathologic *Q* waves, complete left bundle branch block (LBBB), nonspecific intraventricular conduction disorder, epsilon wave, ventricular pre-excitation, long QT interval, Brugada type 1 pattern, profound sinus bradycardia (<30 bpm or sinus pauses >3 sec), profound atrioventricular block (>400 ms), Mobitz Type II second-degree AV block, third-degree AV block, atrial tachyarrhythmias, ventricular extrasystoles, and ventricular arrhythmias.

Statistical analysis

Categorical variables were presented as frequencies and percentages (%) and continuous variables as means and standard deviation (SD). The Kolmogorov-Smirnov test was performed to assess the normality of quantitative variables. An analysis of variance (ANOVA) was performed for multiple comparisons of parametric data and the Kruskal-Wallis's test for non-parametric data. When the comparisons were performed between only two groups, Student's t-test, or the Mann–Whitney test were used as applicable. SPSS version 25 (IBM Corp., Armonk, NY) was used for data analysis. Statistical significance was set at a p-value <0.05.

Results

Athlete characteristics and quantitative ECG variables

A total of 716 ECGs were included in the study, of which 103 were elite football players, 131 elite baseball players, 46 elite basketball players, and 436 sub-elite football players (second division, third division, U-15, U-17, and U-20). Athletes were aged 21.04 ± 6 years (range 14 – 45), the mean height was 178.6 ± 8.4 cm (range 158 – 228), and weight 75.7 ± 15.4 kg (range 49.7 – 131.8). Basketball players were taller and heavier than football and baseball players (Table 1). They also had the lowest fat mass percentage, with baseball players having the highest values. Aerobic capacity, expressed in absolute (l/min) and relative (ml/kg/min) values of maximal oxygen uptake volume, was significantly lower in baseball players than in the other groups of athletes. Training loads were similar in the three groups. Regarding ECG measurements, the

Table 1. Athlete and training characteristics by sport.

Characteristic	Sport			*p*-value
	Soccer (n = 103)	Baseball (n = 131)	Basketball (n = 46)	
Age, y	25.9 ± 4.4	27.79 ± 5.4	28.5 ± 4.3	<0.001
Height, cm	178.4 ± 6.7	182.2 ± 2.3	196.1 ± 10.6	<0.001
Weight, kg	75.3 ± 7.6	96.2 ± 12.5	98.4 ± 13.9	<0.001
BMI, kg/m^2	23.6 ± 1.6	28.9 ± 3.1	25.4 ± 1.8	<0.001
fat-free mass, kg	65.2 ± 6.9	77.6 ± 8.0	87.9 ± 13.1	<0.001
Fat mas, %	13.2 ± 3.1	18.8 ± 5.9	10.6 ± 3	<0.001
Absolute VO_2, l/min	4.3 ± 0.4	4.1 ± 0.5	4.7 ± 0.6	<0.001
Relative VO_2, ml/kg/min	54.1 ± 3	45.1 ± 5.6	48.5 ± 5.4	<0.001
Training				
- Duration, min	134.5 ± 34.2	135.6 ± 69.6	128.6 ± 32.3	0.328
- Frequency, days per week	1.3 ± 0.5	1.7 ± 0.4	1.6 ± 0.4	0.174
- Sessions, per day	5.8 ± 0.6	6.3 ± 0.7	5.4 ± 1.1	0.503

BMI, body mass index; VO_{2max}- maximal oxygen consumption. Mean ± SD.

Table 2. Quantitative ECG variables in elite soccer, baseball, and basketball players.

Variable	Sport			*p*-value
	Soccer (n = 103)	Baseball (n = 131)	Basketball (n = 46)	
Heart rate, bpm	56.17 ± 9.2	63.9 ± 10.7	54.8 ± 11.5	<0.001
PR interval, ms	171 ± 25	164 ± 25	181 ± 33	<0.001
QRS duration, ms	99 ± 81	92 ± 15	92 ± 14	0.631
QTc interval, ms	402 ± 33	385 ± 29	395 ± 31	<0.001

Mean ± SD.

mean heart rate at rest was 60.6 ± 10 bpm, the PR interval 163 ± 25.5 ms, the QRS duration 93.2 ± 38.4 ms, and the QTc interval 398.9 ± 29.6. We observed significant differences in heart rate, PR, and QTc interval among the three elite groups (Table 2).

Training-related ECG findings

Figures 1 and 2 show the prevalence of ECG findings classified as training-related, borderline, or abnormal in elite and sub-elite players. Overall, the ECG was considered normal in 91.6%, with common training-related ECG changes found in 63.1%, 16% had two or more findings. Sinus bradycardia was the most prevalent training-related ECG finding at rest (47.2%), followed by incomplete right bundle branch block (8.2%); both were more frequent in basketball players. The lowest heart rate was 35 bpm, seen in two elite football players. There were differences between elite and sub-elite ECG findings; for example, increased QRS voltage for LVH or RVH and early repolarization were more frequently observed in sub-elite than in elite players. Otherwise, first-degree AV block was seen in 6% of elite players versus 0% in the sub-elite group (Tables 3 and 4). The most prevalent training-related ECG finding with effort was incomplete RBBB (2.1%), followed by early repolarization (0.3%).

Figure 1. Prevalence of training-related, borderline, and abnormal ECG findings in elite football, baseball, and basketball players.

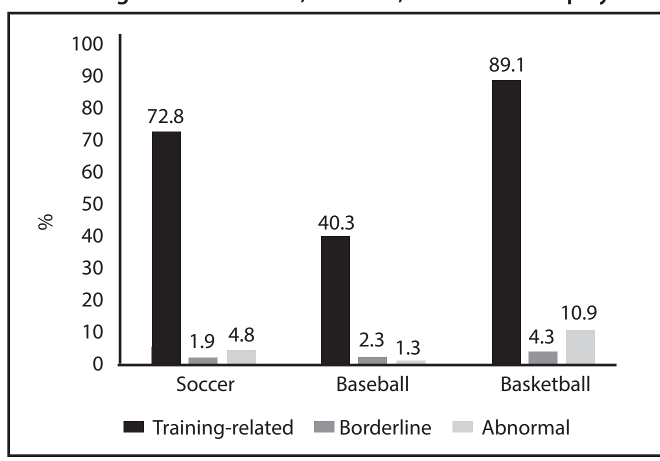

Figure 2. Prevalence of training-related, borderline, and abnormal ECG findings in sub-elite football players.

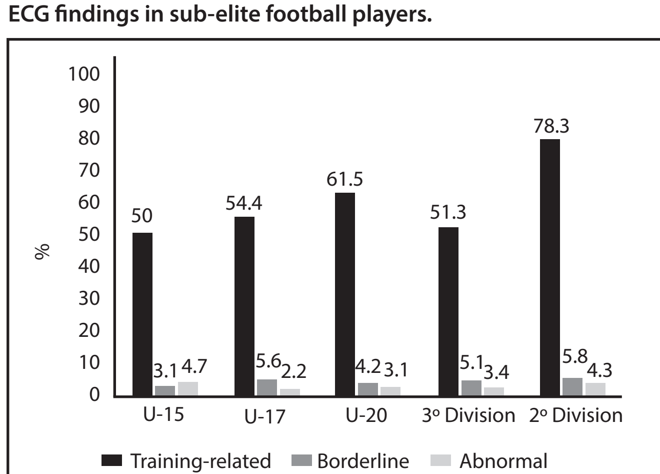

Table 3. Training-Related ECG Findings in elite soccer, baseball, and basketball players.

Finding	Sport No. (%)		
	Soccer (n = 103)	Baseball (n = 131)	Basketball (n = 46)
Increased QRS voltage for LVH or RVH	8 (7.7)	4 (3)	5 (10.8)
Incomplete RBBB	6 (5.8)	11 (8.3)	6 (13)
Early repolarization	0	7 (5.3)	4 (8.6)
T wave inversion V1-V3 < age 16	0	0	0
Sinus bradycardia	66 (64)	49 (37.4)	37 (80.4)
Ectopic atrial or junctional rhythm	1 (0.9)	0	1 (2.1)
1º AV block	4 (3.8)	5 (3.8)	8 (17.3)

LVH: left ventricular hypertrophy; RVH: right ventricular hypertrophy; RBBB: right bundle branch block; AV: atrioventricular.

Table 4. Training-Related ECG Findings in sub-elite soccer players.

Finding	Classification No. (%)				
	U-15 (n = 64)	U-17 (n = 90)	U-20 (n = 96)	3rd Division (n = 117)	2nd Division (n = 69)
Increased QRS voltage for LVH or RVH	2 (3.1)	12 (13.3)	13 (13.5)	16 (13.6)	14 (20.2)
Incomplete RBBB	5 (7.8)	7 (7.7)	15 (15.6)	14 (11.9)	6 (8.6)
Early repolarization	11 (17.1)	3 (3.3)	8 (8.3)	8 (6.8)	11 (15.9)
T wave inversion V1-V3 < age 16	1 (1.5)	0	0	0	0
Sinus bradycardia	24 (37.5)	36 (40)	44 (45.8)	35 (29.9)	44 (63.7)
Ectopic atrial or junctional rhythm	0	0	0	0	0
1º AV block	0	0	0	0	0

U-15: under 15 years; U-17: under 17 years; U-20: under 20 years; LVH: left ventricular hypertrophy; RVH: right ventricular hypertrophy; RBBB: right bundle branch block; AV: atrioventricular.

Borderline and abnormal ECG findings

The prevalence of borderline ECG readings among all the participants was 3.9%. The most frequent finding was right axis deviation, mostly in sub-elite football players (3.4% *vs*. elite, 1.07%).

The prevalence of abnormal ECG findings overall was 4.2%, of which 76% of the cases are represented by *T* wave inversion (3.2%) followed by ventricular pre-excitation (0.5%). However, the only abnormality in the sub-elite group was *T* wave inversion. Further findings are provided in Tables 5 and 6.

Table 5. Borderline and Abnormal ECG findings in elite soccer, baseball, and basketball players.

Finding	Sport No. (%)		
	Soccer n = 103	Baseball n = 131	Basketball (n = 46)
Borderline			
Left axis deviation	1 (0.9)	1 (0.7)	1 (2.1)
Left atrial enlargement	0	0	0
Right axis deviation	1 (0.9)	2 (1.5)	0
Right atrial deviation	0	0	1 (2.1)
Right atrial enlargement	0	0	0
Complete RBBB	0	0	0
Abnormal			
T wave inversion	5 (4.5)	1 (0.7)	2 (4.3)
Pathologic *Q* waves	1 (0.9)	0	0
Complete LBBB		0	0
Ventricular pre-excitation	1 (0.9)	0	3 (6.5)
Prolonged QT interval	1 (0.9)	1 (0.7)	0

RBBB: right bundle branch block; LBBB: left bundle branch block.

Table 6. Borderline and abnormal ECG findings in sub-elite soccer players.

Finding	Classification No. (%)				
	U-15 (n = 64)	U-17 (n = 90)	U-20 (n = 96)	3rd Division (n = 117)	2nd Division (n = 69)
Borderline					
Left axis deviation	0	0	0	0	1 (1.4)
Left atrial enlargement	0	0	0	0	0
Right axis deviation	2 (3.1)	3 (4.6)	3 (3.1)	3 (2.5)	2 (2.8)
Right atrial deviation	0	0	0	0	0
Right atrial enlargement	0	0	0	1 (0.8)	0
Complete RBBB	0	2 (3.1)	1 (1)	2 (1.7)	1 (1.4)
Abnormal					
T wave inversion	3 (4.6)	2 (3.1)	3 (3.1)	4 (3.4)	3 (4.3)
Pathologic *Q* waves	0	0	0	0	0
Complete LBBB	0	0	0	0	0
Ventricular pre-excitation	0	0	0	0	0
Prolonged QT interval	0	0	0	0	0

U-15: under 15 years; U-17: under 17 years; U-20: under 20 years; RBBB: right bundle branch block; LBBB: left bundle branch block.

Discussion

Preparticipation screening (PPS) in athletes is important to assess their physical condition and avoid complications. In the classifications used to evaluate electrocardiograms by expert doctors, we have three types of findings: normal, abnormal, and borderline[2]. It is important to classify each athlete to avoid one of the greatest fears in sports, sudden death.

In our study, the first thing we compared were the demographics: weight, height, and BMI. Our study found that basketball players were taller and heavier than football and baseball players. They also had the lowest fat mass percentage, with baseball players having the highest values. A Stanford study involving 641 college athletes compared teams from different sports and found that athletes who play basketball are taller and heavier but have a lower BMI[7]. This study corroborates that, athletes who practice basketball are taller than athletes of any other sports and have a lower fat mass and BMI. Thus, the type of sport practiced by athletes greatly influences the physical characteristics they need.

The maximal oxygen uptake or aerobic capacity (VO_{2max}), which is affected o related to body weight and expressed in absolute (l/min) and relative (ml/kg/min) values of maximal oxygen uptake volume, was significantly lower in baseball players. There are no studies that compare aerobic capacity between athletes from different sports. We recommend further research in this area of opportunity.

Regarding common ECG findings, we found that sinus bradycardia was the most prevalent training-related ECG change at rest (47.2%), followed by an incomplete right bundle branch block (8.2%). Both were more frequent in basketball players. In a study of 40 runners, 25 of the participants presented sinus bradycardia as the most frequent training-related finding, followed by LVH by voltage criteria in 12 (30%) and early repolarization in 11 (20.4%)[8]. These were also found in Brunei, a cross-sectional descriptive study of 100 athletes, where it was found that the most frequent changes related to training were, first, sinus bradycardia (29%), followed by J-point elevation (18%), and last, right atrial enlargement (7%)[9]. In a study by Beale *et al.,* 43 athletes participated, the most frequent finding was sinus bradycardia (97.6%), followed by left ventricular hypertrophy (65%), and early repolarization (97.6%)[10]. In another study of 519 NBA-affiliated basketball players, early repolarization was the most prevalent training-related ECG finding. It was present in 362 athletes (72.6%)[11]. In Abubakar's study, the only normal finding due to frequent training was sinus bradycardia in 29%[11]. As seen in the previously mentioned studies, the most frequent findings ranged from sinus bradycardia and early repolarization. These changes can be because systematic sports training can produce chronic changes and/or cardiovascular adaptations, defined as "athletic heart syndrome," with the antecedent of prolonged and intense systemic sports practice and required physical performance[12].

Borderline ECG among all our participants was 3.9%, and the most frequent change was right axis deviation, mostly in sub-elite football players (sub-elite, 3.4% *vs.* elite, 1.07%). Kaleta found right atrial enlargement higher at 42.5%, followed by left atrial enlargement at 37.5%[9]. In our study, borderline findings existed in a very low percentage of athletes, and the most frequent was atrial hypertrophy (2.6%), followed by complete right branch block (0.5%)[13]. As seen in previous studies, the most frequent borderline ECG findings are left and right atrial enlargement with 13.3 and 8.9%, respectively[11]. In the study by Beale, the most frequent finding was left axis deviation (4.7%), followed by right atrial enlargement (2.3%)[10]. The most frequent borderline findings found in the different studies were very similar; however, atrial enlargements are more prevalent than in our study, in which axis deviation predominated. We believe that there should be extensive surveillance of these types of patients if they present symptoms because the findings on the ECG are not normal and could affect their physical condition[12].

Finally, the overall prevalence of abnormal ECG findings was 4.2%, of which 76% represented T wave inversion (3.2%), followed by ventricular pre-excitation (0.5%). Like our study, the most frequent training-unrelated ECG change in Beale *et al.*[10] was *T*-wave changes with 4.6%. In the same way, in Waase's study, the most prevalent abnormal finding was the *T* wave inversion with 6.2%[11]. However, Gademan's study found that the most common finding was ST-segment depression. A finding different from all the studies was a pathological *Q* wave in a low percentage[7]. All these studies have in common the findings in changes in the *T* wave; however, Gademan calls our attention to the appearance of a pathological *Q* wave. Additional studies should be performed on this type of athlete regardless of their medical history, even if they do not have symptoms. An initially abnormal ECG may have a predictive value that requires careful follow-up and monitoring due to the possibility of developing heart disease later[12].

Conclusions

Electrocardiographic changes in athletes are frequent; however, constant tracking of abnormal parameters or borderline changes is recommended. The most common electrocardiographic changes were those classified as normal related to physical activity, finding sinus bradycardia first, followed by incomplete right bundle branch block, which was more prevalent in basketball players. On the other hand, the most frequent borderline change in the participants was right axis deviation seen in sub-elite players, and the most prevalent abnormal change was *T* wave inversion. Some of the limitations of our study were that there were only men, and the predominant sport was football. This limitation occurred because we had the athletes' data since 2016 with more information about elite and sub-elite categories. Another limitation of this study is that the athletes who had an ECG abnormality were not followed to assess whether there was an outcome to determine its validity as a finding. It is suggested that further research should study the electrocardiographic changes in elite and sub-elite athletes and compare these changes considering the biological sex of the athletes to see if there is any difference.

Acknowledgment

We thank the Department of Sports Medicine and Rehabilitation of the University Hospital "Dr. José Eleuterio González" for the opportunity to work with elite athletes

Conflict of interest

The authors do not declare a conflict of interest.

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The influence of the menstrual cycle on the practice of physical exercise: narrative review

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doi: 10.18176/archmeddeporte.00148

Received: 19/07/2022
Accepted: 05/06/2023

Summary

Introduction: The menstrual cycle (MC) is the second most important biological rhythm, regulated by the hypothalamic-pituitary-ovarian axis and all the hormones involved in it. In addition to reproductive functions, it is speculated that changes in hormone production during different phases of the menstrual cycle may influence other physiological systems, which may have an impact on women's physical performance. In this way, studying the influences of the menstrual cycle on physical exercises gains importance, since little is said about the organization of strategies and intervention for the performance of physical exercises that take into account the possible impacts and changes caused by the MC.
Objective: To review the influence of MC in the practice of aerobic and resistance exercises.
Material and method: The search for articles was carried out in the databases: PubMed and Google Scholar, from August to September 2021, without restriction on date and type of publication, and all articles in English and Portuguese were considered. The research was based on the phases of the menstrual cycle in eumenorrheic young women, who may or may not be athletes, but without known dysfunctions of the menstrual cycle.
Conclusions: Hormonal fluctuations during MC may not significantly and directly affect the cardiorespiratory or musculoskeletal system during physical exercise, as there is the question of the biological individuality of each woman, as well as the relationship with the self-reported symptoms.

Key words:
Hormones. Menstrual cycle. Physical exercise.

La influencia del ciclo menstrual en la práctica de ejercicio físico: una revisión narrativa

Resumen

Introducción: El ciclo menstrual (CM) es el segundo ritmo biológico más importante, regulado por el eje hipotalámico-pituitario-ovárico y todas las hormonas involucradas en él. Además de las funciones reproductivas, se especula que los cambios en la producción de hormonas durante las diferentes fases del ciclo menstrual pueden influir en otros sistemas fisiológicos, lo que puede tener un impacto en el rendimiento físico de la mujer. De esta forma, el estudio de las influencias del ciclo menstrual sobre los ejercicios físicos cobra importancia, ya que poco se habla de la organización de estrategias e intervención para la realización de ejercicios físicos que tengan en cuenta los posibles impactos y cambios provocados por el CM.
Objetivo: revisar la influencia del CM en la práctica de ejercicios aeróbicos y de resistencia.
Material y método: La búsqueda de artículos se realizó en las bases de datos: PubMed, Scielo y Google Scholar, de agosto a septiembre de 2021, sin restricción de fecha y tipo de publicación, y se consideraron todos los artículos en inglés y portugués. La investigación se basó en las fases del ciclo menstrual en mujeres jóvenes eumenorreicas, que pueden ser deportistas o no, pero sin disfunciones conocidas del ciclo menstrual.
Conclusiones: Las fluctuaciones hormonales durante la CM pueden no afectar significativa y directamente el sistema cardiorrespiratorio o musculoesquelético durante el ejercicio físico, ya que está la cuestión de la individualidad biológica de cada mujer, así como la relación con los síntomas autoreferidos.

Palabras clave:
Hormonas. Ciclo menstrual. Ejercicio físico.

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Introduction

During the menstrual cycle (MC), women are exposed to continuous variations in serum concentrations of various female sex steroid hormones regulated by the hypothalamus-pituitary-ovarian axis. Regular hormonal fluctuations of the four major female sex hormones, estrogen, progesterone, follicle stimulating hormone (FSH) and luteinizing hormone (LH), are essential for regulating ovulatory cycle patterns[1].

Despite individual variations, the MC lasts an average of 28 days comprising two distinct cycles: the ovarian cycle and the endometrial cycle. The ovarian cycle is divided into follicular and luteal phases. In the former, estrogens gradually increase, causing FSH and LH to reach their peak, while progesterone remains low at all time. The luteal phase is determined by the actions of estrogen and progesterone. The endometrial cycle is divided into a proliferative phase, a secretory phase and menstruation. Endometrial growth is the primary outcome of the proliferative phase and it is mediated by the estrogen increase. The primary outcome of the secretory phase is the maturation of the endometrium. Decreasing levels of estrogens halt endometrial lining growth. When conception does not occur, the endometrial lining is replaced to prepare for the next cycle, therefore the ovarian hormones estrogen and progesterone decrease greatly and menstruation begins[2,3].

With the growing number of women who practice regular physical exercises, the *Brazilian Society of Sports Medicine* in 2000 recommended that the prescription of exercises for women should aim to reduce the deleterious effects of physical inactivity, also taking into account the cardiorespiratory conditioning, muscular endurance and strength, body composition and flexibility of these women before exercise prescription[4].

In addition to reproductive functions, it is speculated that changes in hormone production during different phases of the menstrual cycle may influence other physiological systems, such as: cardiovascular system and skeletal muscle, which may have an impact on physical performance and quality of life. of the women. In this way, it is important to return to the primary understanding about the hormones involved in the MC to study their influences on physical exercises, and increasingly gains value and helps to fill scientific gaps, since little is said about the organization of strategies and intervention. for carrying out physical exercises, sports practices, leisure activities, which take into account the possible impacts and alterations caused by MC and its hormones. Therefore, it is necessary to correlate the influence of the hormones that make up the ovarian and endometrial cycles with the practice of physical exercises, in order to improve the exercise prescription, taking into account the volume, intensity and type of exercise, which can be developed according to the peculiarities of each woman. In this sense, the present study aims to review the influence of MC during the practice of aerobic and resistance exercises.

Material and method

As a search strategy for the present study, narrative review was understood as a category of articles suitable for describing and discussing the development of a given subject. It does not inform the sources of information used, such as the methodology for searching references and the criteria for selecting works, therefore it does not have a methodology that allows the reproduction of data and does not provide quantitative answers to specific questions. They basically consist of an analysis of the literature published in books, articles in printed and/or electronic magazines in the interpretation and personal critical analysis of the author[5].

The search for articles was carried out in the databases: PubMed, Scielo and Google Scholar, from August to September 2021, without restriction on date and type of publication, and all articles in English and Portuguese were considered. The research was based on the phases of the menstrual cycle in eumenorrheic young women, who may or may not be athletes, but without known dysfunctions of the menstrual cycle.

The terms used for the search were: (menstrual cycle OR menstrual phase) AND (physical exercise OR physical activity OR physical performance). Then, duplicates were eliminated and the title and abstract were read, discarding all articles not specific to the topic. From then on, the article was read in full to obtain relevant and clear information that could contribute and elucidate the proposed objective. In addition, the lists of bibliographical references of the selected articles were consulted, in order to insert studies that, perhaps, could be relevant to the discussion proposed in the present study. An overview of the search and screening process is provided in Figure 1.

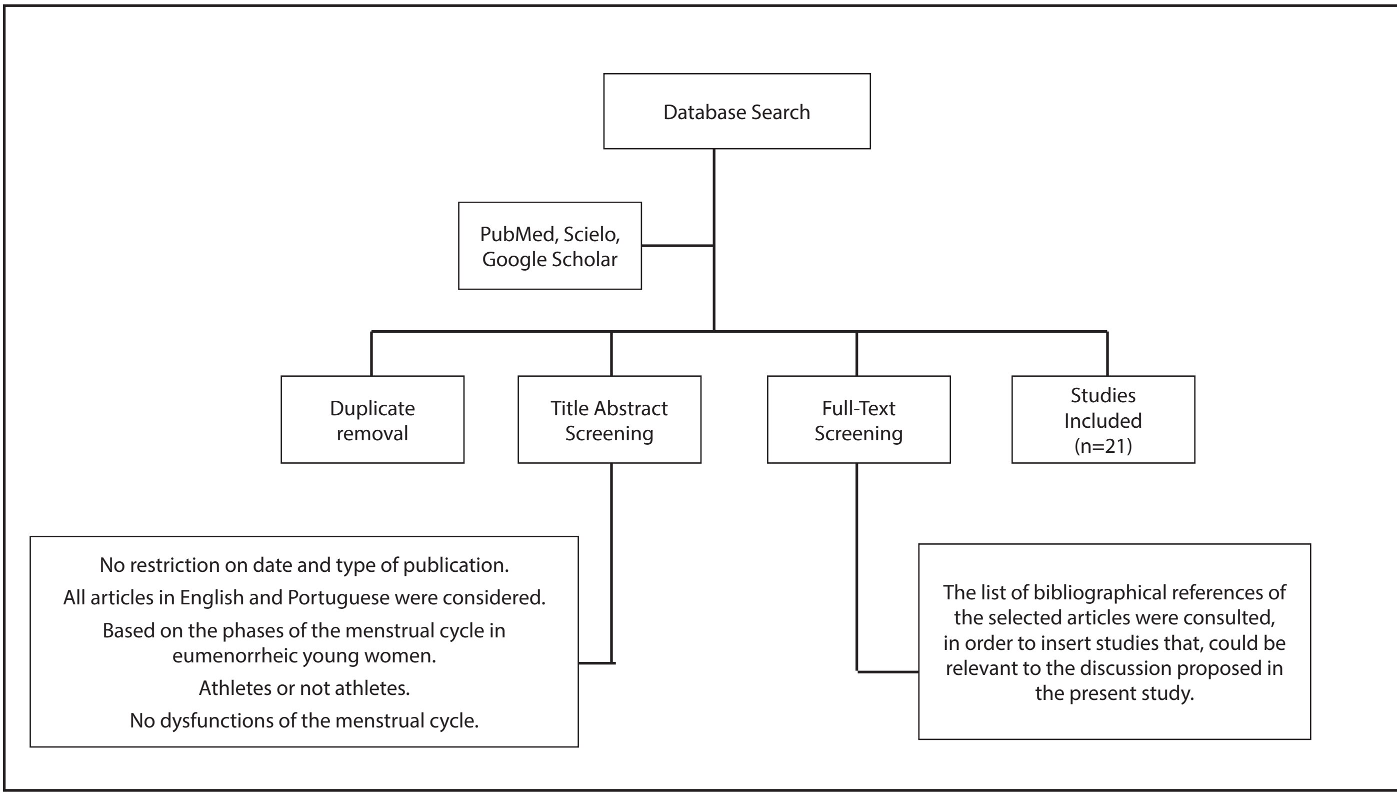
Development

The positive and negative feedback relationship in the hypothalamic-pituitary-ovarian axis can help in understanding variations in physical performance throughout the menstrual cycle. The gonadotropic hormones (LH and FSH) and the ovarian hormones (progesterone and estrogen) play a role in the pituitary, ovarian and endometrial hormonal cycle. However, although the hormonal physiological pattern is widely present in all eumenorrheic women, the concentration and duration of cycle events show great individual variability. These hormonal oscillations generate changes in the perception of the woman's body, such as fluid retention, weight gain, physical performance, as well as changes in mood and sleep, and other variables. Given the complexity of the subject, the aim of this narrative review is to present topics related to the physiology of the hormonal system, female sex hormones, MC itself and its relationship with physical exercise (resistance and aerobic). For a better understanding, a Table 1 was created with the descriptions of the articles included.

Hormones

Hormones are molecules produced by the endocrine glands, secreted into body fluids, and then transported by the blood to target cells. There are different types of hormones that interact with their receptor and trigger a cascade of biochemical reactions in the target cell that eventually modify the cell's function or activity being either general or local. Hormones that affect all or almost all cells in the body are defined as general, however some hormones have only a few target cells and specific receptors, these are designated as local. The target cells of each hormone are characterized by the presence of certain coupling molecules (the receptors) for the hormone that are located on the surface or inside the cell. For instance, ovarian hormones exert specific

Figure 1. Literature review process.



Fuente: autor

effects on the female sex organs as well as the secondary characteristics of women, on the other hand, growth hormone induces the growth of all or almost all parts of the body[6,7].

The female hormonal system presents itself in three hierarchies of hormones: [1] hypothalamic releasing hormone, the gonadotropin-releasing hormone (GnRH); [2] the adeno-pituitary hormones secreted in response to the release hormone of the hypothalamus, follicle-stimulating hormone (FSH) and luteinizing hormone (LH); [3] the ovarian hormones, secreted in response to the two hormones of adeno-pituitary, estrogen and progesterone. These hormones are not secreted constantly occurring changes in levels during the menstrual cycle[6].

Gonadotropins, progesterone and estrogen

Gonadotropins (FSH and LH) are hormones that act on the gonads and these hormones have a clear influence with the menstrual cycle. FSH and LH are small glycoproteins that have observed effects on the ovaries in women, which stimulate their ovarian target cells by combining with highly specific FSH and LH receptors on cell membranes and these activated receptors increase the rate of secretion of these cells, as well as their growth and proliferation. By exposing each one separately, FSH has the function of provoking the growth of follicles and the production of estrogen in the ovaries. Low levels of FSH in women will stimulate estrogen production, whereas high levels will inhibit it. Another gonadotropin is LH, which function is to promote the secretion of estrogen and progesterone, in addition to the follicle rupture, causing the release of the egg[6,8].

The regulation of gonadotropin secretion is quite complex, encompassing pulsatile, periodic, diurnal and cyclic elements involved in the menstrual cycle. The effects of changes in the levels of each of these hormones are influenced by the different stages of a woman's life. Its secretion is controlled by the gonadotropin-releasing hormone (GnRH), secreted by the hypothalamus and acts on the adeno-pituitary[8].

There are estrogens and progestins as far as ovarian hormones are concerned. The most important of the estrogens is estradiol while the most important progestin is progesterone. Steroid or non-steroidal in nature, they are the main mediators of ovarian effects on the hypothalamic-pituitary system. However, ovarian changes during the menstrual cycle are totally dependent on gonadotropic hormones secreted by the anterior pituitary. Estrogens mainly promote the proliferation and growth of specific cells in the body and are responsible for the appearance of most secondary sexual characteristics in women, in addition to stimulating the deposition of body fat, as a way of preparing the mother's body for pregnancy. Its regulation is related to FSH and LH and also depends on the time of life, as well as testosterone[6-8].

Table 1. Description of included studies.

Author(s), year	Purpose of the study	cycle phase	(n)	Protocol or evaluation used	Conclusion
Gil *et al.*, 2017	To analyze the effect of strength training (ST) with blood flow restriction (BFR) training on muscle power and submaximal strength (SS) of upper and lower limbs in eumenorrheic women.	1) EFP 2) OVU 3) LLT	40 women (18–40 years), untrained. (G1) HI ET (low intensity) at 80% of 1RM; (G2) LI TF (high intensity) at 20% of 1RM + BRF; (GC) LI at 20% of 1RM - control group.	Protocol for each group: ST: 8 sessions Tests: Medicine ball (MB), Horizontal jump (HJ), Vertical jump (VJ), Bicep curl (BC) and Knee extension (KE).	ST with BFR does not seem to improve LL and LL potency and may be an alternative to improve LL SS in eumenorrheic women.
Rael *et al.*, 2021	To analyze the impact of sex hormone fluctuations along the MC on the cardiorespiratory response to high-intensity interval exercise in athletes.	1) EFP 2) LFP 3) ELP	Resistance-trained eumenorrheic women.	MC calendar; urinary LH; Serum hormone analysis; Training: 8 × 3 minutes at 85% of your maximum aerobic speed with a 90-second recovery at 30% of your maximum aerobic speed.	It appears that sex hormone fluctuations across the MC are not high enough to disrupt tissue adjustments caused by high-intensity exercise.
Barbosa *et al.*, 2007	Identify the variation in sensory perception and motor response in the different phases of the MC.	1) EFP 2) LFP 3) OVU 4) ELP 5) TLP	30 women (18-40 years old).	Pulse generator: pulsed electrical currents; Sensory Perception Threshold (SPT); Motor response threshold (MST).	SPT and MST varied systematically across the MC phases, influencing sensorimotor behavior.
Darlington *et al.*, 2001	Optokinetic function and postural stability at different MC phases.	1) EFP 2) IFP 3) ELP	16 university physical education students (20-35 years old).	Serum hormone concentrations: estrogen and progesterone.	Although the MC phase has no ↔ in the anteroposterior oscillation , it significantly affected the lateral oscillation, with FFP oscillation significantly > than in the other phases and oscillation on day 25 significantly > than on day 21 of the cycle.
Fouladi *et al.*, 2012	To investigate the effect of CM on knee joint position sense (SDP) in healthy female athletes.	1) EFP 2) MFP 3) ILP	16 healthy athletes.	Measurement: joint position sensor; Serum levels: estrogen and progesterone; Knee Joint Position Measurement (JPS) sensor.	Athletes have different levels of JPS in the knee along the MC. JPS accuracy decreases during menstruation, when circulating levels of sex hormones are low. Therefore, female athletes are > at risk for menstruation injuries.
Fridén *et al.*, 2006	To investigate knee joint kinesthesia and neuro-muscular coordination in women with a moderate level of activity in three well-defined phases of the MC.	1) EFP 2) OVU 3) ILP	32 healthy, moderately active women (25 of them had at least one hormonally verified menstrual cycle).	Kinesthesia of the knee joint; Neuromuscular coordination: jump test.	The variation of sex hormones in the MC has an effect on the performance of knee joint kinesthesia and neuromuscular coordination.
Melegario *et al.*, 2006	To investigate whether there are differences in the degree of flexibility in the MC phases of young adult women practicing academic gymnastics.	1) EFP 2) OVU 3) TLP	20 women (18-35 years old); No use of oral contraceptives.	Consultation: menstrual cycle and physical activity. Flexibility: goniometry with 8 movements. Hormone test: estrone, estradiol and progesterone levels.	The results found showed that there was no ↔ on the degree of flexibility of the studied group, during the different phases of the MC.
César, Pardini and Barros, 2001	Investigate the effects of running training long distances in the MC, bone density, body composition and aerobic power.	1) LUT	Endurance runners and 8 women, non- practitioners of regular physical activity - GC).	Serum levels : estradiol, progesterone and prolactin; Bone density : spine and femur; Lean mass, body fat and % fat; ergospirometric test max; attendance monitoring _ heart training in runners.	The practice of long distance running did not cause menstrual or hormonal disturbances.
Brar , Singh and Kumar, 2015	To observe the effect of MC on cardiac autonomic function parameters in healthy women.	1) EFP 2) LFP 3) ILP	50 young women; cycling practitioners; without using contraceptives.	Heart Rate Variability (HRV)	Increased sympathetic outflow in the secretory phase compared to the proliferative phase and increased parasympathetic outflow in the proliferative phase compared to the secretory phase.

(continued)

Table 1. Description of included studies (continuation).

Author(s), year	Purpose of the study	cycle phase	(n)	Protocol or evaluation used	Conclusion
(Barba-Moreno *et al.,* 2019)	To investigate the effects of these fluctuations on cardiorespiratory responses during steady state exercise in women.	1) EFP 2) IFP 3) LUT to the: 1) HP 2) NHP	23 resistance-trained healthy women, (15 on regular MC and 8 on oral contraceptive cycle).	Test: 40 minutes of running at 75% of your maximum aerobic speed.	The lack of clinical significance of these differences and the non-differences of other physiological variables indicate that MC had a small impact on submaximal exercise in the present study.
Dias *et al.,* 2005	To verify the effect of the different phases of the MC on the performance of the FM in a test of 10 maximum repetitions (10RM).	1) EFP 2) OVU 3) ILP	8 young women (20-25 years old), physically active, practitioners of resistance exercises, who used AO.	Measurements: body weight and height; Strength: 10RM test.	There are no variations in the maximum FM during the different phases of the MC.
Simão *et al.,* 2007	Check if there are differences in the FM levels of the LL and SS.	1) EFP 2) OVU 3) LLT	19 trained eumenorrheic women (21-32 years). Regular MC; experience Minimum 3 years in strength training.	FM: 8RM test, an open front pull on the pulley tall and leg press 45⁰.	Influence of MC on the ability to produce FM in LL. For upper limbs, there were practically no load changes in any of the assessed phases.
Ramos *et al.,* 2018	Check the FM of the lower limbs in the four phases of the MC.	1) EFP 2) LFP 3) OVU 4) ELP	15 women (18-39 years old); Bodybuilders; Use of oral or injectable contraceptives.	Submaximal load test on leg device press 45⁰.	The MC can influence the strength of the LL.
Romero-Moraleda *et al.*, 2019	Investigate fluctuations in muscle performance.	1) EFP 2) LFP 3) ILP	13 eumenorrheic and resistance-trained women. No contraceptive use.	Pre -experimental test: half-squat 1RM; Body mass; Tympanic temperature; daily urinary LH; On the second day of each phase: Strength: half-squats, with 20, 40, 60 and 80% of 1RM. Load, force, velocity and power: measured during the concentric phase using a rotary encoder.	Eumenorrheic women have similar FM and power performance in the Smith machine half-squat exercise during the three phases of the MC.
Dasa *et al.,* 2021	To investigate the effect of female MC on strength and power performance in highly trained athletes.	1) FOL 2) LUT	29 athletes (8 eumenorrheic women and 21 under hormonal contraceptive use - control group). And team sports: football, handball and volleyball.	F M: maximum voluntary isometric grip; Sprint: 20 m; Jump: counter-movement; Leg-press: pneumatic. levels: confirm cycle phase.	Not observed ↔ performance based on the use of hormonal contraceptives. This suggests that MC does not alter acute FM and power performance at the group level in high-level team athletes.
Lima *et al.,* 2012	Investigate whether there are differences in FM levels between menstrual and post-menstrual periods.	1) EFP 2) LFP	25 sedentary women (18-25 years old), 10 not using contraceptives and 15 using contraceptives.	FM: 1RM test - handgrip dynamometer; Questionnaires: depression , tension syndrome Resumen premenstrual period and changes in mood, physical and depressive.	The study reports a > mean of the forces averages and maximums during the post-menstrual phase, however, there were no differences in handgrip strength between user and non-user women. contraceptive users.
Souza *et al.,* 2015	Check possible alterations caused by the phases of the MC in the production of FM and EMG.	1) FOL 2) OVU 3) LUT	9 healthy, physically active women, not using contraceptives.	FM: MVCs; EMG: rectus femoris (RF), vastus medialis (VM) and vastus lateralis (VL) muscles.	The muscles evaluated in the luteal phase presented > FM production when compared to the other phases and the VL was the most activated muscle in all analyzed phases.

n: sample size; MC: Menstrual Cycle; OA: Oral Contraceptive; EFP: Early Follicular Phase; LFP: Late Follicular Phase; UVO: Ovulatory Phase; ELP: Early Luteal Phase; ILP: Intermediate Luteal Phase; LLP: Late Luteal Phase; FOL: Follicular Phase; LUT: Luteal Phase; HP: Hormonal Phase; NHP: Non-Hormonal Phase; FM: Muscular Strength; 1 RM: One Rep Maximum; MVC: Maximum Voluntary Contraction; EMG: Electromyographic Activity; LL: Lower Limbs; SS: Upper Limbs; >: biggest; <: smallest; ↔ : no difference between MC phases.

On the other hand, progesterone increases the vascularization of the body and mainly the cervix, responsible for preparing the uterus for implantation of the egg, increasing core temperature and preparing the breasts for lactation. In body composition, progesterone increases muscle mass and fat storage[7,8]. During the first half of the ovarian cycle, progesterone appears in small amounts in the plasma, being secreted in approximately equal amounts by the ovaries and the adrenal cortex, whereas in the second half of each ovarian cycle it is significantly secreted by the corpus luteum[6,7].

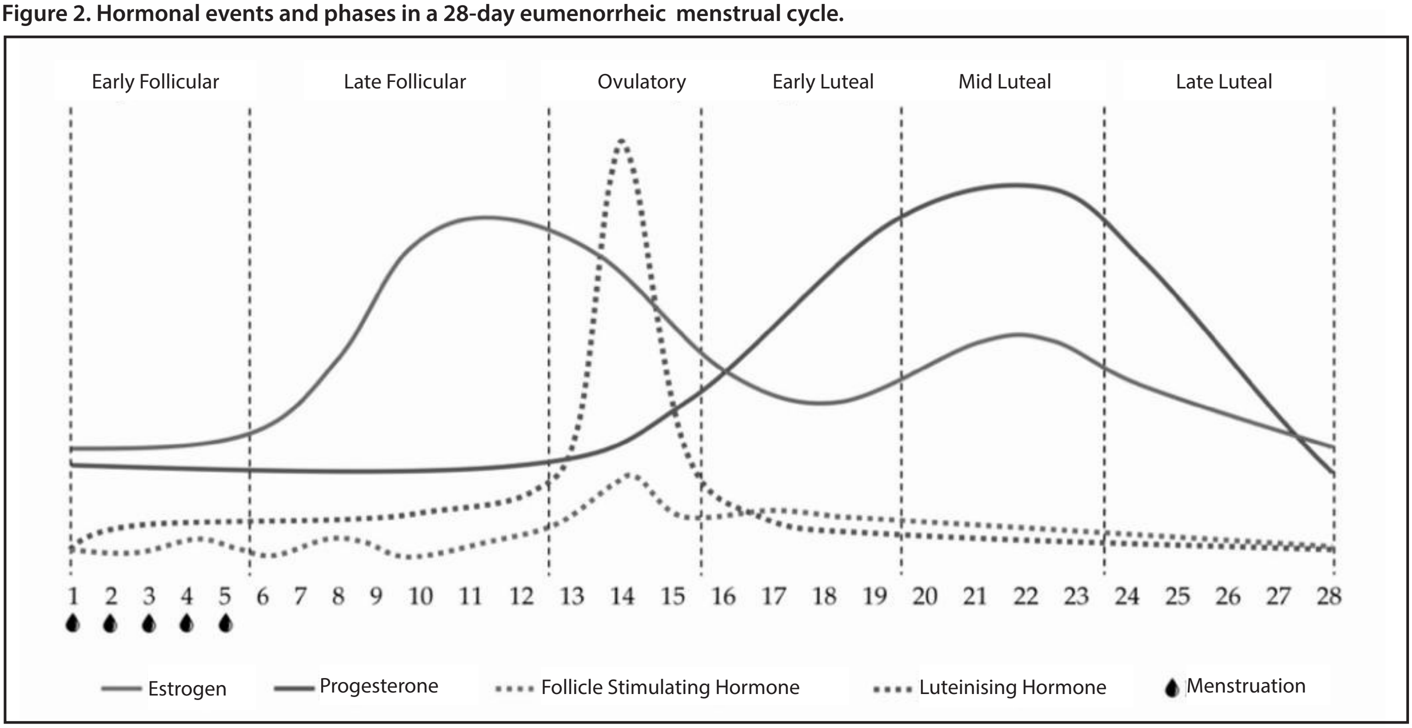
Menstrual cycle

The MC is dependent on endocrine, autocrine, and paracrine factors that regulate ovarian follicular development, ovulation, luteinization, luteolysis, and endometrial remodeling[10]. Ovarian hormones, steroidal or non-steroidal in nature, are the main mediators of ovarian effects on the hypothalamic-pituitary system[11]. The MC has a sequence of circa-monthly rhythms that lasts an average of 28 days, with inter-individual variations, in which there are responses to the concentration of hormones in the hypothalamic-pituitary-ovarian axis.

Endocrine communication between hormones and glands determine the two main phases of MC, separated by mid-cycle ovulation: the follicular phase, which focuses on the maturation of a reproductive cell, and the luteal phase, which is characterized by the formation of the corpus luteum and its regression[1,6,8,12]. However, classifying MC using only these two phases does not sufficiently distinguish the multiple hormonal environments that occur within these two phases. Therefore, MC is typically expressed in surveys using subphases such as: early follicular, late follicular, ovulatory, early luteal, mid-luteal, and late luteal[13].

Despite individual variations, fluctuations in the four major female sex hormones are essential for regulating the patterns of the ovulatory cycle. A few days before menstruation, about two to three days, the corpus luteum involutes, decreasing levels of progesterone, estrogen and inhibin (a glycoprotein hormone, which has a negative feedback effect on the anterior pituitary and hypothalamus). In the absence of fertilization, the endometrium loses its supply and degenerates, breaking down with menstrual bleeding. The early follicular phase (EFP) is considered by the onset of menstruation and usually takes 4 to 6 days to complete. This phase is also characterized by low serum concentration of female hormones. The late follicular phase (LFP) continues until ovulation occurs, during this time estrogen increases as the ovarian follicles mature. Reaching the estrogen peak, there is an increase in the secretion of gonatropin-releasing hormone, which generates a rapid increase in LH. This LH still surges in the LFP triggering ovulation, which follows the rupture of the mature follicle and release of the egg into the uterus. After ovulation, the initial luteal phase occurs, in which the ruptured follicle becomes the corpus luteum and secretes progesterone and a small amount of estrogen. The progesterone peak, with the second peak of less estrogen takes place to prepare the endometrium for implantation of the fertilized egg. This phase ends if a fertilized egg is implanted. But if the egg remains unfertilized, the corpus luteum will be degraded, causing a decline in progesterone and estrogen. In the late luteal phase, the cycle prepares to restart with the shedding of the uterine lining for menstruation to begin again. In MC, the estimated time of each phase is shown in Figure 2, however these phases are variable, mainly due to the moment of ovulation[1,6].

Figure 2. Hormonal events and phases in a 28-day eumenorrheic menstrual cycle.



Adapted from Carmichael *et al.,* 2021.

The relationship between menstrual cycle and physical exercise

Physical exercises are activities systematically programmed with the objective of improving physical performance, promoting improvements in respiratory and cardiac capacity, muscle strength, among others[14]. Physical exercise is considered to be a factor that disturbs the body's homeostasis, which can stimulate the secretion of certain hormones and inhibit others.

Gil *et al.*, 2017 and Rael *et al.*, 2021, explain that physical performance can change throughout a MC due to several mechanisms such as: altered muscle activation, substrate metabolism, thermoregulation and body composition. Female sex hormone concentrations can result in altered strength production, affecting muscle strength and potency. Regarding hormonal effects, estrogen has a neuroexcitatory effect and progesterone inhibits cortical excitability, which result in a positive and negative relationship in strength production. Such studies assume that greater strength and potency results would be produced when progesterone is low during the follicular phase, especially when estrogen reaches peak during the late follicular phase, and lower strength results would be produced in the luteal phase when progesterone is high[10,15].

There is a cyclical regulation of sex hormone levels during MC, which in addition to reproductive functions, can influence other physiological aspects as those related to the cardiovascular system, skeletal muscle and adipose tissue. Some studies suggest that estrogen and progesterone have an influence on aerobic and anaerobic capacity, changes in soft tissues, muscle strength, proprioception, neuromuscular coordination and postural control. Estrogen acts on the CNS and at the cellular level, decreasing collagen production in tendons by attenuating fibroblast activity. In addition to its receptors being present in skeletal muscle, which influences motor control and myofascial force transmission patterns. On the other hand, progesterone during the luteal phase, has a central thermogenic effect increasing body temperature, improving minute ventilation and response to maximal exercise. Still in the luteal phase, the increase in progesterone metabolizes neurosteroids such as: allopregnanolone and pregnanolone which can infer balance and motor function disorders in this phase due to the action on GABA-A receptors[16-19].

Based on this principle, it is assumed that female hormones would be responsible for increased ligament laxity and decreased neuromuscular performance. However, Melegario *et al.*, 2006, in their study with a sample of 20 women who practice gymnastics at a gym, aged between 18 to 35 years, with regular MC and who did not use oral contraceptives, concluded that MC does not interfere with the flexibility variable[20].

Also about connective tissue, Chidi-Ogbolu & Baar, 2019, in a review study, evaluated the effects of estrogen on musculoskeletal function and how these changes affect performance, adaptation and risk of injuries in an active population. The analyzed studies showed that estrogen improves muscle proteostasis and increases collagen content in tendons, however, as more women participate in sports, the physiological effects of estrogen contribute to decrease potency and performance and make women more prone to ligament injuries[21].

Several studies, such as by Carmichael *et al.*, 2021, try to establish whether the MC phase influences muscle and tendon stiffness and whether it can be a risk factor for soft tissue injuries. Some of these studies are presented in the narrative review by (Carmichael *et al.,* 2021) in which the authors present articles that point out that stiffness is affected by the MC phase and can alter performance through changes in tissue stiffness. It has been suggested that increasing estrogen concentration in certain phases of MC can reduce stiffness, decreasing collagen synthesis and therefore collagen density in muscles and connective tissues[13].

Menstrual cycle and aerobic exercises

Cesar, Pardini and Barros, 2001, conducted a study that evaluated women who practiced running and did not practice physical activity to investigate the effects of long-distance running training on the MC and other variables. The practice of long-distance running did not cause menstrual or hormonal disorders, despite the great distances covered weekly by the athletes. Aerobic physical exercise provided the following benefits to runners: greater aerobic power, demonstrated by maximum oxygen consumption and anaerobic threshold, greater lean mass and lower body fat content compared to women who did not practice physical activities[22]. The serum dosage in this study was performed only in the luteal phase (from the 15th day of the MC) which restricts the possible influences of hormonal oscillations on aerobic exercises in other phases of the MC.

Regarding prolonged exercise, De Jonge, 2003, in his review study analyzed the potential effects of fluctuations in female steroid hormones (estrogen and progesterone concentrations) during MC on exercise performance, and exposes that MC may have effect on exercises. Although most research suggest that oxygen consumption, heart rate, and rating of perceived exertion responses to submaximal steady-state exercise are not affected by MC, several studies report an increase in cardiovascular exertion during moderate exercise in the mid-luteal phase. During prolonged exercise in hot conditions, a decrease in exercise time to exhaustion is shown during the mid-luteal phase, when body temperature is elevated. Thus, the mid-luteal phase has a negative potencial effect on prolonged exercise performance through elevated body temperature and potentially increased cardiovascular effort but when it comes to athletes who menstruate regularly and compete in intense aerobic sports, there is no need to adjust the phase of the menstrual cycle to maximize their performance[23]. Unlike the study above which only analyzed the luteal phase of the MC, the De Jonge review in 2003, analyzed studies that measured estrogen and progesterone to check the phase of the menstrual cycle, beisdes that his review speaks very well about the various types of tests used to verify the phases of the MC as well as possible bias in the tests, which helps to guide further research.

The MC hormonal fluctuations are linked to variations in autonomic nervous system (ANS) functions. Physiological changes along the MC can be demonstrated by heart rate variability (HRV) which is a measure of cardiac autonomic tone. Brar, Singh and Kumar, 2015, conducted a study with 50 young women who go cycling regularly, which consisted of analyzing the time and heart rate domain in the different phases of the MC, with the objective of knowing the effect of the MC on the parameters of cardiac autonomic function in healthy women. They concluded that differences in HRV parameters may be due to parasympathetic predominance during the proliferative phase and sympathetic activity in the secretory phase. A difference in the balance of ovarian hormones may be responsible for these changes in autonomic functions during MC[2]. The study excluded women using oral contraceptive pills, serum levels were collected on three different occasions of the MC and always at the same time of day to avoid variations and a complete menstrual history was made, with the nature, flow, regularity and total duration of the cycle but the time in which this history was followed up is not reported.

Responses to submaximal exercise may depend on the MC phase, that is, a less effective cardiorespiratory response may occur with submaximal exercise during the luteal phase when progesterone levels are significantly elevated. However, the lack of clinical results from these differences and the non-differences from other physiological variables indicate that the menstrual cycle has a small impact on submaximal exercise[24]. The study by Barba-Moreno *et al.,* 2019, came to these results after a study of 23 healthy, resistance-trained, eumenorrheic or oral contraceptive users women. Both groups had the same experimental protocol, differing only from the laboratory tests in which the eumenorrheic group had three collections (early follicular phase, medium follicular phase and luteal phase) and the contraceptive group had two collections (non-hormonal phase and hormonal phase). In this study, the history of the MC was also carried out but unlike the previous one, the authors requested information on the last four MC before the beginning of the collections. In the end, the authors Barba-Moreno *et al*., 2019, expose possible limitations regarding the real effects that could be greater or smaller than those reported[24].

The study by Rael *et al.*, in 2021, analyzed the impact of sex hormone fluctuations along the MC on the cardiorespiratory response to high-intensity interval exercise in athletes. Ventilation was impacted by the MC phase during warm-up, interval running protocol, and cool-down. On the other hand, HR had the main effect of the MC phase along the high-intensity intervals and it presented lower values in the PEF compared to the PF. However, the authors show that some previous studies have not reported an effect of the MC phase on the HR response to exercise and would suggest that the increase in cardiorespiratory effort due to high-intensity exercise is greater than any possible increase caused by progesterone. Thus, the effect of progesterone on this physiological variable may be hidden by high-intensity exercise[10]. The study by Rael *et al.,* 2021, carried out a three-step method composed of collecting information on the last six MC of the athletes to determine the phases, measurement of urinary LH and serum hormone levels analysis which soon brings a greater reliability for the data, in addition to the study is part of IronFEMME, an observational cross-sectional study carried out with physically active and healthy women.

In conclusion, most studies presented in a recent narrative review concluded that MC phases had no effect on aerobic exercise performance[13]. In short, current results indicate that exercise performance may be reduced during MC phases, especially in the early follicular phase compared to all others. However, due to the effect, the low methodological quality and the great variation among the studies carried out to the present moment, general guidelines on exercise performance in the MC cannot be made, however it is recommended that a personalized approach can be done based on each individual's response to exercise performance in the MC[25].

Menstrual cycle and resistance exercises

When assessing muscle strength, Dias *et al.,* 2005, verified the effect of the different phases of the MC on the strength performance in a 10 RM test of upper and lower limbs. Eight trained women in regular use of oral contraceptives were evaluated. The results showed that in the front pulley pulldown, there were no significant differences in strength when comparing the three phases of the MC. Regarding the leg press, variations were observed without significant differences in the interphase loads, mainly between the follicular and luteal phases. In conclusion, the study reports that there are no significant variations in maximal muscle strength during the different phases of the MC. The authors explain that there is no relationship between the periodization of strength training as a function of the endocrine profile of each phase. Since such fluctuations in serum concentrations of estrogen and progesterone are not enough to affect physical performance, however they explain that there is indeed a decrease in performance along the MC and that these may be the result of some variables considered individual[26]. In another similar study, the authors also collected strength measurements during MC but their sample did not use oral contraceptives. Unlike the previous study, Simão e*t al.,* 2007, reported that there is an influence of the MC on the ability to produce strength in the lower limbs, however it is not seen in the upper limbs that there were practically no changes in load in any of the phases evaluated[27]. In both studies, there were limitations which should be taken care of when extrapolating the results, the sample size, the difficulty in defining the phases of the cycle and the collection in a single MC.

Ramos *et al.,* 2018, wanted to assess lower limb muscle strength in the four phases of the MC and again observed that the MC did not affect muscle strength performance[28]. When investigating the variations in muscle strength, speed and power production in three different phases of the MC in resistance exercises performed with loads equivalent to 20, 40, 60 and 80% of 1RM, in the half-squat of the Smith machine, Romero-Moraleda *et al.,* in 2019, also observed that the MC did not affect muscle performance for the mean and maximum values of strength, speed and power, which suggests that the muscle strength and power performance of eumenorrheic women are not affected by different phases of the MC[1]. The study by Ramos *et al.,* 2018, evaluated muscle strength in the four phases of the MC but it occurred in a single cycle and did not use the collection of serum hormones, whereas Romero-Moraleda *et al.,* 2019, also had a small sample but with triathletes, used a menstrual history of four months prior to regular cycles and evaluated within three phases of the menstrual cycle but there was also no serum dosage of female sex hormones to confirm the duration of the cycle and the beginning and the end of each phase.

Thompson *et al.,* 2020, conducted a systematic review to identify and critically evaluate studies on the effect of MC and oral contraceptives on responses to resistance training. Less than 20 studies met the inclusion criteria but with a limited number of participants and methodological issues. The results suggest conflicting findings that female hormones may affect resistance training responses[29]. Reinforcing these results, the rapid literature review by Cunha *et al.,* 2021, shows that the regular MC of physically active women can exert an effect on physical performance, however such effect was found in the minority of studies[30].

In these reviews, the limited number of articles implies conflicting results, mainly due to methodological issues such as the reduced number of participants, use of contraceptive methods, different ways of evaluating the phases of the MC, exercises and sports.

Studies carried out with athletes especially during competitions can generate sample loss due to different factors such as: injuries, training/competition schedules, besides length individual variation and beginning of the MC and difficulty in taking exams and tests on specific dates of the cycle. In this sense, the study by Dasa *et al.,* 2021, also analyzed the effect of MC on athletic performance. However, they did not find statistically significant changes in the follicular and luteal phases. These findings propose that the MC phase should not be considered important for athletic testing or competition emphasizing strength and power performance[31].

Hormonal fluctuations can alter physical performance but individual variables influenced by hormones can indirectly generate changes in women's performance. In another aspect, thinking about self-assessment and self-report of symptoms, the study by Costa e Silva *et al.,* 2017, evaluated how premenstrual tension syndrome (PMTS) would influence university women's physical activity and quality of life in the Physical Education course. Regarding to daily life physical activity of university students, PMTS generates losses, since sports practice is part of their daily lives and in their academic performance because of the symptoms[32].

The study by Lima *et al.,* 2012, presents results of higher average of the middle and maximum force during the postmenstrual phase. The authors recommend periodizing training to gain muscle strength in relation to hormonal fluctuations within the MC because such fluctuations in serum concentrations of estrogen and progesterone are sufficient to affect physical performance[33]. In agreement with the periodization of training Souza *et al.,* 2015, show that the greater production of isometric strength of the rectus femoris, vastus medialis and vastus lateralis muscles during the luteal phase can be considered a finding for coaches to modify the periodization of training in women under the same conditions. And possibly increase the intensity of training in the luteal phase would be a good alternative for people who wanted more efficient results in strength gain for the lower limbs. In their study, Souza *et al.,* 2015, verified the possible changes caused by the phases of the MC in the production of force and in the electromyographic activity of the quadriceps femoris muscles and the results suggest that the different phases of the MC in women can influence the performance of muscle strength and electromyographic activity[34]. As foreseen in the other studies, some limitations must be considered to extrapolate the results such as: the reduced number of participants, definition of the menstrual cycle of each woman, the use of serum hormone levels and the collection, being restricted by just one MC.

Finally, in their review Carmichael *et al.,* 2021, present that muscle strength was reported in five studies to be affected by the MC phase while another five studies reported no effects and only 1 study reported a change in some strength outcomes and no change in other strength outcomes. Despite inconsistencies in the findings, muscle strength would be impaired during the late luteal phase[13].

Results

As a result of the research, a Table 1 was used that contains elements for a better understanding, it contains experimental studies, with authors and year, phase of the MC studied, sample and sample number, evaluation processes and study development protocols, and to finalize the completion of studies.

It is worth highlighting two reviews related to the proposed theme, the first a systematic review by Thompson, *et al.,* 2020, which aimed to identify and critically evaluate current studies on the effect of the MC and oral contraceptives on responses to training of resistance. Of the 2,007 articles found, only 17 studies met the criteria and were included, with a total of 418 participants aged between 18 and 38 years. The reviewed articles reported conflicting results and were often limited by methodological issues, but it is realized that female hormones can affect resistance training responses[29]. McNulty *et al.,* 2020, also performed a systematic review with meta-analysis, which examined how exercise performance would be affected by the MC phase in 78 studies, and found that there was a trivial reduction in exercise performance during the CM phase. early follicular compared to other phases of the CM. In addition, they brought a network diagram illustrating the pairwise effect sizes calculated in the six phases of CM from 73 studies[25].

Finishing with Carmichael, *et al.*, 2021, who contemplated a narrative review with the aim of complementing some existing systematic reviews, in which they explored the impact of the MC phase on perceived and objectively measured performance in athletic populations. Research has found that the MC plays a mediating role in physical performance and shows that the phases of the MC affect strength, aerobic and anaerobic performance differently. If the training is modified based on the MC phase, the performance variable to be used and the objectives of the sessions must be considered[13].

Conclusions

The present study aimed to review the influence of the MC on the practice of exercises and despite the divergences in the literature, it is considered necessary to relate the variables of the practice of physical exercises with the phases of the MC. Therefore, in the initial follicular phase, lighter exercises are suggested. More intense exercise may be prescribed in the late follicular phase, when estrogen rises and peaks, which affects body fat distribution. In the ovulatory phase, there is the possibility of a decrease in physical performance, but estrogen still circulating maintains physical performance. In the medium luteal phase, there is an increase in progesterone, in which women are more prone to fat loss, so their muscular and aerobic resistance can be developed. With a late luteal phase, hormones begin to drop, but it is worth mentioning that in this phase there is a perception of decreased performance by women, mainly because it is the phase that precedes menstruation, with a new cycle.

Hormonal fluctuations during MC may not significantly and directly affect the cardiorespiratory or musculoskeletal system during physical exercise, as there is the question of the biological individuality of each woman, as well as the relationship with the self-reported symptoms.

By developing this theme, we believe that we can clarify some doubts, but also demonstrate the importance of physiologically understanding the hormones related to BC, for a better performance of several professionals who deal with women inside and outside the competitive environment.

There are several limitations regarding the study and research on MC, namely: difficulty in determining the stages of MC, sample number, type of sample (eumenorrheic women, use of contraceptives or not, what are the dosages of these contraceptives), types of exercises and evaluators of physical performance. So, it remains for future research to determine in which phases of the MC there are oscillations that really influence the practice of physical activity, as well as which exercise prescription strategies, such as intensity and volume, would be ideal for a woman's best performance.

Acknowledgements

This study was supported by the Fundação de Amparo à Pesquisa de Minas Gerais (FAPEMIG) - APQ-02915-21.

Conflict of interest

The authors declares that there no conflict of interest.

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