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The prescription of physical exercise, a necessity

La prescripción de ejercicio físico, una necesidad

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There is increasingly more scientific evidence to support the positive effects of the physical exercise-health relationship, evidence that is now solid and is accepted by scientific societies and bodies such as the World Health Organisation.

It is recognised that physical fitness is an excellent predictor of life expectancy and quality of life, while there is also an inverse relationship between physical fitness and morbidity -mortality in the general population.

Medicine is advancing, providing effective treatments for many pathologies that are accessible to most of the population, however scientific progress is also most certainly demonstrating that the regular practice of physical exercise, even at low intensities, is extraordinarily effective in both prevention and as a complement to treatment for a growing number of chronic pathologies, some with a prevalence at a pandemic magnitude. The problem is so great that the Council of the European Union has made a recommendation to Member States "To work on effective policies with regard to Health-Enhancing Physical Activity, promoting a cross-sectoral approach that covers political areas such as sport, health, education, the environment and transportation".

Unquestionably, society as a whole must accept the incorporation of physical activity and exercise as a health strategy to prevent disease and to serve as a complementary treatment for the same.

From a healthcare point of view, doctors and other healthcare professionals have a major role to play in managing exercise for health and also, outside the healthcare sector, physical activity and sports professionals play a key role in promoting and implementing active lifestyles as health-promoting strategies.

The prescription of physical exercise must be like any other prescription for medicine, containing all the elements required for the execution of the exercise program: type of exercise, intensity, duration, number of repeats and sets, rest periods, progression criteria, evolution, etc.

The prescription must be made by taking into consideration the contraindications and precautions of physical exercise adapted to each individual patient. It must comply with established guidelines, based on scientific and medical evidence, and must be part of the patient's overall treatment.

The exercise program that is directed at improving one or more of the physical fitness components must be prescribed by taking account of the pathology, the medical treatment and other treatments, the functional situation, socioeconomic and cultural aspects, and patient preferences, so that the program can be maintained without the patient dropping out. The fact is that the correct programming of exercise facilitates the regular participation, enjoyment and safety of the participants in the program..

The periodical evaluation of the response to the therapeutic exercise program is an essential part of the prescription and the program itself. Therefore, attention should be paid to those circumstance in which the patient: does not achieve the initially expected targets, or there are symptoms or signs of excessive effort or inadequate responses to physical exercise, or the patient rejects the proposed program.

In this context, it is necessary to routinely include in the medical monitoring and follow-up, an assessment of the physical condition as a baseline for the prescription of physical exercise and the monitoring of its progress.

Basically the assessment of those components of physical fitness that are health-related such as the aerobic profile, strength and body composition, without forgetting flexibility and balance.

For this purpose, it will be necessary to routinely conduct different tests to assess these components, based on the material means

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available: ergospirometry, ergometry, 6 minute tests, 4 metre speed test, dynamometer hand-grip, weight, height and waist circumference, among others.

Thus, the physical exercise prescribed shall be directed at improving the health-related physical fitness qualities, which have been assessed and periodically monitored with the tests conducted.

It is of the utmost importance to personalise exercise prescription, in other words to adapt the prescription as far as possible to the physiological characteristics and response to exercise of each patient and, as indicated above, to the pathological and medical treatment constraints and to the financial, social and cultural situation of each patient.

The physical exercise programs proposed must be easy to prescribe and simple to undertake by the patients in question, avoiding any possible negative effects: drop-out, injuries of the locomotor system, increased cardiovascular and metabolic risks.

The entire process requires assessment, control and supervision by qualified personnel, as indicated above.

At present, all these actions are being performed magnificently, and in some cases almost "heroically", by work groups and professionals at different geographical points of our country, but in a disjointed, unstructured way and not included in the normal portfolio of healthcare services.

Today, the most obvious examples of the need to assess and prescribe physical exercise of quality include surgical prehabilitation and persistent COVID, which add to the pathologies that were typically the target of prescription, such as cardiovascular, respiratory, metabolic, oncological pathologies, among others.

The best trained professionals, doctors specialising in sports medicine, are not part of the public health system, while the doctors in the system - primary health care and other specialties - normally lack quality training in this subject.

We therefore find ourselves in a situation in which, although scientific evidence indicates the benefit of the prescription of exercise for the health of individuals and populations and its positive effect on all levels of the health care systems, including economic benefits in the medium and long term, the general public is not offered this service on a widespread, generalised basis.

As professionals of Sports Medicine and of the Sociedad Española de Medicina del Deporte (SEMED - Spanish Association of Sports Medicine) in particular, we are concerned about this situation, which is included among our priorities of action.

We believe that the measures to be adopted must include information to the general public, the training of doctors in the public health system in the prescription of exercise, and that doctors specialising in sports medicine should act as consultants in complex cases and also support other colleagues, particularly with regard to primary care.

Public healthcare and sports institutions and administrations should resolutely address the progressive implementation of exercise prescription in the portfolio of healthcare services.

At the Sociedad Española de Medicina del Deporte, and on behalf of sports medicine specialists, we offer our collaboration to inform the population in general (as we have already been doing), to give quality training in the prescription of exercise for health care purposes to our colleagues in primary care and other specialties, with programs that have already been developed, as well as to continue to work to convince administrations and institutions that this is a matter of far-reaching significance and importance due to its positive effect on the health and quality of life of the general public and must therefore be addressed as a matter of priority.

Conflict of interest

The authors do not declare a conflict of interest.

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Original article

Evaluation of the maximum speed in a 30-metre sprint among young Argentine football players

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Summary

Introduction: the objective of this study was to compare in young federated soccer players, the speed in a sprint of 30 meters in different ages. The times used in two phases were also compared (0 to 10 meters and 10 to 30 meters) was analyzed according to age.
Material and method: 505 male soccer players were measured with the 30-meter test, in an age range between 11,0 and 16,9 years. They were divided into 5 groups per chronological age. Anthropometric measurements (body weight and size) were analyzed. To measure the 30-meter test, three pairs of infrared synchronizations beam lamps (photocells) placed at; 0,0 m, 10,0m and 30,0 m from the starting line.
Results: group 1 (11 years) traveled the distance of 30 meters in 5,48±0,36 s, group 2 (12 years) in 5,17±0,42 s, group 3 (13 years) in 4,94±0,44 s, group 4 (14 years) in 4,64±0,29 s, group 5 (15 years) in 4,56±0,28 s, and group 6 (16 years) in 4,42±0,22 s.
Conclusion: The older youth, on average, traveled the distance of 30 meters in less time, although they only varied significantly between 11,5 and 14,5 years (p>0,01). During the segment o to 10m, the same trend was also observed, being significantly at all ages, except for 12,5 years (p>0,01).

Key words:
Sprint. Anaerobic power. Children. Field test. Soccer.

Evaluación de la velocidad máxima en un esprint de 30 metros en jóvenes futbolistas argentinos

Resumen

Introducción: El objetivo de este estudio fue comparar en jóvenes futbolistas federados, la velocidad en un esprint de 30 metros en diferentes edades. También se compararon los tiempos empleados en dos fases (segmentos 0 a 10 metros y 10 a 30 metros), de acuerdo a la edad.
Material y método: 505 futbolistas masculinos fueron medidos con el test de 30 metros, en un rango de edades entre 11,0 y 16,9 años. Fueron divididos en 5 grupos de acuerdo a la edad cronológica. Se realizaron mediciones antropométricas (peso corporal y talla parada). Para medir el test de 30 metros se utilizaron tres pares de lámparas de haz de sincronización por infrarrojos (fotocélulas) colocadas a; 0,0 m, 10,0 m y 30,0 m de la línea de salida.
Resultados: El grupo 1 (11 años) recorrió la distancia de 30 metros en 5,48±0,36 s, el grupo 2 (12 años) en 5,17±0,42 s, el grupo 3 (13 años) en 4,94±0,44 s, el grupo 4 (14 años) en 4,64±0,29 s, el grupo 5 (15 años) en 4,56±0,28 s, y el grupo 6 (16 años) en 4,42±0,22 s.
Conclusión: Los jóvenes de mayor edad, en promedio, recorrieron la distancia de 30 metros en menor tiempo, aunque solo variaron significativamente entre los 11,5 a 14,5 años (p>0.01). Durante el segmento 0 a 10 m, también se observó la misma tendencia, siendo significativamente en todas las edades, a excepción la de 12,5 años (p>0,01).

Palabras clave:
Esprint. Potencia anaeróbica. Niños. Prueba de campo. Fútbol.

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Introduction

During a football game, players cover an average distance of 10,000 to 12,000 metres, depending on the position they play.[1] These distances are classified, depending on the displacement speed. Speeds over 23 km·h^{-1} are known as a "sprint".[1] During a sprint, a player covers a distance of 20 metres, accumulating a total between 200 and 400 metres.[1,2]

Although, when compared to the total distance covered in a match, these actions only represent 5% on average, sprints play an important role. Faude *et al*[3] looked at the German league and observed that, out of 360 goals, 60% were the result of linear sprints, 9% came from a sprint with changes in direction, 22% from a jump, and only 8% from other types of actions, concluding that sprints play an important role.[3] According to this study, 69% of goals involved a sprint. For this very reason, physical trainers assess, monitor and train this quality in their athletes.[4-6]

One simple way of evaluating a sprint is to measure the time taken to run in a straight line, at the maximum speed that the players can reach.[7] The devices used are photocells or a video camera. In general, these distances are between 30 and 50 metres.[7,8] These distances are used to assess two phases: a first phase known as acceleration speed (AS) and another known as maximum speed (MS).[9] According to the bibliography, the distances to cover in each of the aforementioned phases can vary.[4-11] Distances of 5, 10, 15 and 20 metres are used to evaluate the AS, while distances over 20 metres are used to assess the MS.[4-11] Another way of pinpointing the MS is to use several photocells (or a video camera) to measure the time taken in several 10-metre segments.[11] For instance, after measuring a 40-metre sprint, the average is calculated for the time taken in each segment, 0-10, 10-20, 20-30 and 30-40 metres, and the MS is located in one of the segments (generally the 20-30 or 30-40 segment[11]). This method is widely used nowadays.[11] Buchheit *et al*[11] worked with trained football players to demonstrate that 70% of boys aged under 14 years old reached the MS in the 20-30 m segment, and 30% achieved it in the 30-40 m segment.[11] However, between 15 and 18 years old, 60% reached the MS in the 30-40 m segment and 40% in the 20-30 m segment.[11] Consequently, it is important to monitor this quality during the training period.

Football is one of the most widely-played sports in Argentina.[12] Although it is widely known that physical trainers assess and train this skill, it is difficult to find studies run on young Argentine players. Consequently, the aim of this study was to compare the time taken in the 30 m test for males aged between 11.0 and 16.9 who took an active part in federated football in Neuquén. The second aim was to observe the relationship between the two phases being measured: the 0-10 m segment and the 10-30 m segment, by age. This knowledge will provide useful information for trainers to assess and monitor progress among their athletes in the training stages.

Material and method

Study Design

The study was carried out in the facilities of each club involved, in September and October. The measurements were taken in training hours, between 3 and 5 pm. In all the measurements, the subjects wore sports clothing (shorts, t-shirt and boots). The field assessments took place on the playing field. The subjects did not do intense physical exercise 48 hours before the assessments.

Subjects

The sample was made up of 505 males. All subjects were federated football players belonging to Alto Valle de Río Negro and Neuquén and they were in the playing season (tournament). Subjects were only included if they met the following characteristics: a) have taken part in the activity for at least 6 months; b) no neuromuscular and/or cardiorespiratory injury; c) aged over 11.0 years old and under 17.0 years old; d) have experience in speed tests and e) experience in speed training. The study was clearly explained to all subjects, including the risks and benefits of taking part. Informed consent was obtained from their parents because they were minors. Furthermore, the study was endorsed and approved by LIFUNE (Neuquén football league). For analysis, they were divided into 6 groups, according to their decimal age: group 1 (between 11.0-11.9 years old), group 2 (between 12.0-12.9 years old), group 3 (between 13.0-13.9 years old), group 4 (between 14.0-14.9 years old), group 5 (between 15.0-15.9 years old) and group 6 (between 16.0-16.9 years old).

Assessments

Anthropometry: Body mass (BM) and foot size (FS) were measured. The measurements were taken, according to the International Society for Kinanthropometry Progress (ISAK)[13]. The Body Mass Index (BMI kg/ m^2) was calculated by dividing the body weight of the subject by their height expressed in square metres.

Equipment

Three pairs of infrared synchronised beams (Winlaborat equipment with a sampling speed of 14 us of photocells and software sampling rate of 1,000 Hz, Argentina) were used with a beam height of 0.9 m from the ground. They were placed 0.0 m, 10.0 m and 30.0 m from the start line. The terrain used for the tests was grass and all the subjects wore football boots.

Procedures

Following the anthropometric measurements, participants completed a general warm-up consisting of 10 minutes of light jogging and dynamic stretching. This was followed by a warm-up with specific exercises for the speed test.

The subjects lined up behind the start line and the initial light beam to avoid any odd premature movement breaking the beam at 50 cm. The position was held with one foot forward and the other behind (Split start) as recommended in the bibliography.[10] On the command of "go", the subjects began to run. They were instructed to run as fast as possible over a distance of 30 metres. The speed was measured with an accuracy of 0.01 seconds, taking the fastest speed of the two attempts. Between attempts, the subjects rested between 5 and 7 minutes.

The distances of 10 m and 30 m were shown to be valid[16] and reliable[17] (r= 0.90 and 0.95), as was the technical measuring error (1.3% and 0.5%), respectively.[18]

Statistical analysis

The data was analysed using the IBM SPSS 18.0 statistics package. The Kolmogorov-Smirnov test and the Levene test checked for the presence of normality and homoscedasticity in the study sample. Descriptive statistics were subsequently applied to calculate the frequencies, mean and standard deviation, maximum and minimum value. The ANOVA one way test was used to determine the statistically significant differences between the BM, FS, BMI and the time taken in the 30-metre test. The Scheffé test was applied to find the difference between the average of the groups. The ratio between the various speed phases was calculated using the Pearson correlation coefficient, with the following criteria: 0.1 very low; 0.1-0.3, low; 0.3-0.5, moderate; 0.5-0.7, good; 0.7-0.9, very good; and 0.9-1.0, perfect.[14] In all cases, an alpha $p<0.05$ was accepted.

Results

Table 1 shows the anthropometric characteristics of the samples distributed by ages and the time used in the 30-metre test.

Differences were found between the groups in the anthropometric measurements.

The MC for group 1 was significantly lower than groups 3, 4, 5 and 6. Group 2 was significantly lower than groups 4, 5 and 6. Group 3 was significantly lower than groups 5 and 6. No difference in BM was observed between groups 4, 5 and 6.

The FS for group 1 was significantly lower than all groups. Group 2 was significantly lower than groups 3, 4, 5 and 6 and higher than group 1. Group 3 was significantly lower than groups 4, 5 and 6 and higher than groups 1 and 2. No difference in FS was observed between groups 4, 5 and 6.

Concerning BMI, the only statistically significant difference was between groups 1 and 6.

Figure 1 shows the times taken in the section from 0.0 to 10.0 meters (A), the section from 10.0 to 30.0 metres (B) and the section from 0.0 to 30.0 metres in the different groups.

Table 2 shows the correlations obtained in the different phases of the 30-metre sprint.

Figure 2 shows the percentage representation of the maximum speed achieved in each group, taking the oldest group as a reference. The curves correspond to the maximum speed in both segments (0-10 m and 10-30 m).

Table 3 is constructed by using the following quartiles, where the 0-25 quartile is low performance, 26-50 is low-moderate performance, 51-75 is moderate-high performance and 76-100 is high performance. This table aims to give the physical trainer some reference points to assess their athletes.

Discussion

For the first time, a large number of young Patagonian footballers were measured using the 30-metre test, in both segments: acceleration speed (0-10m) and maximum speed (10-30m).

According to the results obtained, the older subjects, on average, cover the 30 m distance in less time, although they only vary significantly

Table 2. Correlations between the two 30-metre sprint phases, in the different age groups.

Groups	Phases	10-30 m	0-30 m
11 to 11.9 years old	0-10 m	r = 0.83	r = 0.92
12 to 12.9 years old	0-10 m	r = 0.74	r = 0.88
13 to 13.9 years old	0-10 m	r = 0.78	r = 0.91
14 to 14.9 years old	0-10 m	r = 0.65	r = 0.86
15 to 15.9 years old	0-10 m	r = 0.68	r = 0.88
16 to 16.9 years old	0-10 m	r = 0.48	r = 0.77

Table 1. Anthropometric characteristics of the young players and the time taken in the 30-metre test.

Units Sample	Age (years)	BM (Kg)	FS (cm)	BMI (kg·m²)	Time taken (s)			Speed (km/h) *		
					0 to 10 m	10 to 30 m	0 to 30 m	0 to 10 m	10 to 30 m	0 to 30 m
G1 (n=28)	11.5± 0.3	44.3;12.1	148.1;7.6	19.8± 3.7	2.15;0.13	3.33;0.25	5.48;0.36	16.8;1.0	21.7;1.6	19.7;1.2
G2 (n=106)	12.5;0.3	49.4;10.2	155.2± 9.0	20.4± 3.3	2.04;0.16	3.13;0.29	5.17;0.42	17.7;1.4	23.2;2.0	21.0;1.7
G3 (n=138)	13.4;0.3	53.8;11.9	161.5± 8.7	20.4± 3.4	1.99;0.16	2.95;0.30	4.94;0.44	18.2;1.5	24.6;2.4	22.0;1.9
G4 (n=85)	14.5;0.3	59.7;10.7	168.6± 7.0	21.0± 2.9	1.90;0.13	2.74;0.20	4.64;0.29	19.0;1.3	26.4;1.8	23.3;1.4
G5 (n=81)	15.6;0.3	63.7;12.7	170.9± 6.4	21.5± 3.9	1.86;0.12	2.70;0.18	4.56;0.28	19.5;1.3	26.9;1.7	23.9;1.4
G6 (n=67)	16.4;0.3	63.8;7.8	171.0± 6.3	21.9± 2.5	1.82;0.10	2.60;0.16	4.42;0.22	19.7;1.0	27.5;1.6	24.3;1.2

BM: Body mass FS: foot size in bare feet. BMI: body mass index. m: metres. s: seconds
*The speed was calculated; distance/time used.

Figure 1. Time taken in the different segments according to age, A: 0-10 m segment; B: 10-30 m segment; C: 0-30 m segment.

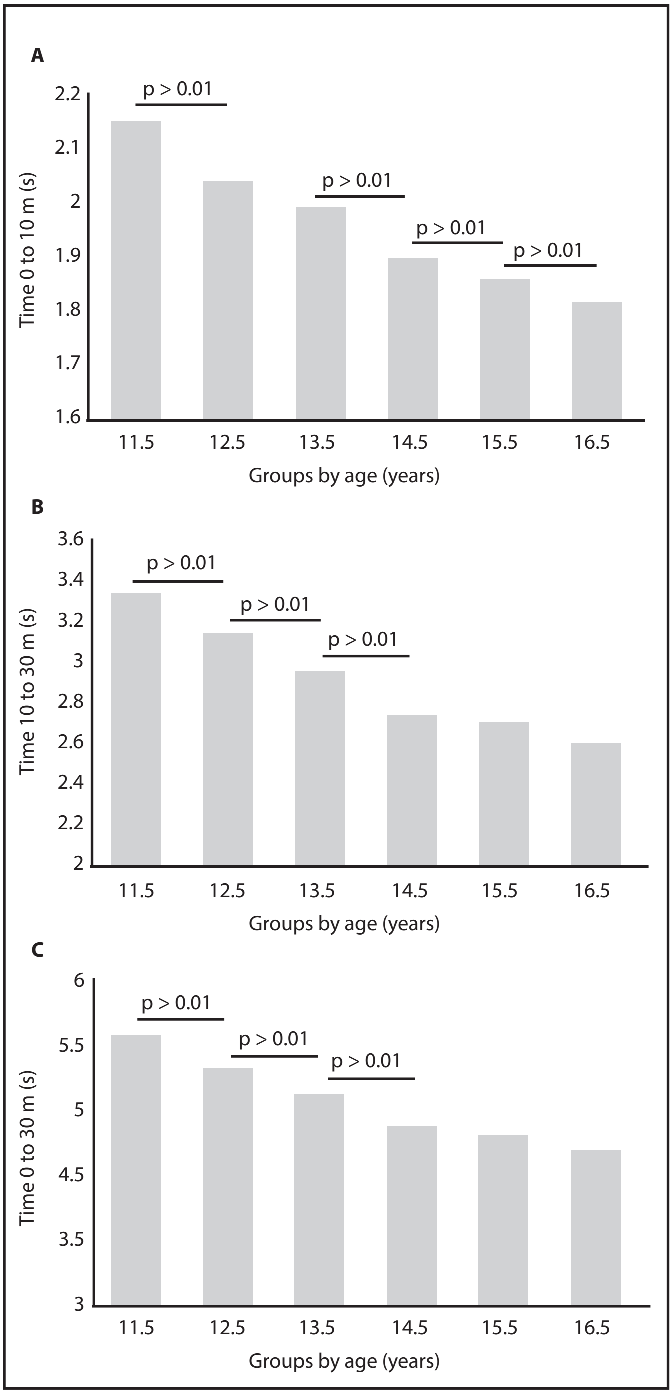


Figure 2. Evolution of the speed, according to age.

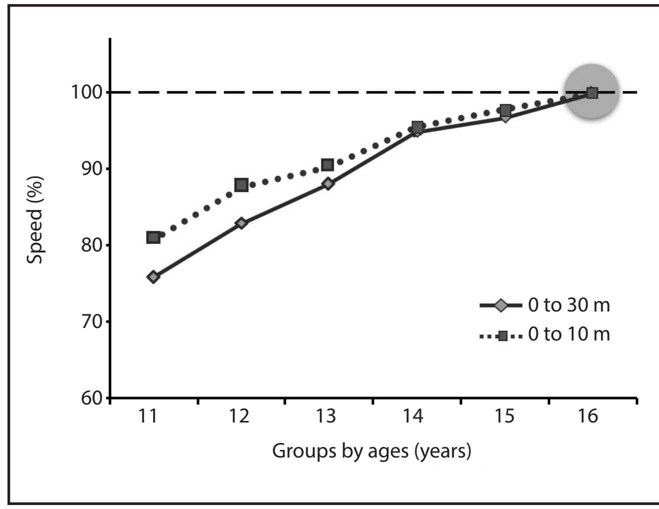
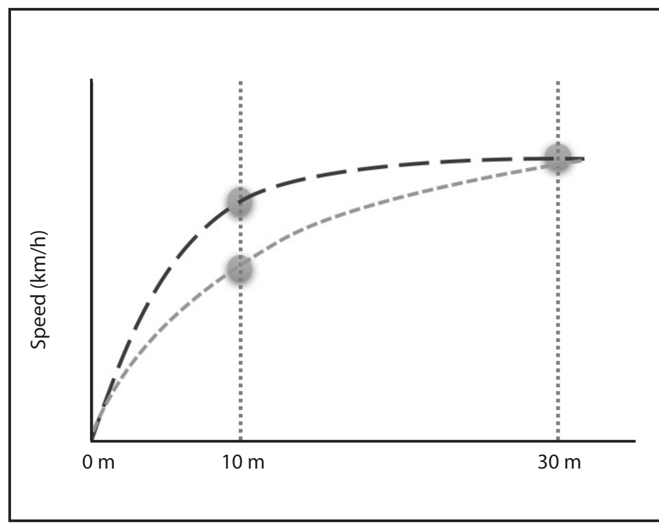


Figure 3. Example of the two study cases, that take the same time over 30 metres, but different times in the 0-10m segment.



between 11.5 and 14.5 years old (p>0.01). This finding is similar to other studies. Mathisen and Pettersen applied a 20-metre sprint in young players aged between 10 and 16 years old.[15] They compared the times used by each age group in the segments: 0-20 m, 0-10 m, and 10-20 m. As age increased, the time used fell significantly in all segments.

Bucheitt *et al*[11] applied a 40-metre sprint among young players aged between 13 and 18 years old.[4] Between groups, they compared the acceleration speed (0-10 m segment) and the maximum speed (locating it in one of the other segments (10-20, 20-30 and 30-40). As the players' age rose, the time used fell in both phases; acceleration and maximum, although they were significant between 13 and 15 years old. Meyers *et al* assessed the maximum speed with a 30-metre sprint among school children aged between 11 and 15 years old.[18] In the same way as other studies, they found that, as the age increased, the speed was greater between the groups, although this was only significant between 11 and 14 years old. The differences were attributed to the length of the stride, the frequency of steps and the contact time with the ground, ruling out the flight time as no differences were seen in any group.

To get a better understanding of the discrepancies found between the ages, Figure 2 shows the differences expressed as a percentage, tak-

Table 3. Proposal to assess the performance in the 2 segments of the 30-metre sprint.

Age (years)	Time taken from 0 to 10 metres (s)			
	Low	Low-Mod	Mod-High	High
11	≥ 2.24	2.23 - 2.14	2.13 - 2.09	≤ 2.08
12	≥ 2.15	2.14 - 2.03	2.02 - 1.93	≤ 1.92
13	≥ 2.10	2.09 - 1.98	1.97 - 1.89	≤ 1.88
14	≥ 2.0	1.99 - 1.90	1.90 - 1.83	≤ 1.82
15	≥ 1.93	1.92 - 1.85	1.84 - 1.77	≤ 1.76
16	≥ 1.90	1.89 - 1.84	1.83 - 1.78	≤ 1.77
Age (years)	**Time taken from 10 to 30 metres (s)**			
	Low	**Low-Mod**	**Mod-High**	**High**
11	≥ 3.49	3.48 - 3.32	3.31 - 3.17	≤ 3.16
12	≥ 3.30	3.29 - 3.09	3.08 - 2.94	≤ 2.93
13	≥ 3.10	3.09 - 2.92	2.91 - 2.76	≤ 2.75
14	≥ 2.84	2.83 - 2.71	2.70 - 2.61	≤ 2.60
15	≥ 2.79	2.78 - 2.67	2.66 - 2.56	≤ 2.55
16	≥ 2.71	2.70 - 2.60	2.59 - 2.53	≤ 2.52

ing the speed obtained by the oldest group (group 6) as the reference value (100%). The speed achieved over the 30 metres by the 15-year-old group represents 96.8%, the 14-year-old group 95.0%, the 13-year-old group 88.2%, the 12-year-old group 83.0% and the 11-year-old group 76.5%. This same trend is seen for values measured in the 0.0 to 10.0 metre segment (AS): for the 15-year-old group it represents 97.8%, the 14-year-old group 95.6%, the 13-year-old group 90.6%, the 12-year-old group 87.0% and the 11-year-old group 81.2%. Papaiakovou *et al*[19] found similar percentages to our study among school children.19 The authors found that among 11-year-old children, the speed obtained in the 0-30 metre segment represented 85% of the speed of the 18-year-olds, and this increased, reaching 98% in 16-year-olds and 100% among 18-year-olds. To sum up, as the boys grow, the time they take to complete both phases of the test drops, because they are maturing biologically: their muscle mass increases, their fat tissue drops, their muscular strength increases, their male hormones rise, the length of their stride increases, their jumping height increases and the jump becomes longer, their mechanical efficiency improves, among other aspects, even when they are not in a training programme.[6,18,20-26] Therefore, if the point is to monitor and/or improve speed in training stages, the physical trainer should consider other variables as a whole for a correct comprehensive interpretation of their athletes' performance.

Another point to be discussed concerns the correlations obtained between the 0-10 and 0-30 m segments. The boys who are the fastest over the first 10 metres are also the fastest over 30 metres (range between r=0.92 and r=0.77). However, this does not happen when correlating the segments separately, 0-10 and 10-30. The correlation drops considerably (from r=0.83 to r=0.48) as the boys grow. The fastest subject over the first 10 metres is not necessarily the fastest over the 10-30 m segment. One of the reasons is each player's capacity for acceleration and the peak time in which the maximum running speed is reached in this segment.[6] The less time their foot is on the ground, the shorter the time they take to cover the first 10 metres.[6] To understand this concept better, Figure 3 presents 2 cases that obtain the same final speed over 30 metres, although they accelerate differently. This is the main reason why there is a strong relationship between the measured segments.

As opposed to athletics, in this sport it is important to know the football players' ability to accelerate over short distances, as most plays are resolved over distances under 30 metres.[1,2,6] Consequently Anselmi6 proposes filming the first 3 steps during the assessment with the photocells or, as far as possible, filming all the steps in the 0-10 metre segment.[6] This would differentiate the 10-metre segment better.

To round off, we would like to highlight two limitations: 1) no biological maturing was assessed (Tanner stages) and 2) the players' positions were not differentiated. Although this can influence the outcomes, the football federations and associations organise categories by chronological age, and so this is the real-life situation for the physical trainers. Future research must confirm the results obtained among football players from other regions or provinces.

Conclusions

The older boys, on average, cover the 30-metre distance in less time, although they only vary significantly between 11.5 and 14.5 years old (p>0.01). During the acceleration phase (0 to 10 m), the same trend was seen, significant in all ages, with the exception of 12.5 years old (p>0.01).

Practical application

Table 3 can be used to assess both speed phases, in populations that meet similar characteristics.

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Conflict of interest

The authors do not declare any conflict of interests.

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Is ultradistance sport healthy? A descriptive observational study of a cohort of ultradistance runners

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Summary

Objective: To describe the physical and physiological characteristics of a group formed by ultra-distance runners, to compare their training habits with the guidelines established by the WHO and to study the possible harmful consequences of the high volume of physical activity performed.
Material and method: The sample was formed by runners who repeated their participation in the "Ehunmilak" ultra-distance race in 2017 and 2018. Data collected through the medical certificates of the race and an own questionnaire were analyzed. For the analysis of variables, the Mann-Whitney U and Chi-square tests were used, with a 95% confidence interval. A value of p <0.05 was considered statistically significant.
Results: A low prevalence of several well known risk factors was observed (HT 1.8%, DM 0%, dyslipidemia 0-1.8%, smoking 5.3-10.5%, overweight 17.5%). During the last two years, 0% suffered cardiovascular injuries and 52.6% suffered musculoskeletal injuries. Medical examinations were performed frequently, each year by 91.2%. 72% complied with the latest WHO recommendations regarding volume of physical activity. Finally, no relationship was found between the parameters that indicate a high volume of physical exercise and the ECG result. The same occurred with musculoskeletal injuries, although in this case significant relationships were observed with BMI (p = 0.004) and training intensity (p = 0.009).
Conclusions: It was observed that the group of runners studied is in good health and that their training habits are correct, according to the latest WHO recommendations. In addition, their characteristics and training habits did not show a relationship with the risk of developing a pathological ECG or suffering musculoskeletal injuries, except for the significant relationship that BMI and training intensity showed with the latter.

Key words:
Running. Resistance training. Athletic injuries. Electrocardiography. Sports medicine.

¿Es la ultradistancia saludable? estudio descriptivo observacional de una cohorte de corredores de ultradistancia

Resumen

Objetivo: Describir las características físicas y fisiológicas de un grupo de corredores de ultradistancia, comparar sus hábitos de entrenamiento con las directrices establecidas por la OMS y estudiar las posibles consecuencias lesivas del alto volumen de ejercicio físico realizado.
Material y método: Muestra compuesta por corredores que repitieron participación en las carreras de ultradistancia Ehunmilak de 2017 y 2018. Se analizaron datos recogidos mediante los informes médicos de la carrera y un cuestionario creado específicamente para este estudio. Para el análisis de variables, se utilizaron las pruebas de U de Mann-Whitney y Chi-cuadrado, con un intervalo de confianza del 95%. Un valor de p <0,05 fue considerado estadísticamente significativo.
Resultados: Se observó baja prevalencia de varios factores de riesgo conocidos (HTA 1,8%, DM 0%, dislipemia 0-1,8%, tabaquismo 5,3-10,5%, sobrepeso 17,5%). Durante los dos últimos años, el 0% sufrió lesiones cardiovasculares y el 52,6% lesiones musculoesqueléticas. Los exámenes médicos son realizados con frecuencia, cada año por el 91,2%. El 72% cumplió con las últimas recomendaciones de la OMS en cuanto a volumen de ejercicio físico. Por último, no se encontró relación entre los parámetros que indican gran volumen de ejercicio físico y el resultado del ECG. Lo mismo ocurrió con las lesiones musculoesqueléticas, aunque en este caso se observaron relaciones significativas con el IMC (p=0,004) y la intensidad del entrenamiento (p=0,009).
Conclusiones: Se observó que el grupo de corredores estudiado goza de buena salud y que sus hábitos de entrenamiento son correctos, acorde a las últimas recomendaciones de la OMS. Además, sus características y hábitos de entrenamiento no mostraron relación con el riesgo de desarrollar un ECG patológico o de sufrir lesiones musculoesqueléticas, exceptuando la relación significativa que mostraron el IMC y la intensidad del entrenamiento con estas últimas.

Palabras clave:
Correr. Entrenamiento de resistencia. Lesiones deportivas. Electrocardiografía. Medicina deportiva.

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Introduction

Inactivity, a sedentary lifestyle and poor physical shape are considered independent high-risk factors for mortality due to any cause, cardiovascular pathology or cancer, this can present estimated risks similar to other well-defined entities such as smoking, arterial hypertension (AHT), hyperglycaemia on an empty stomach or a high body mass index (BMI).[1,2]

Consequently, physical activity provides undeniable health benefits: it reduces mortality for any reason, the lethality and incidence of cardiovascular diseases and many cancers, also AHT and diabetes mellitus (DM).[2-7] Benefits have also been demonstrated for mental health, reducing anxiety and depression, improving cognitive function and the risk of suffering dementia.[3,8,9]

However, some sports such as ultramarathons, demonstrate the need to investigate the limits of excessive physical exercise. The ultramarathon, a race that exceeds the 42 km marathon, is a discipline that has seen a boom in events, and so also participants, over the last few years.[10] As one example, 2 of these races were run in North America 1979 and more than 50 in 2008.

Various studies endorse the concept that individuals capable of completing this calibre of race are healthier than the general population and have less need for medical attention. Apart from asthma and allergies, they suffer from fewer chronic diseases (cancer, coronary diseases, heart attacks, DM and AIDS among others), they have lower absenteeism, and they require less use of the health system.[10-12]

Nevertheless, this extreme sport also carries some risks. In the short term, the stress that the body suffers during the race leads to an acute phase reaction,[13] although most changes are transitory.[14] Musculoskeletal,[15-17] digestive[18-22] and dermatological[22,23] disorders are usual; although cardiovascular,[24,25] renal,[15,26] hepatic[27,28] or blood[29,30] anomalies also appear.

Even so, the anomalies that cause the most concern are possible long term damage, where once again the musculoskeletal system is one of the most affected due to the great stress on bones and joints, increasing the risk of osteoarthritis[31-33] or stress fractures among others.[33] A special mention should also go to the "triad of the female athlete",3[4,35] asthma[36] and allergies.[37] However, the greatest interest has been aroused by cardiovascular injuries, given that recently a U-shaped dose-response relationship has been suggested between the intensity of physical exercise and cardiovascular morbidity.[38] One of the most accepted theories is a direct association between extreme physical exercise and atrial fibrillation (AF),[39-41] although other studies have also proposed a J-shaped relationship between the volume of the physical activity and the risk of AF.[42,43] On the other hand, it has been described that athletes doing resilience sports for many years have a greater prevalence for arteriosclerosis plaque in their arteries, although they have a lower risk profile.[44,45]

In this respect, given the growing importance of this sporting discipline and the need to continue researching it, this study proposes to describe the physical and physiological characteristics of a group of ultradistance runners, determine if their training habits can be considered healthy and finally study the possible harmful consequences of this high volume of physical exercise.

The latest WHO recommendations will be taken, published in late 2020,[3] to work out if these training habits are healthy. In the case of healthy adults (18-64 years old), they recommend a minimum of 150-300 minutes of moderate aerobic physical activity, a minimum of 75-150 minutes of intense aerobic physical activity or an equivalent combination of the two each week. Even so, the same recommendations have observed a drop in mortality due to any cause with moderate-intense physical activity of up to 750 minutes per week, a limit that was considered to determine whether the training volume remains healthy.

Material and method

This is a descriptive observational study of a cohort of ultradistance runners The sample comprises individuals who had taken part for two consecutive years (2017-2018) in the *Ehunmilak Ultra Trail* race. This is an ultradistance mountain race that takes place around towns in Gipuzkoa, with a circular route of 172 Km, climbing 11.000 m in total. The sample size was 57 participants, with an alpha level defined as 0.05 and a statistical power of 95%.

The inclusion criteria for the sample selection were as follows: having taken part in the Ehunmilak race in both 2017 and 2018; presenting the race's medical report signed by a doctor as suitable to compete and a 12-lead electrocardiogram (ECG) at rest; having signed the relevant permission to send data to the race organisation for research and having properly filled in the questionnaire received by mail.

The work was accepted by the research ethics committee from Donostia Hospital and met the current data protection law. Study participants remained anonymous at all times during the data transfer from the Ehunmilak ultradistance race organisation, identified only by alphanumerical codes.

The medical report consists of a printed form with various sections to be filled out. In addition to the relevant administrative data, they must provide information on the following parameters: allergies, AHT, DM, dyslipidaemia, smoking habits, weight, height, family history of ischemic heart disease, history of syncope due to physical exercise, usual treatment, resting heart rate and blood pressure. Furthermore, it is optional but recommended to provide information on completing an echocardiogram and stress test. This report must come with a 12-lead ECG carried out at rest.

The questionnaire sent to the participants requested information on their sporting experience (when they first took part in an ultramarathon, number of events in total, how many of them were completed and if they are currently doing physical exercise), training habits (weeks of rest per year, total training hours per week, hours of purely aerobic training per week, proportion of weekly training carried out over the anaerobic threshold, complementary strength training or other type, stretches and physiotherapy), medical examinations (frequency of medical check-ups, resting ECG, stress ECG and echocardiogram) and musculoskeletal and cardiovascular injuries suffered over the last two years (2019-2020).

The statistical analysis on the data uses the SPSS Statistics computer program, version 25. To analyse the numerical variables, descriptive statistics procedures were used (calculation of central trend and dispersion measurements and frequency calculations). Subsequently, the quantitative variables and their association were analysed using the Mann-Whitney U test and the categorical variables and their association using Chi-squared. A value of $p<0.05$ was considered statistically significant for all the analyses.

Results

113 patients were recruited who met the criteria to receive the questionnaire by mail. 68 sent their questionnaire back and 11 were excluded because it was not properly filled out. Finally, 57 patients were included in the study, of which 53 were men and 4 were women. The average sample member had the profile of a healthy runner described in other works:[10-12] 43.96 years old, normal weight with a Body Mass Index (BMI) of 23.31, 53 bpm and blood pressure of 120/70. Table 1 shows the distribution of the numerical variables in the study sample.

Table 2 presents the categorical variables, comparing them in 2017 and 2018, and shows the results from the questionnaire carried out in 2020. Regarding the medical report data, little variability was observed from one year to another, with small changes in the prevalence of allergies, smoking, dyslipidaemia and excess weight among others. The training habits showed that most athletes rest for ≤4 weeks a year (56.1%) and train between 8-13 hours a week (59.7%), and that cross training was usual (56.1% cycling, 63.2% strength and 61.4% stretching). Furthermore, a great tendency was observed to get medical check-ups, as the majority underwent a medical examination (91.2%), resting ECG (70.2%) and stress test (70.2%) every year.

No member of the sample mentioned that they had suffered cardiovascular injuries over the previous two years. Consequently, electrocardiographs were used to study the relationship of the different variables with possible cardiac damage. Although the changes in the ECG were initially compiled in three categories (normal, physiological alterations caused by the physical exercise and pathological), they were cut back to two categories to make the associations (normal and pathological). To identify pathological ECGs, guidelines were followed that were proposed by international consensus on interpreting the athlete's ECG, as a result of the consensus of experts in cardiology and sports medicine who met in Seattle (USA) in 2015.[46] In this way, as compiled in Table 3, using the Mann-Whitney U test, no relationship was observed between the different variables and the ECG. However, the relationship between the number of participants in ultramarathons and ECG was very close to the proposed level of statistical signification ($p=0.053$); given that the number of participations in the normal ECG group was 4.75±3.16, compared to 7.80±3.49 from the group with a pathological ECG.

Table 1. Distribution of the numerical variables in the study sample.

Medical certificate						
Variables	**N**	**N***	**Mean±SD**	**Median**	**Min.**	**Max..**
Current age (years)	57	0	43.96±8.63	44	29	67
Weight (Kg)	57	0	71.18±8.4	73	47	86
Height (cm)	57	0	174.6±7.59	174	155	193
BMI (Kg/m2)	57	0	23.31±2.04	22.91	18.94	29.41
Resting HR (bpm)	57	0	53.72±9.67	53	32	78
SBP (mmHg)	57	0	120.14±11.24	120	90	155
DBP (mmHg)	57	0	71.86±8.61	70	55	90
Questionnaire						
Variables	**N**	**N***	**Mean±SD**	**Median**	**Min.**	**Max.**
First participation	57	0	2015±2.43	2016	2010	2017
Participations in UM	57	0	5.02±3.28	4	0	14
No. of UM completed	57	0	3.46±3.34	2	0	13
Rest (weeks/year)	55	2	5.44±4.73	4	0	20
Weekly training over the AT (%)	48	9	14.88±10.63	11	0	50
Rest due to musculoskeletal injuries (weeks/year)	32	25	3.87±5.51	2	0	20
Rest due to cardiovascular injuries (weeks/year)	57	0	0±0	0	0	0

BMI: Body Mass Index; HR: Heart rate; SBP: Systolic blood pressure;
DBP: Diastolic blood pressure; UM: Ultramarathon; AT: anaerobic threshold; N: valid cases;
N*: non valid cases; SD: standard deviation

Table 2. Distribution of the qualitative variables (2017-2018) and questionnaire results (2020).

	Medical certificate				Questionnaire		
Año	**2017**		**2018**			**2020**	
Variables	**N**	**%**	**N**	**%**	**Variables**	**N**	**%**
Gender					**Participations**		
Male	53	93	53	93	1-4	32	56.1
Female	4	7	4	7	5-9	19	33.3
Age groups					≥10	6	10.5
<30	3	5.3	0	0	**Currently doing sport**		
30-39	16	28.1	17	29.8	Yes	57	100.0
40-49	26	45.6	24	42.1	No	0	0.0
50-59	9	15.8	13	22.8	**Reduction due to health**		
≥60	3	5.3	3	5.3	Yes	4	7.0
Allergies					No	53	93.0
Yes	3	5.3	6	10.5	**Weeks of rest/year**		
No	54	94.7	51	89.5	0-4	32	56.1
AHT					5-9	11	19.3
Yes	1	1.8	1	1.8	10-14	9	15.8
No	56	98.2	56	98.2	≥15	3	5.3
DM					**Total training/week**		
Yes	0	0.0	0	0.0	5-7	7	12.3
No	57	100	57	100	8-10	20	35.1
Dyslipidaemia					11-13	14	24.6
Yes	1	1.8	0	0.0	14-16	11	19.3
No	56	98.2	57	100	17-19	3	5.3
Smoking					≥20	2	3.5
Yes	6	10.5	3	5.3	**Aerobic training/week**		
No	51	89.5	54	94.7	5-7	15	26,3
BMI				8-10	20	35.1	
Low (<18.5)	0	0	0	0,0	11-13	13	22.8
Normal (18.5-24.9)	47	82.5	44	77.2	14-16	7	12.3
Overweight (24.9-29.9)	10	17.5	13	22.8	17-19	2	3.5
FHIHD					≥20	0	0.0
Yes	1	1.8	2	3.5	**Over aerobic threshold/week**		
No	56	98.2	55	96.5	0-5	9	15.8
FHSD					6-10	14	24.6
Yes	1	1.8	1	1.8	11-15	5	8.8
No	56	98.2	56	98.2	16-20	12	21.1
Syncope					21-25	4	7.0
Yes	0	0.0	0	0.0	26-50	4	7.0
No	57	100	57	100	**Cross training**		
MH					Static bike/strider	32	56.1
Yes	5	8.8	3	5.3	Strength	36	63.2
No	52	91.2	54	94.7	Stretching	35	61.4
Treatment					Others	8	14.0
Yes	6	10.5	4	7.0	Physiotherapy		
No	51	89.5	53	93.0	Normally no	24	42.1
Heart murmurs					Due to discomfort	17	29.8
Yes	0	0.0	0	0.0	Yes	16	28.1
No	57	100	57	100	**Frequency of medical checks**		
Echocardiogram					1year	52	91.2
Normal	48	84.2	42	73.7	2 years	2	3.5
PCDE	9	15.8	9	15.8	3 years	1	1.8
Pathological	0	0	0	0	≥ 4years	2	3.5
Stress test					**Frequency of resting ECG**		
Normal	13	22.8	11	19.3	No	2	3.5
PCDE	41	71.9	41	71.9	1 year	40	70.2
Pathological	0	0	0	0.0	2 years	6	10.5
ECG					3 years	0	0.0
Normal	15	26.3	18	31.6	≥ 4 years	9	15.8
CFIE	38	64.9	34	59.6	**Frequency of stress ECG**		
Patológico	5	8.8	5	8.8	No	7	12.3

(continúa)

Table 2. Distribution of the qualitative variables (2017-2018) and questionnaire results (2020) *(continue)*.

	Medical certificate				Questionnaire		
Year	**2017**		**2018**			**2020**	
Variables	**N**	**%**	**N**	**%**	**Variables**	**N**	**%**
Changes in ECG					1 year	40	70.2
IRBBB	19	33.3	20	35.1	2 years	5	8.8
ER	16	28.1	14	24.6	3 years	1	1.8
T wave alterations	19	33.3	6	10.5	≥ 4 years	7	7.0
LVH	8	14.0	13	22.8	**FFrequency of echocardiogram**		
ST+	4	7.0	0	0	No	29	50.9
BCRD	0	0	0	0	1 year	17	29.8
VC	0	0	0	0	2 years	6	10.5
WPW	1	1.8	1	1.8	3 years	1	1.8
CLBBB	1	1.8	0	0	≥ years	4	7.0
VAV 1º	1	1.8	0	0	**Musculoskeletal injuries**		
					Yes	30	52.6
					No	27	47.4
					Cardiological injuries		
					Yes	0	0.0
					No	57	100.0

N: cases; AHT: arterial hypertension; DM: diabetes mellitus; BMI: Body Mass Index; FHIHD: family history of ischemia heart disease; FHSD: family history of sudden death; MH: medical history; ECG: electrocardiogram; PCDE: physiological changes during exercise; IRBBB: incomplete right bundle branch block; ER: early repolarisation; VC: ventricular contraction; LVH: left ventricle hypertrophy; ST+: rise in the ST segment; WPW=Wolff-Parkinson-White; CLBBB: complete left bundle branch block; VAV 1º: first degree atrioventricular block.

Table 3. Relationship between the variables studied and the ECG.

Variables	Norma ECG n=52	Pathological ECG n=5	P
Age	43.37±8.50	38.80±9.98	0.351
BMI	23.34±2.07	23.01±1.90	0.832
Participations in ultramarathons	4.75±3.16	7.80±3.49	0.053
Ultramarathons completed	3.19±3.16	6.20±4.32	0.081
Weeks of rest/year	5.59±4.76	3.50±4.44	0.310
Total hours of training /week	11.19±3.57	11.80±5.22	0.826
Total hours of aerobic training /week	9.92±3.23	10.20±4.55	0.907
Training over anaerobic threshold(%)	14.98±10.93	13.75±7.50	0.985

52.6% of the sample mentioned that they had suffered a musculoskeletal injury over the previous two years. Using Chi-squared, no relation was observed between the qualitative variables studied and musculoskeletal injuries, as compiled in Table 4. However, as can be seen in Table 5, the Mann-Whitney U test showed a significant relationship between musculoskeletal injuries and two quantitative variables: BMI (p=0.004) and the proportion of weekly training over the anaerobic threshold (p=0.009). On the one hand, the average BMI for the injured group was 22.53±1.75 compared to 24.17±2.02 in the uninjured group.

Table 4. Relationship between the dichotomous qualitative variables and the musculoskeletal injuries.

Variable	Subgroup	Musculo-skeletal injuries Yes n=30	Musculo-skeletal injuries No n=27	P
Static bike/strider	Yes	18	14	0.536
	No	12	13	
Strength	Yes	20	16	0.563
	No	10	11	
Stretching	Yes	19	16	0.752
	No	11	11	
Physiotherapy	Yes	20	13	0.157
	No	10	14	

On the other hand, the average percentage of training carried out over the anaerobic threshold for the injured group was 18.04 ±10.42 compared to 11.71±10.06 in the uninjured group.

Discussion

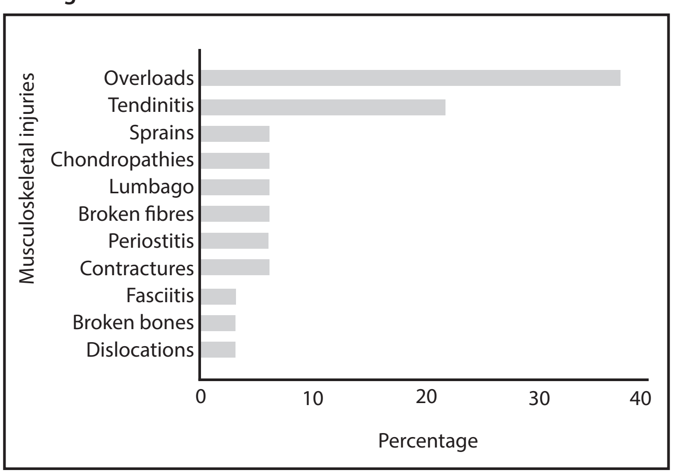
As described in the bibliography[10-12] and in the results section, it was observed that the athletes in the study sample were in good health. The injuries recorded in this cohort were musculoskeletal and mainly not very severe (Figure 1). Cardiovascular injuries were not objectified so ECGs were used to analyse this type of data.

Regarding whether the training habits of these runners might be considered healthy, considering the aforementioned recommendations

Table 5. Relationship between different variables and musculoskeletal injuries.

Variable	Musculo-skeletal injuries Yes n=30	Musculo-skeletal injuries No n=27	P
Age	43.83±8.47	42±8.86	0.620
BMI	22.53±1.75	24.17±2.02	0.004
Participations in ultramarathons	5.03±3.34	5±3.27	0.981
Ultramarathons completed	3.2±3.11	3.74±3.61	0.650
Weeks of rest/year	5.20±4.69	5.72±4.86	0.733
Total hours of training /week	11.37±3.81	11.11±3.61	0.817
Total hours of aerobic training /week	10.10±3.39	9.78±3.29	0.690
Training over anaerobic threshold(%)	18.04±10.42	11.71±10.06	0.009

Figure 1. Proportions of the different musculoskeletal injuries among the runners that suffer from them.



and that the sample's runners train for 10-11 hours (~600 minutes) a week on average and 72% of the sample trains between 5 and 13 hours per week (Figure 2), we can say that the training habits could mostly be considered healthy and not excessive.

Although there are opinions to the contrary, some authors have described a U-shaped dose-response relationship between physical exercise and cardiovascular risk.[38] With the ECGs available in this study, no relationship was seen between them and the study variables. In other words, it seems that the parameters that could be associated with excess physical activity (taking part in more races, resting for fewer weeks per year, training for more hours per week, that this training is purely aerobic, or a greater proportion of the training is over the anaerobic threshold) were not related to the risk of suffering cardiovascular

Figure 2. Proportions of the study sample according to the total weekly hours of training.

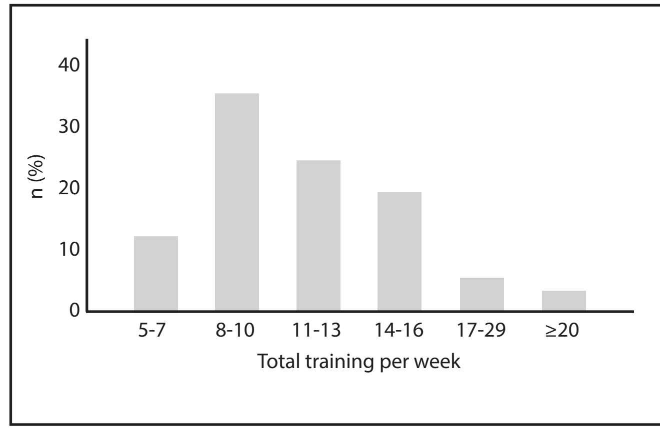


Figure 3. Comparison between the runners with a normal and pathological ECG, regarding the number of ultramarathons run.

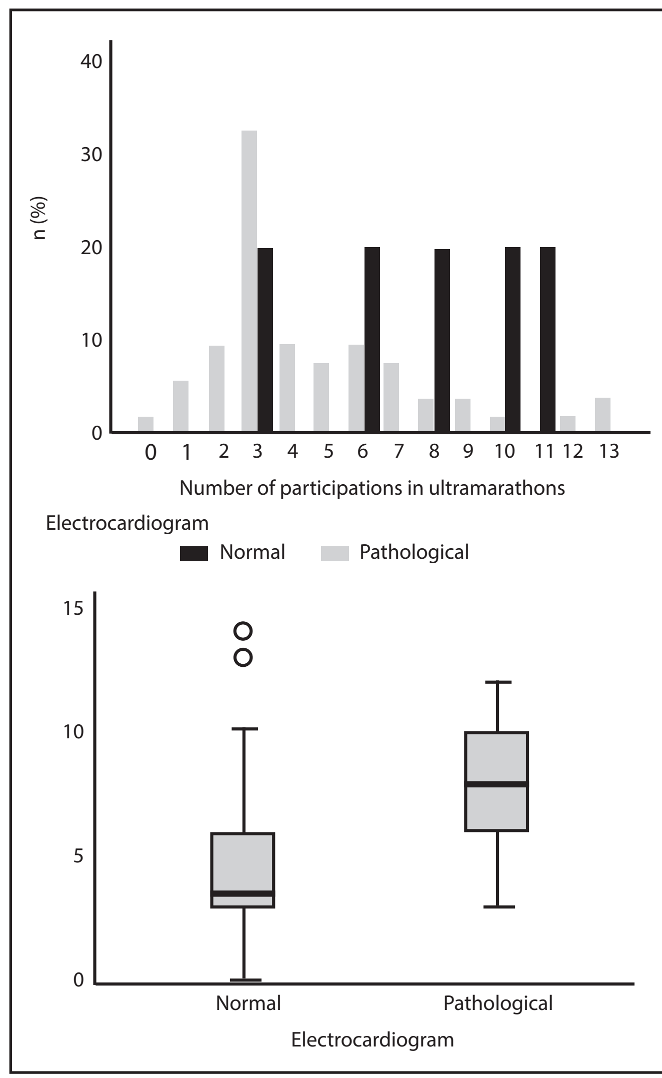


Figure 4. Comparison between the runners who suffer musculoskeletal injuries and those that do not, regarding the percentage of weekly training over the anaerobic threshold.

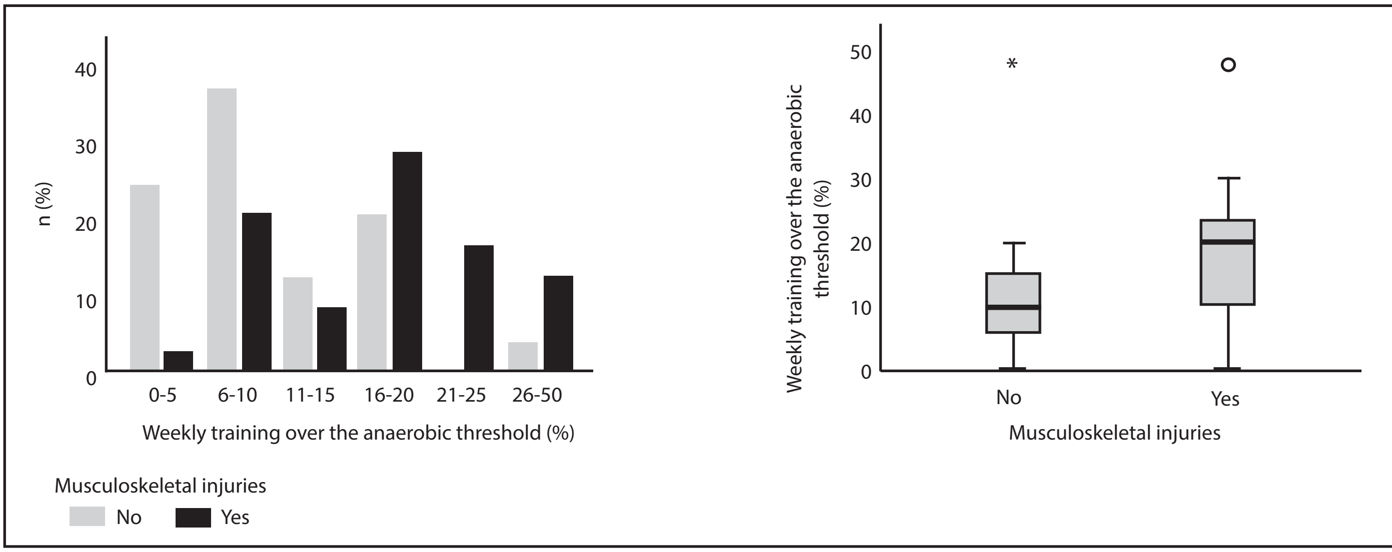
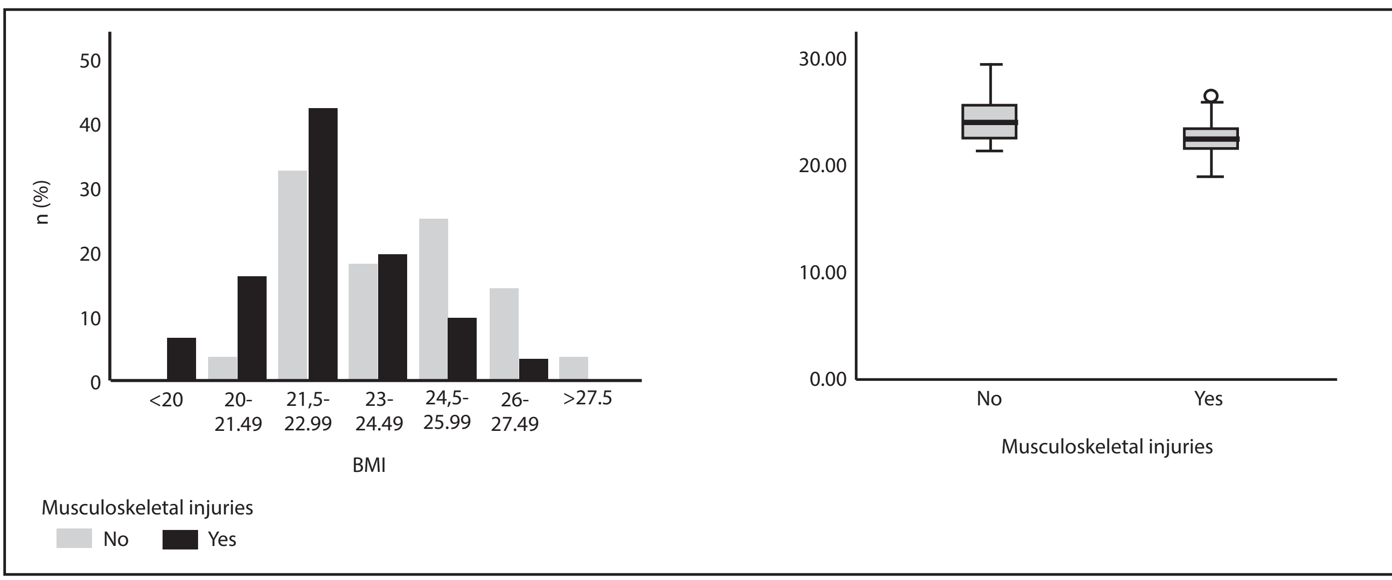


Figure 5. Comparison between the runners who suffer musculoskeletal injuries and those that do not, regarding the Body Mass Index.



damage. However, we should mention that, although it did not reach the proposed significance level, the relationship between the number of participations in ultramarathons and a pathological ECG was not far off (p=0.053). This trend might suggest a possible relationship between higher participation in races and developing a pathological ECG (Figure 3). This might be due to the stress represented by these extreme races inducing an acute phase reaction in the body, causing a rise in some biomarkers, among others, that suggest cardiac damage.[24]

The musculoskeletal system receives some of the worst strain in this type of athletes,[15-17,31-33] although the injuries are generally not severe.[47] In the sample used, no association was found between musculoskeletal complaints and most of the variables studied. However, in this case, two significant relationships were found: with the proportion of training over the anaerobic threshold (p=0.009) and with the BMI (p=0.004).

It seems that individuals who train over the anaerobic threshold in a higher proportion were more likely to suffer damage to the musculoskeletal system (Figure 4). In other words, it is possible that doing more high intensity training increases the risk. However, according to several authors, it is not only a higher intensity of physical exercise that increases this risk, but the total volume of physical exercise performed and with this the effect of interaction between the actual intensity, frequency and duration of the training.[48-50] Furthermore, although greater experience has been related to a smaller amount of damage in this type of race,[12,47] it has described that a more professional or competitive profile is more likely to suffer injuries compared to a more recreational profile.[51] Therefore, the participants with more competitive objectives might be the same athletes that train with greater intensity, thereby increasing the risk of a musculoskeletal issue.

Finally, a relationship was seen between the BMI and musculoskeletal injuries. Initially, it could be interpreted that it is logical for a higher BMI to increase the risk of damage to the musculoskeletal system and a lighter weight should act as a protective factor.[52-54] However, in the study cohort, the runners with lower BMI suffered more damage (Figure 5). This trend has also been described in other studies: a systematic review showed that there was some evidence to suggest that higher weight and a BMI > 26 could act as a protective factor against pathologies in the lower limbs in long distance runners.[55] It proposed that this relationship could be due to less activity during the training in the overweight group. Another study observed a different distribution of the musculoskeletal pathology in runners with different BMIs: it described fewer knee problems for overweight athletes, but a higher proportion of leg injuries.[56]

Conclusions

The ultradistance runners in the study demonstrated parameters that indicate a good state of health, plus healthy training habits in line with the latest WHO recommendations. Therefore, we could say that although the actual race is not risk-free and can be harmful, the lifestyle and the training habits required to be able to take part in a race with these characteristics can be considered as beneficial.

It was also stated that there was no relationship between the characteristics and physical exercise habits of this group and the risk of developing electrocardiographic disorders, although the relationship between the number of participations in ultramarathons and a pathological ECG was close (p=0.053), suggesting a possible association between these factors. Some studies have described that the stress represented by these extreme races induces an acute phase reaction in the body, and a rise in some myocardial damage markers.[24] Could it be that this situation, which is transitory in principle, might cause irreversible damage to the heart in the long term? As mentioned, this conclusion cannot be drawn from this study, although it might be interesting to investigate this relationship in the future.

The same occurs with the musculoskeletal issue, where no significant associations have been observed, except for those described between the musculoskeletal injuries and the training intensity (the proportion of training carried out over the anaerobic threshold), proposing the possibility that participants with more competitive objectives are the same athletes who train with greater intensity, thereby increasing the risk of musculoskeletal issues; and the BMI where, considering the sports habits among the study sample and that the formula for the BMI (weight/height*2) does not consider muscle mass, the hypothesis is proposed that a stronger, and therefore heavier, muscle is in this case the factor that protects the athlete from injury. Consequently, it would also be interesting to study this possible relationship in future works.

Although aware of its limitations, this work might be useful to ease the way for future studies in search of increasing the knowledge which is still limited around the participants of this sporting discipline, as there are still more questions than answers on this topic. What will happen with these athletes in the future? Will there be considerable long-term damage?

Thanks

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Conflict of interest

The authors do not declare a conflict of interest.

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Original article

Assessment of the functional movement screen and injuries in gymnasts

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Summary

Objective: To identify possible differences in movement quality through the functional movement screen (FMS) between injured and non-injured adolescent acrobatic gymnasts in the last season.
Method: descriptive, comparative, cross-sectional study involving 20 adolescent female gymnasts divided into two groups, one composed of 9 gymnasts who had suffered an injury in the last season (14,7±1,56) and the other composed of 11 gymnasts who had not suffered any injury (13,9±2,25). The FMS battery was used, consisting of seven tests: deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability in push-ups, trunk rotational stability.
Results: Of the nine gymnasts who had sustained an injury, 66.6% were located in the lower limb, ankles and knees. The results of the total functional assessment of FMS using the Mann Whitney U statistic for independent samples showed no statistically significant differences between groups ($Z = -.393$; $p > 0.05$), with the average range of FMS being similar in both cases (10.05 and 11.06 in injured and non-injured gymnasts respectively). It also showed the absence of significant differences in each of the tests of the battery, and no relationship was found through Spearman's R statistic, between the overall FMS score and the group of injured gymnasts.
Conclusion: The results of the FMS total score were slightly higher in gymnasts who were not injured last season, as well as slightly better in all the lower body tests, hence the FMS can be used as a preventive programmed to detect possible deficiencies.

Key words:
Functional movement. Functional movement screen. Motor competence. Acrobatic gymnastics. Sports injuries.

Evaluación del *functional movement screen* y lesiones en gimnastas

Resumen

Objetivo: Identificar posibles diferencias en la calidad de movimiento a través del *functional movement screen* (FMS) entre gimnastas adolescentes de acrobática lesionadas o no lesionadas en la última temporada.
Método: Estudio descriptivo, comparativo y transversal donde participaron 20 mujeres adolescentes divididas en dos grupos, uno compuesto por 9 gimnastas que habían sufrido alguna lesión en la última temporada (14,7±1,56) y otro por 11 gimnastas que no habían sufrido ninguna (13,9±2,25). Se usó la batería FMS, compuesta por siete pruebas: sentadilla profunda, paso de valla, estocada en línea, movilidad de hombro, elevación activa de la pierna recta, estabilidad del tronco en flexiones, estabilidad rotatoria del tronco.
Resultados: De las nueve gimnastas que habían sufrido alguna lesión, 66,6% se localizaron en el miembro inferior, tobillos y rodillas. Los resultados de la valoración funcional total del FMS mediante el estadístico U de Mann Whitney, para muestras independientes no mostró diferencias estadísticamente significativas entre grupos ($Z = -,393$; $p > 0,05$), siendo el rango promedio de FMS similar en ambos casos (10,05 y 11,06 en gimnastas lesionadas y no lesionadas respectivamente). Igualmente arrojó la ausencia de diferencias significativas en cada una de las pruebas de la batería, no encontrándose ninguna relación a través del estadístico R de Spearman, entre la puntuación global del FMS y el grupo de gimnastas lesionadas.
Conclusión: Los resultados de la puntuación total del FMS fueron mayores en las gimnastas que no sufrieron lesión en la temporada pasada, así como ligeramente mejores en todas las pruebas del tren inferior. Sin embargo, estas diferencias no fueron significativas. No existió ninguna relación entre la puntuación total del FMS y el grupo de gimnastas lesionadas.

Palabras clave:
Movimiento funcional. Functional movement screen. Competencia motriz. Gimnasia acrobática. Lesiones deportivas.

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Introduction

Acrobatic gymnastics (AG) is a gymnastic discipline which joined the International Gymnastics Federation in 1999 and is now consolidated as an international competitive sport. It is essentially a highly cooperative sport in which the gymnasts perform a conjunction of technical movement and body movements set to music[1].

The morphological profile for this discipline depends on the role played by each gymnast. The smaller, younger, more agile ones are called 'tops' and they perform elements of balance, flexibility or air jumps. The 'bases' are those who support these elements or perform propulsions and receptions of them[1,2]. The competitive categories exclusive to women are pairs and groups of three.

The risk of injury in these gymnasts is increasing due to the extremely difficult motor skills involved in and great technical demands of the discipline[3]. The most frequently reported injuries are in the lower limbs, the most affected areas being the ankle and knee. The injuries mostly consist of tendon and ligament injuries[3–8].

Specifically, in female gymnasts who perform this discipline, the injuries most reported are in the lower limbs, with an emphasis on sprains, followed by contractures and strains, which tend to be mild to moderate in terms of severity and occur during training[3]. Although these gymnasts are fundamentally concerned about injury for the sake of their own health, being an extremely cooperative sport in all its modalities, injury to an acrobatic gymnast would also necessarily have an impact on their partners' performance in the sport and could mean pulling out of competitions.

Of all the evaluation tests which aim to reduce the risk of injury in athletes, Bennett *et al.*[9] maintain that the *Functional Movement Screen* (FMS) is becoming a key tool. It is a standardised evaluation method through which movement quality can be categorised in a systematic, reproducible, reliable and valid way. It serves to assess fundamental movement patterns, motor control and movement quality, and allows us to establish profiles and comparisons between athletes of the same or different disciplines[10,11].

It consists of seven specific movement tests related to stability, mobility and balance which can detect the existence or not of possible bilateral imbalances in each body segment involved[12,13], making it a potential predictor of injuries[14]. The tests are simple, do not require much time and space, require little material and their reliability is excellent according to the meta-analysis carried out by Bonazza *et al.*[15].

Although there exist controversies about its ability to predict injury[16], several studies with judokas and CrossFit athletes[17,18] have reported its power as a key information tool for coaches so they can intervene in their athletes' development or check if they have recovered properly following injury[19].

Therefore, performing a functional evaluation with the FMS on a group of adolescent gymnasts who had an injury the previous season may allow us to analyse if they are more likely to suffer further injuries or check if they have recovered properly.

The fact that the FMS offers the chance to evaluate core instability, neuromuscular control, joint mobility and muscle imbalances allows us to obtain valuable data on the deficits that these gymnasts may have so we can address them better in the future with adequate rehabilitation programmes aimed at reducing the likelihood of recurrence. The most noteworthy limitations of this instrument in relation to the most frequent injuries in acrobatic gymnasts are its inability to detect injuries in the ankle area (an area extremely prone to injury in the discipline) and the issue which exists regarding the shoulder test, because although the bilateral information from the test can provide functional guidelines of interest, it can also breed controversy as the score obtained may mean a risk of injury or it may mean greater development of muscle mass in the area[20].

To date, we are only aware of the use of the FMS in one study conducted in AG, but it only describes movement quality in a sample of gymnasts who did acrobatics compared to others who did not20. Hence, our objective was to use the FMS to identify possible differences in movement quality between adolescent acrobatic gymnasts who had been injured the previous season and others who had not.

Material and method

Participants

Descriptive cross-sectional, comparative study with the voluntary participation of 20 female gymnasts between 12 and 17 years of age (age= 14.3±1.97 years; weight= 50.4±8.98 kg; height= 1.59±.09; BMI= 19.53±1.78 kg/m^2), all members of the same AG club in Granada. The participants had experience in the discipline of 3±1 years and trained at national competitive level 3 to 4 days a week for an average of 3±1 hours per session. Of the total sample, 9 had suffered an injury the previous season (one top and eight bases). The inclusion criteria were: adolescent females, federated acrobatic gymnasts, who attended training regularly, national level competitors; and as exclusion criteria: some type of current injury preventing them from performing the FMS at the time of the evaluation. Before starting the study, all the parents or legal guardians of the gymnasts signed an informed consent where the objective of this research and the procedure to be used was described. The study respected the principles of the Declaration of Helsinki and was approved by the Ethics Committee at the University of Granada (number 1.011).

Instrument and materials

To analyse the movement quality variable, the test used was the FMS created by Gray Cook and Lee Burton in 1998, whose three fundamental objectives are: to evaluate basic movement patterns, detect asymmetries and assess motor control[21].

The FMS consists of seven tests: deep squat, hurdle step, inline lunge, shoulder mobility, active straight-leg raise, torso stability push-up and torso rotary stability. The following materials were used to evaluate the different tests: a 1.22 m dowel, two 0.61 m dowels, a 2x6 cm wooden plank, a rigid measuring rod and two high-definition cameras with 4K recording technology to record the execution of the exercises.

For the injuries variable, a self-record sheet was handed out with questions about the existence of injuries (type, severity and when they occurred: training or competition) during the preparatory and competition period from October to June 2020/2021.

Finally, weight and height were used to calculate BMI. Weight was determined with a TEFAL digital scale with an accuracy of 0.05 kg and height was measured with a SECA 220 height rod with an accuracy of 1 mm. The two measurements were entered into the formula weight (kg)/height (m)^2 to arrive at the BMI (kg/m^2).

Procedure

First, informed consent was obtained from the club to which the gymnasts belonged and the confidentiality of the results was emphasized.

The evaluation procedure was carried out at the beginning of the season during a training session after a day of rest. First, they were given a self-record questionnaire with questions about the existence or not of injuries in the previous season. According to the data obtained, the gymnasts were divided into two groups depending on whether or not they had had an injury the previous season (in the last eight months), corresponding to the preparatory and competition period. Before starting, all the participants were informed about the evaluation procedures. The evaluations were carried out individually, carrying out each of the tests that make up the FMS three times. All the gymnasts followed the same order of tests and the guidelines established by Cook[22] to minimise any possible bias or negative effect on the tests.

Both sides (left and right) were evaluated in all the tests except the deep squat and torso stability push-up. The participants performed a small dynamic warm-up before completing the FMS tests. They were given verbal instructions for each exercise following the description guidelines proposed by Cook[22] and each participant had three opportunities for correct execution.

The maximum score which can be obtained in the FMS is 21 points, three points being the maximum score per exercise. Three points were awarded if the gymnast was able to perform the movement without needing to apply any compensations, two points if she managed to perform the movement applying one or more compensations, one point if she could not complete the exercise and zero if she experienced pain, regardless of whether she could complete the exercise. In the bilateral tests, the lower score of the two was taken to calculate the total FMS score[12].

When the subject earns the maximum score in the screen, it can be concluded that they have highly developed movement patterns with no limitations on basic movements. If they get between 15 and 20 points, it is understood that they need to improve some weaknesses found, but in general have an acceptable level of movement patterns. Finally, if a subject's score is 14 or lower, the subject's situation is a cause for concern or he/she is at risk of suffering an injury[23,24].

Two different planes of movement (front and side) were digitally recorded when the tests were performed by each participant and these were analysed jointly by two evaluators with previous experience in the use of the FMS[25].

All the gymnasts had sufficient functional capacity to perform each of the tests and were active, with optimal sports performance within their competitive modality (pairs or groups of three) at the time of recording.

Statistical analysis

Statistical analysis was conducted using SPSS version 22.0 (SPSS Inc., Chicago, IL, USA). The descriptive data for each of the FMS tests are shown with the mean and standard deviation. The frequency and percentage values of all tests were also calculated, differentiating the body side in the bilateral tests. Since the variables presented a non-normal distribution, the Mann-Whitney U test was used to check the FMS scores based on whether or not injuries had been suffered in the previous season. The value of statistically significant difference between groups (injured and uninjured) was shown whenever $p < 0.05$. Finally, correlational analysis was performed using Spearman's rho to see whether the overall FMS score was related to injury or non-injury in AG.

Results

As seen in Table 1, the injuries were mostly ligament injuries (n=7). Meanwhile, six injuries (66.6%) were located in the lower limbs, the knee (n=2) and ankle (n=4) being the most affected areas. Focusing on these areas, the injured structures were the posterior cruciate ligament in the knee (n=1) and the external lateral ligament of the ankle (n=4). It is noteworthy that most of the injuries occurred in the dominant segment (n=6).

All the injuries occurred during training (n=9) and none in competition. In terms of severity, most of the injuries were mild and moderate, meaning the subject could not engage in sporting activity for one week or less in 44.4% of the cases and between 9 and 20 days for the other 44.4%.

Table 2 shows the descriptive statistics (mean and standard deviation) and the differences in the scores obtained in each of the FMS tests by the two groups (uninjured and injured). No significant differences were observed in terms of the performance obtained in each of the evaluation tests carried out by the gymnasts belonging to the two groups evaluated.

Table 3 shows the frequency and percentage obtained in the different tests. The great majority of the members of both groups got the maximum score of 3 in all the tests. The score was never zero for any of the gymnasts. The test with the lowest score was shoulder mobility, which was worse in the non-injured than it was in the injured, although without a significant difference.

Table 4 classifies the sample based on the total score obtained in the FMS. As can be seen, all the gymnasts displayed an acceptable level of movement quality.

The Mann-Whitney U statistic for independent samples showed an absence of statistically significant differences between the two groups (Z = -.393; p >0.05), with the mean rank of the FMS similar in both cases (10.05 and 11.06 in injured and uninjured gymnasts, respectively). Finally, Spearman's rho statistic did not show a statistically significant positive relationship between the variables *overall FMS score and presence of injuries*.

Table 1. Type of injuries, body region, location, severity and time of injury.

Type of injuries	Gymnasts injured (n=9)
Torn ligament	1 (11.1)
Sprains	6 (66.6)
Fissures and fractures	1 (11.1)
Others	1 (11.1)
Body region	
Upper limb	3 (33.3)
Trunk	-
Lower limb	6 (66.6)
Location	
Knee	2 (22.2)
Ankle	4 (44.4)
Waist	1 (11.1)
Forearm	1 (11.1)
Hand	1 (11.1)
Severity	
Mild	4 (44.4)
Moderate	4 (44.4)
Severe	1 (11.1)
Time of injury	
Training	9 (100.0)
Competition	-

Discussion

The injuries in the group of gymnasts injured the previous season chiefly affected the lower limbs, particularly knees and ankles, and were mainly ligament injuries. These data confirm the results obtained by different authors studying young acrobatic gymnasts[3,4,6]. 100% of the injuries occurred during training and most were mild or moderate, putting the subjects out of sports action for no more than three weeks, during which time they were active and the injury did not excessively impact their training. These data are in line with the results found by Vernetta *et al.*, Purnell *et al.*, and Caine and Vernetta *et al.*[3,6,20,26].

Regarding the movement quality data, it is worth highlighting acceptable FMS test levels in the entire sample, there being practically the same movement quality in the non-injured gymnasts and no statistically significant difference between the two groups in the overall FMS score or each test taken independently. However, the values obtained in the tests related to core stability, balance and neuromuscular control (hurdle step, inline lunge and squat) show that the group which had had an injury the previous season got a slightly lower score.

In our study, it should be noted that none of the gymnasts obtained a total FMS score less than or equal to 14, which indicates that, according to Cook *et al.* [22], neither of the groups had a greater risk of injury. Most of the gymnasts in both groups obtained scores between 18 and 20 points, corresponding to an acceptable level, these results being consistent with

Table 2. Comparison of the scores obtained in the different tests in the FMS according to the presence or not of injuries.

FMS test	Not injured (n=11)	Injured (n=9)	p
Deep squat	2.91±.302	2.78±.441	0.441
Hurdle step (right)	3.00±0.0	2.89±.333	0.269
Hurdle step (left)	3.00±.0.0	2.89±.333	0.269
Inline lunge (right)	2.91±.302	2.78±.441	0.425
Inline lunge (left)	2.91±.302	2.89±.333	0.884
Shoulder mobility (right)	2.09±944	2.33±.707	0.596
Shoulder mobility (left)	2.09±539	1.89±.782	0.489
Active straight-leg raise (right)	3±.0	3±.0	1
Active straight-leg raise (left)	3±.0	3±.0	1
Trunk stability push-up	2.55±.522	2.67±.5	0.592
Torso rotary stability (right)	2.64±.674	2.89±.333	0.354
Torso rotary stability (left)	2.73±.647	2.78±.441	0.913
Total FMS score	19 ±1.26	18.89±1.61	0.710

*p < 0.005. **p < 0.001

Table 3. Frequency and percentage of each score in the different tests in the FMS obtained by the sample.

Test	Not injured N=11				Injured N=9			
	0	1	2	3	0	1	2	3
Deep Squat	-	-	1 (9.1)	10 (90.9)	-	-	2 (22.2)	7 (77.8)
Hurdle step (right)	-	-	-	11 (100)	-	-	1 (11.1)	8 (88.9)
Hurdle step (left)	-	-	-	11 (100)	-	-	1 (11.1)	8 (88.9)
Inline lunge (right)	-	-	1 (9.1)	10 (90.9)	-	-	1 (11.1)	8 (88.9)
Inline lunge (left)	-	-	1 (9.1)	10 (90.9)	-	-	1 (11.1)	8 (88.9)
Shoulder mobility (right)	-	4 (36.4)	2 (18.2)	5 (45.4)	-	1 (11.1)	4 (44.4)	4 (44.4)
Shoulder mobility (left)	-	1 (9.1)	8 (72.7)	2 (18.2)	-	3 (33.3)	5 (44.4)	2 (22.2)
Active straight-leg raise (right)	-	-		11 (100.0)	-	-	-	9 (100.0)
Active straight-leg raise (left)	-	-		11 (100.0)	-	-	-	9 (100.0)
Trunk stability push-up	-	-	5 (45.5)	6 (54.5)	-	-	3 (33.3)	6 (66.7)
Torso rotary stability (right)	-	1 (9.1)	2 (18.2)	8 (72.7)	-	-	1 (11.1)	8 (88.9
Torso rotary stability (left)	-	1 (9.1)	1 (9.1)	9 (81.8)	-	-	2 (22.2)	7 (77.8)

Table 4. Frequency and percentage of the total score obtained in the FMS in all gymnasts divided according to the presence or not of injuries.

FMS score	Not injured N (%)	Injured N (%)
≤ 17	1 (9.1)	1 (11.1)
18-20	8 (72.8)	8 (88.8)
21	2 (18.2)	0 (0)

those found in the studies by Vernetta *et al.*, Gil-Lopez *et al.* and Vernetta *et al.* [20,27,28] in adolescents engaged in sports such as judo, basketball and AG, possibly due to the relationship between motor performance in basic movement patterns and organised physical activities[29]. Taking into account these scores, it can be assumed that the training to which the different athletes in the above studies are subjected has a significant effect on the most optimal FMS results[20,30].

It should be noted that none of the gymnasts injured in the previous season obtained the maximum score of 21 points, which was achieved by two gymnasts from the non-injured group.

Regarding the results obtained in each of the tests, it can be observed that the scores are very similar in the two groups, except in those tests which involve the lower body (deep squat, right/left hurdle step and right/left inline lunge), where the injured gymnasts got worse scores, albeit without statistically significant differences. This may in part be due to the fact that most injuries in these gymnasts were located in the lower limbs, with the ankle and knee being the most affected areas. Specifically, considering that 22.2% of the injuries were in the ankle and 44.4% in the knee, the slightly worse scores in the hurdle step and inline lunge tests, which require knee, hip and ankle stability, according to Cook *et al.*[22], could be to do with a small fault detected in these gymnasts in relation to the ability to maintain stability in their lower limbs. In this regard, Nadler *et al.*[31] recommend balanced mobility and stability work centring on the foot, ankle, knee and hip joints to avoid imbalances and possible injurious states in large chain exercises.

Regarding joint mobility, the two groups obtained the maximum score of 3 points in the leg raise test on both sides, results which should be expected due to the importance of the flexibility of the coxofemoral joint in gymnastic sports[32], coinciding with the maximum scores obtained in acrobatic gymnasts assessed using the FMS[20].

As for possible asymmetries in the five bilateral tests, in general the gymnasts in both groups got very similar scores on both sides in all the tests, except shoulder mobility, where slight asymmetries were observed in those gymnasts who had been injured, with lower scores on the left side. In these gymnasts, this could be justified by the fact that they were all right-handed, since as Arango[33] indicates, athletes have a natural tendency to reach higher amplitudes of movement with the dominant limb due to repetition. In the specific case of AG, gymnasts often perform specific technically very difficult movements with only one arm. Therefore, it is essential to raise awareness among coaches to encourage work on flexibility with the same intensity in both upper limbs and avoid decompensations which could, in the long term, manifest themselves in the form of injury.

Finally, no relationship was found between the overall FMS score and previous injuries. Since Cook *et al.*[12] published the FMS, there have been several controversies about its use as a tool for identifying the risk of injury. Several studies have found a clear association between FMS scores and the occurrence of injuries and significant differences between injured and non-injured subjects in overall FMS scores[14,34-36]. Other studies, however, have not found such differences or association, as was the case in the results of our study[18,37–39].

Perhaps the differences not found between the two groups in this study could be due to the lack of a larger sample. As indicated by Alemany *et al.*[25], several studies carried out these days use small samples that are not statistically representative, which leads to a lack of association between the risk of injury and the FMS. Another point could be the criterion chosen to determine the group of injured subjects, because they were gymnasts who had recovered from injuries suffered the previous season. Additionally, the demanding neuromuscular training that these gymnasts receive, acrobatic gymnastics being a sport that requires a very high level of technical execution, may have influenced the very acceptable FMS scores obtained in the two groups[20,40]. Future studies should investigate the ability of the FMS to identify the risk of injury in a larger sample using prospective designs or retrospectively by evaluating gymnasts recently injured prior to the FMS evaluation or who are even in the recovery phase, as long as evaluation is possible and convenient. Likewise, it seems essential to observe the compensations used in the execution of each FMS test.

Finally, with regard to BMI, it should be noted that the majority of the gymnasts (75%) were classified as normal weight, thus obtaining a healthy BMI, with only a low percentage of gymnasts with grade I thinness (20%) and a single gymnast with grade III thinness according to the indicators proposed by Cole *et al*.[41].

The chief limitations of this study lie in the small size of the sample, which means that the results cannot be generalised to the rest of young gymnasts in this discipline.

Conclusions

In view of the above, we can conclude that the results of the total FMS score were slightly higher in those gymnasts who had not suffered injury the previous season. These gymnasts scored better in all the tests except trunk stability in push-ups and torso rotary stability on both sides. These differences, however, were not significant. Likewise, there was no relationship between the total FMS score and the group of injured gymnasts.

Practical applications

As a practical application, this series of tests is valid to establish the functional profile of these gymnasts. It could, therefore, be used as a basic tool for their coaches at the beginning of the season, since it would allow them to identify limitations in certain movement patterns in their gymnasts, design exercises which can correct those deficits individually and reduce in part the risk of possible injuries[41]. Additionally, the five bilateral tests in the FMS can provide information which may be valid in order to programme training aimed at achieving symmetry between limbs and reducing possible future injuries. Finally, it can be used to monitor fitness after an injury and define the appropriate time for gymnasts to return to training, especially in the case of knee injuries[42].

Conflict of interest

The authors do not declare a conflict of interest.

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Electro-echocardiographic correlation in high-performance athletes

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Summary

Background: Functional and structural cardiac adaptations are generated by sustained physical training. The objective of our investigation was to evaluate the association in electrocardiographic and echocardiographic findings in a population of high-performance athletes.
Material and method: 30 male athletes (10 water polo players, 10 triathlonists and 10 swimmers), ages 18 to 40 years old, training 20 to 30 hours per week for at least one year, were evaluated. Clinical, electrocardiographic (ECG) and echocardiographic examination was performed on each of them at Instituto Vozzi.
Results: Echocardiographic results showed that the mean septal thickness, the mass index of the left ventricle (LV), the anteroposterior diameter and the area of the left atrium (LA), the area of the right atrium (RA) and the base of the right ventricle (RV) were found above normal values for the general population. None of the athletes ECGs presented LA, RA or RV enlargement. Nine of 30 (30%) presented signs of LV enlargement. After adjusting for age, weight, height, body surface area, and sport performed, LV diastolic diameter (LVDD) indexed to body surface area (BSA) was higher in athletes with LV enlargement on ECG (adjusted mean 28.94 ± 0.56 mm; 95% CI = 27.78-30.10) vs without (27.67 ± 0.36 mm; 95% CI = 26.93-28.41). More triathlonists presented LV enlargement signs on the ECG compared to the other groups.
Conclusions: Certain echocardiographic parameters in our population of athletes are above normal values for the general population. There was no relationship comparing electrocardiographic and echocardiographic signs of LA, RA and RV enlargement. An association was found between ECGs LV enlargement and increased LVDD indexed to BSA on the echocardiograms. LV enlargement on the ECGs was more frequent in the triathlon group.

Key words:
Sports. Electrocardiography. Echocardiography. Athletes. Hypertrophy.

Correlación electro-ecocardiográfica en deportistas de alto rendimiento

Resumen

Introducción: El entrenamiento físico sostenido genera adaptaciones cardíacas estructurales y funcionales. El objetivo de nuestro trabajo fue evaluar la correlación entre los hallazgos electro-ecocardiográficos en una población de deportistas de alto rendimiento.
Material y método: Se evaluaron 30 deportistas varones (10 waterpolistas, 10 triatletas y 10 nadadores), entre 18 y 40 años, con 20 a 30 horas semanales de entrenamiento por al menos un año. Se efectuó evaluación clínica, electrocardiográfica y ecocardiográfica a cada uno de ellos en el Instituto Vozzi.
Resultados: En la evaluación ecocardiográfica, se observó que la media del espesor septal, el índice de masa del ventrículo izquierdo (VI), el diámetro anteroposterior y el área de la aurícula izquierda (AI), el área de la aurícula derecha (AD) y la base del ventrículo derecho (VD) se hallaron por encima de los valores normales para la población general. En los ECG, ninguno de los deportistas presentó crecimiemto de AI, AD o VD. Nueve de los 30 (30%) presentaron signos de hipertrofia del VI. Luego de ajustar por edad, peso, talla, superficie corporal y deporte realizado, el diámetro diastólico del VI (DdVI) indexado a la superficie corporal (SC) fue mayor en los deportistas con hipertrofia del VI en el electrocardiograma (ECG) (media ajustada 28,94±0,56 mm; IC95%= 27,78-30,10) vs sin hipertrofia (27,67±0,36 mm; IC95%= 26,93-28,41). Los triatletas presentaron con mayor frecuencia hipertrofia del VI en el ECG respecto de los otros grupos.
Conclusiones: Ciertos parámetros ecocardiográficos en nuestra población de deportistas se hallan por encima de los valores normales para la población general. No se halló relación entre los signos electrocardiográficos y ecocardiográficos de crecimiento de la AI, la AD e hipertrofia del VD. Se halló relación entre hipertrofia del VI en el ECG y aumento del diámetro diastólico del VI indexado en el ecocardiograma. La hipertrofia del VI en el ECG fue más frecuente en el grupo de triatletas.

Palabras clave:
Deportes. Electrocardiografía. Ecocardiografía. Deportistas. Hipertrofia.

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Introduction

Studies conducted in the 1950s and 1960s, with angiographic correlation and by autopsy, established the limitations of the electrocardiogram (ECG) to detect ventricular hypertrophy and observed that the greatest accuracy in diagnosis was achieved in persons with hypertension and in patients with left-sided valvular heart disease, particularly when they exhibited moderate or acute hypertrophy[1]. Although new criteria were progressively developed over time, this did not improve the accuracy of the method.

It cannot be ignored that most of the electrocardiographic criteria for the detection of left ventricular hypertrophy (LVH) were validated in populations with a high prevalence of cardiovascular diseases (chronic kidney failures on haemodialysis[2], chronic arterial hypertension[3]). The obvious consequence is the low performance of these criteria when applied to populations with a low prevalence of these diseases. Athletes are one such population, in whom the interpretation of the ECGs is normally based on the traditional criteria used for the non-athletic population[4]. The validation of the hypertrophy criteria was made in principle by correlation with the anatomical piece, later through different imaging methods. In this respect, little information is available regarding the electro-echocardiographic correlation of the cardiac modifications that occur as an adaptive phenomenon to sustained physical training.

The aim of our study was to determine whether or not there is a relationship between the electrocardiographic and echocardiographic signs of growth of the cardiac chambers in high-performance athletes, understanding such an athlete to be one who systematically and regularly trains, with a high physical demand, for the purpose of being successful in a competition[5].

Material and method

Selection of subjects

We conducted a prospective, observational study between June and September 2018 on male athletes aged between 18 to 40 years, selected from high-performance centres of the city of Rosario and who were training from 20 to 30 hours per week in three types of sport: triathlon (T), swimming (S) and water polo (W) with a minimum training time of one year. The inclusion criteria also established that they must be free from cardiovascular or systemic diseases and that they were not taking any medication when joining the study. A medical, electrocardiographic and echocardiographic evaluation was made at the Vozzi Institute on each of the athletes on the same day. Their informed consent was requested for their participation in the study.

Medical examination

A physical examination was made, consisting in taking the vital signs and obtaining the anthropometric parameters (weight, height and body surface area).

Electrocardiogram

The 12-lead ECGs were performed in the supine position with a Fukuda Cardisuny model 501 B electrocardiogram machine with a recording speed of 25 mm/second with a standard of 1 mV/Cm. The tracings were interpreted by one of the authors, who was unrelated to the results of the echocardiograms, which were analysed in accordance with the guidelines issued by the European Society of Cardiology in 20106. An evaluation was made of heart rhythm, heart rate, electrical axis, duration and voltage of the P wave, PR interval, QRS complex (duration and voltages), QT interval (its duration corrected using the Bazett formula), ST segment and the T wave. The left atrial enlargement (LAE) was defined as a duration of the P wave greater than 120 milliseconds in Lead II or a negative portion of the same ≥ 0.1 mV and ≥ 40 ms in V1[7]. Right atrial enlargement (RAE) was defined as a P wave with an amplitude greater than 0.25 mV at leads II and III or greater than 0.15 mV in V1 or V2[8]. The LVH and right ventricular hypertrophy (RVH) with the presence of at least 1 criterion with specificity greater than 85% (Tables 1 and 2) (Figure 1).

Table 1. Left ventricular overload criteria.

Left ventricular overload	Criterion N°
(R I) + (S III) ≥ 25 mm (Gubner 1943)	1
R of aVL ≥ 7.5 mm (Minnesota)	2
R of aVL > 11 mm (Sokolow 1949)	3
R of aVF > 20 mm (Golderberg 1949)	4
(S of V1) + (R of V5-6) > 35 mm (Sokolow 1949)	5
Product of Sokolow (Sokolow x duration QRS) >2880 mm/ ms (Molloy 1992)	6
R avL + S V3 >28 mm en ♂ (Cornell 1985)	7
Product of Cornell (Cornell x duration QRS) >2440 mm/ ms (Molloy 1992)	8
Maximum S + S V4 > 28 mm (Peguero Lo Presti 2017)	9
S (maximum) + R (maximum)= 45 mm (Friedman 1977)	10
R V5 or V6 > 26 mm (Sokolow 1949)	11

Table 2. Right ventricular overload criteria.

Right ventricular overload	Criterion N°
R/S at V1 ≥ 1 (Myers 1948)	1
R at V1 ≥ 7 mm (Sokolow 1949)	2
R/S at V5 or V6 ≤ 1 (Sokolow 1949)	3
S at V5 or V6 ≥ 7 mm (Sokolow 1949)	4
R at V1 + S V5/ V6 ≥ 10.5 mm (Sokolow 1949)	5
R V5/ V6 ≤ 5 mm (Sokolow 1949)	6
R of avR ≥ 5 mm (Sokolow 1949)	7
Electrical axis ≥ 110°	8

Figure 1. V1 and V6 leads for athlete with Sokolow positive for LVO.

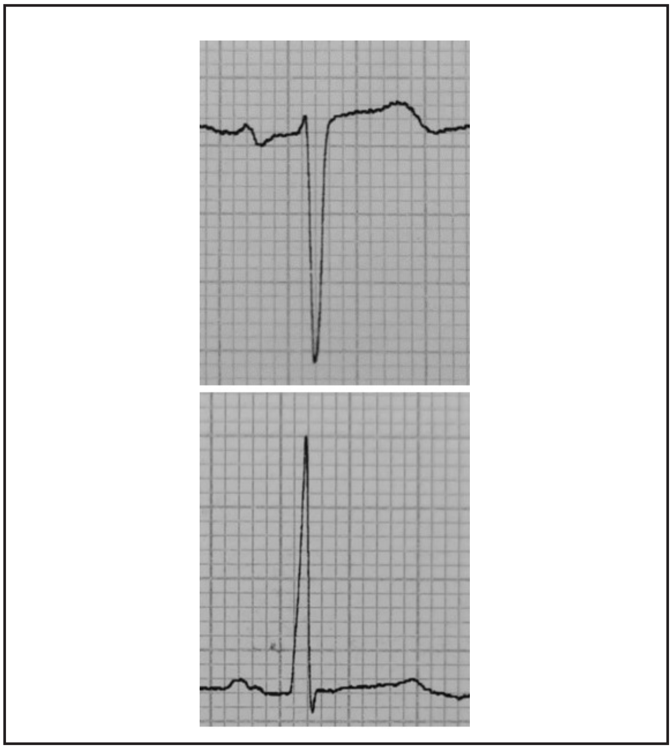
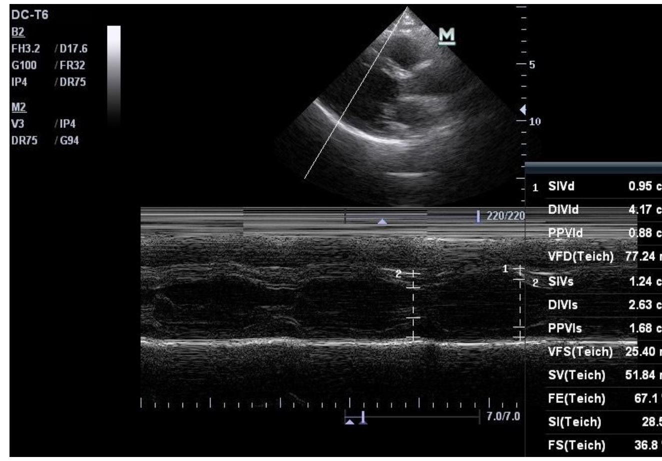


Figure 2. Measurement of size and thicknesses of LV.



Echocardiogram

The Doppler echocardiograms were performed by the same operator with a Mindray DC-T6 machine with a 2 to 4 MHz transducer. The operator was unrelated to the ECG results. The athletes were studied at rest, in a left lateral decubitus position. The dimensions and thickness measurements of the LV were obtained by M-mode two-dimensional images from the long-axis and short-axis parasternal views, based on the recommendations of the American Society of Echocardiography in effect at the time of the study[9] (Figure 2). The left ventricular mass was determined by the linear method with the cube formula (mass of Vl = 0.8 x (1.04 x (diastolic diameter of LV (LVDd) + septal diastolic thickness + diastolic thickness of posterior wall)^3 - LVDd^3} + 0.6 g). The values were compared to those considered to be normal, adjusted for body surface area (BSA) (obtained according to the formula of Du Bois and Du Bois). A cutoff value was taken as an LV mass index of 15 g/m^2. The end-systole areas and volumes of both atria were obtained from an apical 4-chamber view. In the same view, but focused on the right chambers, measurements were made of the dimensions of the right ventricle (RV); the transverse diameters were obtained at the base level of the same (inflow tract) and in the middle third at the level of the papillary muscles, all at the end of the diastole, in accordance with the echocardiographic evaluation guidelines for the right chambers[10]. Measurements of the RV were also obtained on the short axis of the large vessels, where the diameter of the proximal and distal outflow tracts was measured. Finally, the right ventricular free wall thickness was measured from a subxiphoid view. The LV systolic function was evaluated following Simpson's biplane method, from apical 4- and 2-chamber views.

Atrial dilation, by echocardiography, was defined as an increase in atrial diameters, area and/or volume. With regard to the ventricles, dilation was defined as an increase in ventricular diameters and hypertrophy due to increased wall thickness (in the case of the RV) or of the indexed mass (for the LV). The measurements were valued as quantitative variables.

Statistical analysis

Descriptive statistics were calculated for all the variables studied.

The means obtained for each variable were compared by applying the ANOVA tests for independent samples, once compliance with the necessary assumptions had been evaluated. The Kolmogorov-Smirnov test was used to verify whether the data were normally distributed, while the homogeneity of variance was determined with the Levene test.

Furthermore, analyses of covariance (ANCOVA) were conducted in order to make adjustments for any possible confounding variables (age, weight, height, body surface area and sport practised) according to the parameters compared between athletes with and without hypertrophy. The adjusted means were as expressed as a ± standard error of the mean. By using the analysis of covariance , we considered the possibility of "correcting" or "adjusting" the difference found between the groups for the covariates with significant differences in order to make the study groups comparable.

An evaluation was made between the presence of LAE in the ECG and the presence of increased echocardiographic diameter, area or volume of the same cavity. Furthermore, an evaluation was made between the presence of RAE in the ECG and the presence of increased echocardiographic area or volume of the same.

An evaluation was also made of the relationship between the presence of LVH in the ECG and the mean values of the absolute and indexed LV diastolic diameter, posterior wall thickness, absolute mass and indexed mass of the LV.

To analyse the existence of differences in the presence of LVH in the ECG between the 3 groups of athletes, the absolute and relative frequencies were calculated and these were compared by applying the Freeman-Halton test (extension of Fisher's exact probability test for a 2-row by 3-column contingency table).

For all the LVO criteria that were positive, we determined sensitivity, specificity, positive and negative predictive value in relation to the presence of an increased LV mass index.

In all cases, the accepted significance cutoff value was $p < 0.05$.

Results

30 athletes (10 per group) were included in the study period with a mean age of 23.9 ±5 years (Table 3). A comparison of the mean age of the athletes in the three disciplines studies revealed statistically significant differences (W: 21.1 ± 2.1; S: 22.9 ± 4.4; T: 27.7 ± 5,5; p= 0.005). When performing post hoc multiple comparisons, it was found that the differences observed were attributed to the age differences of T (older) in relation to the W (p=0.005). The mean blood pressure was 117/69 mm Hg; the mean heart rate was 55 beats per minute. There were no differences in these parameters between the different groups. With regard to the anthropometric parameters, statistically significant differences were found in the mean height of the athletes of the three disciplines studied

(W: 183.70 ± 6.897; S: 177.90 ± 7.172; T: 172.90 ± 9.480 cm; p= 0.019). When performing post hoc multiple comparisons, it was found that the differences observed were attributed to the height difference between the W and T (greater in W, p=0.015). Likewise, a significant difference was found in the mean weight of the athletes in the three disciplines

(W: 88.0 ± 8.4; S: 73.0 ± 10.1; T: 69.5 ± 13.7 kg; p= 0.002). In this case, the differences are due to the fact that the W have a greater mean weight than the T (p=0.002) and the S (p=0.015). For this reason, the mean body surface area was 1.942 m^2, greater in W in relation to T (1.8±0.20, p=0.004) and S (1.9±0.16, p=0.003) (Table 3).

With regard to the echocardiographic evaluation, it was observed that the mean of the septal thickness, the LV mass index, the anteroposterior diameter and the area of the LA, the area of the RA, and the RV base were above the normal values for the general population (Table 4). The type of hypertrophy found was eccentric (16 athletes) and concentric (1 athlete); 9/10 athletes, 6/10 water polo players and 2/10 swimmers exhibited hypertrophy.

With regard to the ECG analysis, none of the athletes showed LA or RA enlargement. Nine of the 30 athletes (30%) exhibited signs of LVH (3W and 6T). None exhibited RVH. The evaluation of sensitivity, specificity, positive and negative predictive value for all the LVH criteria that showed positive results in relation to the increase of the LV mass index are shown in Table 5. Of particular note is the low sensitivity of the criteria, as well as a high specificity and positive predictive value.

As can be seen in Table 6, the LV diastolic diameter (LVDd) indexed to the body surface area (BSA) was greater in athletes with LVH in the ECG (29.68 vs 27.35 mm, p=0.015). The measurements adjusted by age, weight, height, body surface area and the sport practised (p*) continued to show the same behaviour (means adjusted for the LVDd indexed to the BSA of athletes with LVH in ECG: 28.4±0.6 mm; CI95%= 27.78-30.10; for athletes with no LVH in ECG: 27.67±0.36 mm; CI95%= 26.93-28.41). A significant difference was also found for the left ventricular mass index (LVMI), being greater (in the hypertrophy range) in athletes with LVH by ECG (126.89 vs 111.67 g/m^2; p= 0.049). When the ANCOVA was applied,

Table 3. Characteristics of the athletes.

Parameter	Range	Mean				p (between groups)*
		Overall	W	S	T	
Age (years)	19-39	23.9	21.1	22.9	27.7	T vs W: p=0.005 T vs N=NS
Systolic pressure (mm Hg)	100-138	117.2	120.0	118.0	113.5	NS (p=0.416)
Diastolic pressure (mm Hg)	60-80	69.7	68.0	69.0	72.0	NS (p=0.429)
Heart rate (beats per minute)	44-94	65.8	61.9	70.1	66.3	NS (p=0.290)
Height (cm)	162-193	178.16	183.7	177.9	172.9	W vs T: p=0.015 W vs N=NS
Weight (kg)	55-100	76.83	88.0	73.0	69.5	W vs N: p=0.015 W vs T: p=0.002
Body surface area (m^2)	1.58- 2.31	1.9	2.1	1.9	1.8	W vs N: p=0.003 W vs T: p=0.004

*Bonferroni.post-hoc tests

Table 4. Description of the echocardiographic values for the athletes studied.

Echocardiographic parameter	Mean ± SD	Minimum	Maximum	P50 (Mean)	% abnormal values
Diastolic diameter left ventricle (mm)	54.29 ± 3.80	48.50	64.70	54.40	10
LVDD indexed to body surface area (mm)	28.05 ± 2.47	24.15	32.71	27.56	20
Diastolic interventricular septum (mm)	11.22 ± 0.86	9.70	12.70	11.30	63
Diastolic posterior wall (mm)	10.27 ± 0,91	8.30	11.80	10.40	36
Left ventricular mass (grams)	229.00 ± 41.50	168.00	323.00	222.50	46
Left ventricular mass index (g/m²)	116.23 ± 19.72	59.00	158.00	117.00	56
Relative parietal thickness	0.37 ± 0.04	0.30	0.45	0.38	13
Left atrial anteroposterior diameter (mm)	40.19 ± 3.52	35.00	48.50	40.10	36
Left atrial area (cm²)	21.25 ± 3.10	15.00	26.85	21.28	60
Left atrial volume (ml/m²)	33.91 ± 5.43	22.60	43.00	34.34	40
Right atrial area (cm²)	19.84 ± 2.81	14.64	27.14	19.83	56
Right atrial volume (ml/m²)	31.69 ± 5.88	21.90	46.00	30.85	33
Right ventricular base diameter (mm)	42.31 ± 4.00	35.00	50.00	42.00	56
Right ventricular mean diameter (mm)	31.60 ± 7.50	24.4	42.00	33.00	20
Proximal right ventricular outflow tract (mm)	33.36 ± 3.46	28.00	40.00	33.00	30
Distal right ventricular outflow tract (mm)	25.09 ± 5.60	20.00	30.00	26.00	33
Right ventricular thickness (mm)	4.45 ± 0.59	3.00	5.80	4.50	0

Note: In all cases, the data distribution normality and the variance homogeneity were verified.

Table 5. Sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of the different ECG criteria for LVO in relation to the presence of hypertrophy due to the increased LV mass index.

ECG criteria	Sensitivity %	Specificity %	PPV %	NPV %
R of aVF > 20 mm	6	100	100	47
(S of V1) + (R of V5-6) > 35 mm	35	95	86	63
Product of Sokolow >2880 mm/ms	35	95	86	64
R aVL + S V3 >28 mm	6	100	100	47
Maximum S + S V4 > 28 mm	24	100	100	57
S (maximum) + R (maximum)= 45 mm	24	100	100	57
R V5 or V6 > 26 mm	24	94	80	57

it was observed how the adjustment made the previously encountered significant differences disappear (LVMI adjusted means in athletes with LVH in ECG; 126.53±7.53 g/m²; CI95% = 111.41-141.65; for athletes with no LVH in ECG: 111.37±4.93 g/ m²; CI95%= 101.11-121.62). The remaining echocardiographic variables showed no statistically significant differences between athletes with or without LVH in the ECG.

The relationship between the sport practised and LVH in the ECG is shown in Figure 3. The proportion of athletes with LVH differs according to the sport practised (p=0.0155). The proportions between the S and W were compared by applying the Fisher test, obtaining a value of p=0.2105. Therefore, the proportion that differs corresponds to the T, who exhibited a greater LVH in the ECG than the athletes from the other disciplines.

Discussion

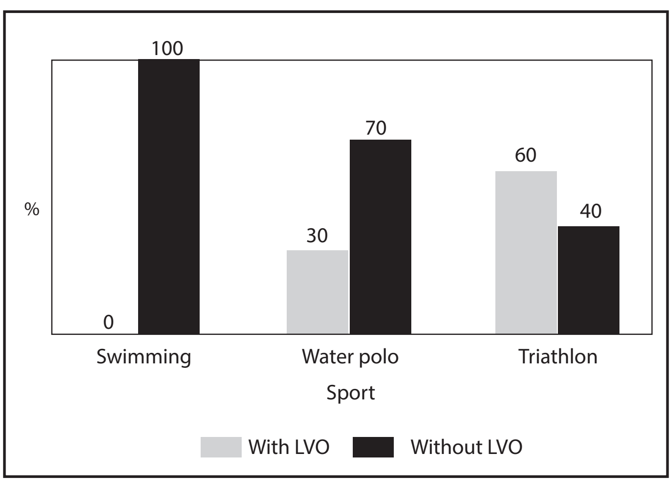
The principal electrocardiographic changes related to ventricular hypertrophy are shown in the QRS voltage and duration, the electrical axis and the ventricular repolarisation alterations. The increase in the voltage of the ventricular activation complex is due to the increase in the ventricular depolarization mass; the increase in the QRS duration is the product of the prolongation of the propagation of the impulse in the hypertrophic myocardium. The electrical axis deviation is a factor that supports the diagnosis of hypertrophy and is most significant in confirming the right hypertrophy criteria. The secondary ST-T alterations support the diagnosis of LVH in the presence of voltage criteria; by themselves they are insufficient to make a diagnosis. The atrial enlargements are reflected in the duration, morphology and voltage of the P wave[4,6].

Tabla 6. Comparison of the echocardiographic variables of the left ventricle in relation to the presence or absence of LV overload in the ECG.

	LVO in ECG	S	Mean ± SD	CI 95%	Minimum	Maximum	p	p*
Left ventricular diastolic diameter (mm)	No	21	53.86 ± 3.74	52.16-55.56	48.50	64.70	0.359	0.134
	Yes	9	55.28 ± 4.00	52.21-58.35	49.70	60.30		
	Total	30	54.29 ± 3.80	52.87-55.71	48.50	64.70		
LVDd indexed to the body surface area (mm/m²)	No	21	27.35 ± 1.98	26.45-28.25	24.20	32.30	0.015	0.001
	Yes	9	29.68 ± 2.84	27.50-31.87	24.75	32.71		
	Total	30	28.05 ± 2.47	27.13-28.98	24.15	32.71		
Diastolic interventricular septum (mm)	No	21	11.04 ± 0.89	10.64-11.45	9.70	12.50	0.090	0.645
	Yes	9	11.62 ± 0.66	11.12-12.13	10.80	12.70		
	Total	30	11.22 ± 0.86	10.90-11.54	9.70	12.70		
Diastolic posterior wall (mm)	No	21	10.29 ± 0.88	9.89-10.68	8.30	11.50	0.865	0.323
	Yes	9	10.22 ± 1.05	9.41-11.03	9.00	11.80		
	Total	30	10.27 ± 0.92	9.93-10.61	8.30	11.80		
Left ventricular mass (grams)	No	21	224.71 ± 38.62	207.13-242.30	168.00	323.00	0.397	0.287
	Yes	9	239.00 ± 48.52	201.71-276.29	186.00	321.00		
	Total	30	229.00 ± 41.50	213.50-244.50	168.00	323.00		
Left ventricular mass index (gr/m²)	No	21	111.67 ± 18.29	103.34-119.99	59.00	140.00	0.049	0.124
	Yes	9	126.89 ± 19.78	111.68-142.10	93.00	158.00		
	Total	30	116.23 ± 19.72	108.87-123.60	59.00	158.00		
Relative parietal thickness	No	21	0.38 ± 0.04	0.36-0.39	0.30	0.45	0.449	0.944
	Yes	9	0.37 ± 0.04	0.33-0.40	0.33	0.45		
	Total	30	0.37 ± 0.04	0.36-0.39	0.30	0.45		

p*: Analysis adjusted by age. weight, height, body surface area and sport.
Note: the calculations are made as if all the groups had the same covariate distribution.
In all cases, the data distribution normality and the variance homogeneity were verified.

Figure 3. Relationship between the sport practised and LVH in the ECG.



These changes were directly correlated (autopsy in which the LV was weighed following removal from the heart of the right chambers, left atrium, aorta and epicardial fat, or else the thickness of the RV wall was measured) or indirectly (through imaging methods such as radiography, ventriculography, echocardiography and nuclear magnetic resonance) with the dimensions and/or mass of the different cavities in order to establish the overload criteria by ECG[1,11-16].

The LV was the most-studied cavity and its electrocardiographic expression falls to the QRS voltage. This does not only depend on the presence of hypertrophy, but it is also influenced by age, sex, ethnicity, physical habits, the geometric pattern of the hypertrophy, its severity and the orientation of the heart in the thorax.

With regard to the athletes, the prevalence of morphological and electrical changes varies according to sex (predominantly male), ethnicity (black), type (greater in endurance sports such as rowing and athletics and lower in strength sports), the intensity and standard of competition, in response to physical training[17-20]. Most sports have mixed components, that is to say that they combine volume overload and pressure and, unlike other pathological processes, the overload of the cardiovascular system is of an intermittent nature. This leads to the physiological remodelling of the LV which, on an echocardiogram, is manifested as varying increases in its size, thickness and mass, the latter being either concentric or eccentric. With regard to the sports that we are evaluating, triathlon is considered to be a sport with high/high static and dynamic components, swimming moderate/high, while water polo does not appear in the classification of the last Bethesda conference [21], given that it is a little-studied sport.

The remodelling of the LV is expressed in the ECG as an increase in the QRS voltage as an isolated criterion of LVH, and is not accompanied by non-voltage criteria (LAE, electrical axis deviation, pathological Q waves, slow intrinsicoid deflection of the QRS, or repolarisation alterations)[17,22,23]. In this regard, Pelliccia *et al*[17] evaluated the ECGs of 1005 elite Italian athletes, observing 40% anomalies of which 60% had voltage criteria for hypertrophy with greater prevalence in endurance athletes. The voltage was associated with the male sex and the presence of an increased cavity and mass, on echocardiography. None of the athletes with isolated voltage criteria had structural abnormalities such as hypertrophic cardiomyopathy, as suggested by studies that observed this isolated alteration in less than 2% of patients with this cardiomyopathy[24-26]. Non-voltage criteria were not observed.

Most studies that have evaluated the ECG criteria of LVH were conducted on endurance athletes and taking the echocardiogram as a reference, however the results are not homogeneous. One fact that cannot be ignored is that the mass cut-off values when defining LVH by echo have varied over time (their value has decreased).

A study by Somauroo *et al*.[27] on adolescent soccer players observed that 50% exhibited Sokolow's positive LVH criteria, with poor echocardiographic correlation. Age appears not to be a determining factor in these findings, given that similar results were found in veteran long-distance runners with a mean age of 56 years[28]. Finally, a study by Douglas *et al* on marathon runners showed a 57% increased LV mass by echo. The Sokolow criteria had the most S (65%) with an E of 61%, while the most specific was Cornell (95%), but with an S wave of 8%[29]. No correlation was found between the LVH signs with the LV mass and size. There were no non-voltage signs of LVH in any of the mentioned tests.

In our study, we found a statistically significant correlation between the LVH by ECG and the LVDd indexed to the BSA as shown by earlier studies that have demonstrated that persons with increased LVDd, with no increase in thicknesses, may exhibit electrocardiographic criteria for LVH[30,31]. However, there are no criteria that make it possible to clearly distinguish between concentric or eccentric hypertrophy or dilation of the LV without hypertrophy[32]. It should be emphasised that in 8 out of 9 cases with ECG criteria of LVH, the athletes showed more than one criterion for hypertrophy in the ECG. The products of the Sokolow and Cornell criteria did not improve the S wave of the same, probably because there was no prolongation of the QRS in the athletes.

Other studies have found that the ECG criteria for LVH detection are more correlated with the increase of the LV mass than with the thickness and size of the same, by echo[33,34]. In our study, 56% of athletes had an increased LV mass index (94% eccentric type); Sokolow was the criteria with more S (35%); the E wasgreater than 90% for all criteria. However, there was no significant correlation between the LVMI and the LVH in the ECGs.

With regard to the sports assessed in our study, we found a greater frequency of LVH in the ECG of triathletes compared to the other groups, coinciding with the finding of LVH by echo in 90% of them. This could be related to the fact that this is the most demanding discipline, given that it combines three types of sport, added to the fact that their weight is lower than swimmers and water polo players, which facilitates detection of LVH by voltage criteria.

Worthy of note is the low voltage found in the avL lead, to such an extent that no athlete had this positive criterion and this also had a bearing on a low S wave for Cornell. Some of the causes that could explain this are the predominantly vertical electrical axes of the athletes or the neutralisation of the left electrical forces by the right ones, although these did not frequently appear in the ECGs, they did appear in the echocardiograms (with dilation of the right chambers).

In relation to the time that the cardiac adaptations take to appear, a study on pre-adolescents with a mean age of 12 years and with at least 3 years of training, showed significant differences in the precordial voltages and in certain echocardiographic parameters (diameter of the LA of the LV and mass index) compared to a control group[35].

With regard to the right chambers, Pellicia *et al*[17] reported a prevalence of 0.08% RAE and 0.6% 110º main axis in the same population of athletes. Another study showed 0.6% for Sokolow criteria for right VH in 172 adolescent soccer players[27]. Given the prevalence of the said alterations, the presence of RAE and RVH in the ECG should not be interpreted as physiological and it would be worth examining the images in order to rule out a pathology.

In our population, 56% of the athletes exhibited an increase in the size of the RV inflow tract, however this was not reflected in the ECGs.

With regard to the atria, dilation was observed, which varied according to the quantification method used (diameter, area, volume) from 36 to 60% for the LA and from 33 to 56% for the RA. Neither was this reflected in the ECGs, reflecting their low S wave.

The abnormal echocardiographic findings in our athletes were interpreted as adaptive given the normal biventricular Systo-diastolic function in all of them. In the ECG, we observed no pathological alterations of the ST and T wave, another indication of physiological changes in the athletes.

Based on our analysis, we could say that the S wave of the ECG for the detection of LVH in athletes is low and it is very unlikely that the refinement of the criteria may improve this relationship. However, we did find a correlation between the LVH by ECG with the diastolic dimensions of the LV by echo. The capacity of the ECG to detect physiological hypertrophy, dilation and thickness increases may differ from the pathologies and the different structural or geometrical characteristics of the myocardium between one pathology and another, may exert an influence on this.

Finally, although the number of athletes included in our study is small for the purpose of issuing valid conclusions, it should be emphasised that many studies that have evaluated the electro and echocardiographic manifestations of training, some of which we have cited herein, were based on a number of athletes that is similar to ours[28,29,33,36,37].

Limitations

A limitation of this study is the small number of athletes included to date. Even so, we consider that this limitation has been offset by a thorough collection of information on the variables evaluated and with the application of rigorous statistical analyses.

Another limitation was the fact that we had no precise information on how long the athletes had been training, which could have an influence on the adaptive phenomena observed.

It should be pointed out that the results of our study cannot be generalised to recreational sports. Furthermore, this evaluation only includes men.

Conclusions

Certain echocardiographic parameters in our population of athletes were above the normal values for the general population. No relationship was found between the electrocardiographic signs of the enlargement of the LA, RA or hypertrophy of the RV with the echocardiographic findings.

The ECG criteria for LVH voltage were correlated to a greater LVDd indexed by echocardiography and were most frequently observed in the triathlon group.

The morphological and functional adaptive changes to training on the cardiovascular system continue to be the subject of prospective investigations in order to provide new evidence with regard tot he best way to evaluate high performance athletes. Each and every one of the sports disciplines must be included and analysed in order to identify the cardiac impact generated by the different stimuli sustained, particularly those disciplines that are still little studied.

Conflict of interest

The authors do not declare a conflict of interest.

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Original article

ACTN-3 and ECA genes expression do not influence the acute change in muscle mechanical and functional properties in youth handballers

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Summary

The purpose of this study was to explore the potential relationship between ACTN-3 and ACE gene expression over the change in muscle mechanical and functional properties in youth handballers through a congested tournament. 30 players of the first handball division of Costa Rica participated in this study. The participants played a national tournament during three consecutive days (one match per day). The collection of genetic samples was through a mouth rinse with a 5% sucrose solution before the tournament. PCR tests were used to detect the alleles of the ACE and ACTN3 genes and the product´s reaction was visualized by electrophoresis. Before and after each match, tensiomyography (TMG) and Countermovement jump (CMJ) tests were used to assess mechanical and functional properties respectively. Descriptive frequency analyses and a one-way analysis of variance of independent groups were the statistics test applied. The results showed that the most prevalent polymorphisms expression was ACTN-3 R-X (56.7%) and ECA I-D (43.3%). No significant differences (p> 0.050) were found between genes expressed in the mechanical responses (contraction time (TC), delay time (TD) and, maximum radial displacement (DM)) of the rectus femoral muscle of the dominant leg neither in performance in the test CMJ. Likewise, there was no significant change (p> 0.050) in muscle mechanical or functional properties post official matches. In conclusion, handball players have the genes ACE and ACTN. Nevertheless, it seems to have no influence of these genes on the mechanical or functional muscles acute responses. More investigations will be needed to explain and understand the real impact of this gene's expression on muscle performance in handball players.

Key words:
Sport. Muscles. Genes. Physical functional performance. Genetics.

Expresiones de los genes ACTN-3 y ECA no influyen en el cambio agudo de las propiedades musculares mecánicas y funcionales en jugadores juveniles de balonmano

Resumen

El propósito de este estudio fue explorar la relación potencial entre la expresión ACTN-3 y ACE sobre el cambio en las propiedades musculares mecánicas y funcionales de jugadores juveniles de balonmano a través de un torneo congestionado. Participaron 30 jugadores de la primera división de balonmano de Costa Rica. Los participantes jugaron un torneo nacional durante tres días consecutivos. La recolección de muestras genéticas se realizó mediante un enjuague bucal con una solución de sacarosa al 5% antes del inicio del torneo. Pruebas de PCR fueron usadas para detectar los aleros de los genes ACTN-3 y ACE y la reacción del producto fueron visualizadas por electroforesis. Antes y después de cada partido, se utilizaron las pruebas de tensiomiografía (TMG) y de salto contramovimiento (CMJ) para evaluar las propiedades mecánicas y funcionales respectivamente. Las pruebas estadísticas aplicadas fueron análisis descriptivo de frecuencias y un análisis de varianza de una vía para grupos independientes. Los resultados mostraron que la expresión de polimorfismos más prevalente fue ACTN-3 R-X (56,7%) y ECA I-D (43,3%). No se han encontrado diferencias significativas (p> 0,050) entre genes expresados en las respuestas mecánicas (tiempo de contracción (TC), tiempo de retardo (TD) and, máximo desplazamiento radial (DM)) del músculo recto femoral de la pierna dominante ni en el rendimiento en la prueba de CMJ. Asimismo, no hubo cambios significativos (p> 0.050) en las propiedades mecánicas o funcionales de los músculos después de los partidos. En conclusión, los jugadores de balonmano tienen los genes ACE y ACTN, sin embargo, parece que estos genes no influyen en las respuestas agudas mecánicas o funcionales de los músculos. Se necesitan más investigaciones para explicar y comprender el impacto real de la expresión de estos genes en el rendimiento muscular de los jugadores de balonmano.

Palabras clave:
Deporte. Músculo. Genes. Rendimiento físico funcional. Genética.

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Introduction

The study of genetic factors within sports science has been relevant due to their influence on sports performance[1,2]. Genetics has long been used to understand individual performance capacities in different sports[3]. Genetic polymorphisms are associated with muscular strength and aerobic capacity, improving sports performance in training and competition[4,5]. Within performance in elite sports, a more complex phenotypic composition is needed, which is why it is influenced by anatomical, biochemical, and psychological factors[2,6]. Likewise, genetic profiles offer a piece of valuable information that can help talent identification[7].

The high-level sport requires strength directly related to muscle fibres; these respond specifically from enzymatic activity, muscle contraction, morphology and metabolism[1]. To these responses, the angiotensin-converting enzyme (ACE) is related to the aerobic capacity of athletes and ACTN-3 that is associated with strength, speed, and power as predominant capacities[5,8]. At a physiological level, observing the ACTN-3 and ACE genes and their respective polymorphisms can become fundamental within performance in sport[9]. Genetic factors do not determine an athlete's success, but it is useful to identify them to enhance performance from the genotype[3].

The presence of ACTN-3 in the muscle benefits sports performance, specifically in strength and power, and the absence of the polymorphism of this gene benefit those athletes that participate in endurance events[1]. In collective sports such as soccer, it is found that the combination of homogeneous RR and heterogeneous RX alleles reflects better performance in strength and speed. In contrast, the combination of homogeneous XX alleles show better performance in endurance competitions; this is associated at a physiological level with the function of the contractile apparatus that is generated from the muscle fibres when doing sports[9]. Female young soccer players, who are faster and more powerful, had a high prevalence of ACE DD and ACTN-3 RX genotypes[10]. ACTN-3 has been shown to have higher performance with R alleles within strength and power[9].

ACE is associated with the D allele with greater volume, muscle strength and a higher percentage of muscle fibres[9]. Subjects with ACTN-3 (RR) polymorphism have longer muscle and specific fibres; in this genotype, the anabolic contribution increases muscle mass[8]. In the ECA polymorphism, it is found that the D allele has greater changes at the muscular level (muscle cross-sectional area) and this condition can enhance the performance on isometric and dynamic strength testing[8]. Therefore, the purpose of this study was to explore the potential relationship between ACTN-3 and ACE gene expression over the change in muscle mechanical and functional properties in youth handballers through a congested tournament.

Material and method

Participants

Thirty players (15 men and 15 women) belong to first division handball teams that participated in a national tournament of I division organised by the Costa Rican Handball Federation. The average age of the 30 participants was 19.3 years (± 3.6) and with an average number of hours of weekly training of 7.5. Those players who participated >45min of an official competition match were included. All participants provided written informed consent for participation in this study, according to the criteria of the Declaration of Helsinki by the World Medical Association[11].

Tournament

A total of 12 matches took place over three consecutive days (Saturday, Sunday, and Monday). Four matches were held each day (two for men and two for women). Each team played one match per day. The pitch had the official measurements (20x40 m) and the matches had 60 minutes of duration (30 minutes each period of play).

Collection and treatment of the genetic sample (DNA epithelial cells)

A mouth rinse was performed with a 5% sucrose solution for 60 seconds, and each rinse was collected in a 15 ml centrifuge tube. Subsequently, 3 ml of TNE [17 mM Tris / HCl (pH 8.0), 50 mM NaCl and 7 mM EDTA] diluted in 66% Ethanol prepared previously in the laboratory were added, the rinsing solution was divided into four tubes, one was used as a rapid test, and the others were kept refrigerated for 2, 15, and 30 days respectively[12].

The DNA was left in isolation, and its respective purification was carried out: using the DNA extraction kit, DNA Blood and Tissue Mini kit (Qiagen, West Sussex, UK), according to the manufacturer's instructions. The purity level of the extracted DNA was analysed using a Nanodrop and an agarose gel 1% to confirm its integrity. PCR and PCR RFLP were used respectively to detect the alleles of the ACE (rs1799752) and ACTN3 (rs1815739) genes. Specific primers were used for the identification of the polymorphisms[13]. To perform the enzymatic digestion of the ACTN3 gene, the enzyme DdeI from the manufacturer Thermo Scientific was used. The product´s reaction was visualized by electrophoresis on agarose gel at 3%, buffer TBE 0,5%; stained with Gel Red (Biotum).

Mechanical muscle properties (tensiomyography)

Before and after each match, rectus femoral muscle contractile responses of the dominant leg were assessed through a tensiomyography (TMG) (TMG, Ljubljana, Slovenia). For this, each participant took a supine position on a portable massage table. The knee joint was fixed in a comfortable extension on a padded pillow where the participants remained relaxed. Two electrodes (5 x 5 cm) (TheraTrode, TheraSigma, Orange, CA, United States) were used, placed at 5 cm from each other on the point of the maximal radial circumference of the muscle. A stimulator (TMG-S2 doo, Ljubljana, Slovenia) induced a quadrangular, single-phase, and 1ms wave of pulse duration between 0.1 s and 110 mA and a precise digital displacement transducer (40 GK, Panoptik doo, Ljubljana, Slovenia) positioned perpendicular to the measurement point of muscle was used this had a spring constant of 0.17 Nmm21 and registered muscle contraction time (TC) and delay time (TD), both expressed in milliseconds (ms), and, maximum radial muscle displacement (DM) expressed in millimetres.

The stimulus was started by inducing muscle contraction, beginning with 40 mA and increasing by 20 mA; a 10-second rest separated the electrical stimuli to avoid post-tetanic activation[14].

Functional muscle properties (Countermovement jump)

This test was used to assess the power of the players. An Axon Jump platform (Bioingeniería Deportiva, San Martín, Argentina) was used with special software (Smart Axon 4.02). Before and after each match, the participants were placed on the platform with their legs shoulder-width apart and their hands on the waist. When prompted, 15 seconds of consecutive explosive jumps were performed. To record the Rate of Perceived Effort (RPE), the Borg scale was used, where 6 corresponds to "very, very light" effort and 20 as "maximum" effort[15].

Statistical analysis

Using a statistical software (SPSS v23, SPSS Inc., Chicago, USA), descriptive frequency analyses (absolute and relative values) were performed to determine the distribution of polymorphisms in the ACTN-3 and ACE genes. Then, a one-way analysis of variance of independent groups was performed to compare the mechanical and functional muscle responses between the polymorphisms expressed for each gene. Bonferroni's post hoc test was considered to determine specific differences. Also, it was calculated the percentages of the changes of each variable analyzed between pre- and post-match. $p< 0.050$ was the level significance selected for all analyses

Results

Table 1 shows the percentage frequencies of gene expression in which it is shown that the polymorphisms most expressed in handball players are ACTN-3 R-X (56.7%) and ACE I-D (43.3%).

There were no neuromuscular differences between groups of polymorphisms in the ACE gene in the variables of the dominant rectus femoris TC (F= 0.113, p= 0.893), TD (F= 0.116, p= 0.891), DM (F= 0.709, p= 0.501), and CMJ (F= 0.825, p= 0.893). Likewise, no differences were found in TC (F= 1.832, p= 0.236), TD (F= 0.205, p= 0.816), DM (F= 1.352, p= 0.276) or CMJ (F= 1.522, p= 0.236) in the ACTN-3 gene (Table 2).

There were no variations in mechanical functions after an official match according to the expressed polymorphism. in the variables according to polymorphism expressed in the ACTN-3 gene: TC (F=3.358, p=0.05), TD (F=1.064, p=0.359), DM (F=1.772, p=0.189), and CMJ (F= 0.827, p= 0.448). No significant differences were found in the ECA gene: TC (F= 0.114, p = 0.892), TD (F= 0.658, p= 0.526), DM (F= 1.216, p= 0.312), and CMJ (F= 0.490, p= 0.618) (Table 3).

Table 1. Frequency and percentage of expression of polymorphisms in ACTN-3 and ECA genes.

	R/R	R/X	X/X	I/I	I/D D/D
ACTN-3	10 (33%)	17 (56.7%)	3 (10%)		
ACE			11 (36.7%)	13 (43.3%)	6 (20%)

Table 2. Muscle mechanical and functional differences according to polymorphism expressed in ACTN-3 and ACE.

	ACTN-3			ACE		
	R/R	R/X	X/X	I/I	I/D	D/D
TC (ms)	25.9 ± 2.9	25.6 ± 3.7	21.8 ± 2.4	25.9 ± 4.1	24.4 ± 2.3	26.1 ± 4.3
TD (ms)	22.4 ± 1.7	22.8 ± 1.8	22.2 ± 1.5	22.6 ± 1.1	22.4 ± 1.7	22.9 ± 2.6
DM (mm)	7 ± 1.8	7.4 ± 1.6	5.8 ± 0.3	7 ± 1.9	7.3 ± 1.5	7.1 ± 1.6
CMJ (cm)	28.3 ± 5.5	32.4 ± 6.1	31.4 ± 6.3	30.2 ± 6	31.4 ± 6.2	31.2 ± 6.6

TC: contraction time; TD: delay time; DM: maximum radial muscle displacement; CMJ: countermovement jump; ms: milliseconds; mm: millimetres; cm: centimetres.

Table 3. Percentage of change in post-match of muscular mechanical and functional variables according to polymorphism expressed in ACTN-3 and ACE.

	ACTN-3			ACE		
	R/R	R/X	X/X	I/I	I/D	D/D
TC (ms)	11.2 ± 13.8	0.2 ± 9.1	1.9 ± 7.5	2.7 ± 13.2	4.7 ± 9.7	5.0 ± 14.4
TD (ms)	1.8 ± 9.5	-2.5 ± 6.13	-0.9 ± 7.4	-3.0 ± 6.3	0.4 ± 6.6	-0.2 ± 10.9
DM (mm)	6.9 ± 24.9	1.1 ± 23.1	28.4 ± 16.2	14.5 ± 32.5	1.9 ± 15	-1.8 ± 19.7
CMJ (cm)	92.9 ± 313.1	6.6 ± 8.9	-13.1 ± 5.7	4.3 ± 11.5	71.2 ± 274.2	4.7 ± 15.9

TC: contraction time; TD: delay time; DM: maximum radial muscle displacement; CMJ: countermovement jump; ms: milliseconds; mm: millimetres; cm: centimetres.

Discussion

The purpose of this study was to explore the potential relationship between ACTN-3 and ECA gene expression over the change in mechanical muscle properties in youth handballers through a congested tournament. According to the available evidence, few studies have explored the genetic influence on handball player´s physiology, physical performance, or other critical factors (risk of injury, anthropometrical characteristics). Only two studies were found that reported outcomes related to handballers[5,16]. The expression frequency of polymorphisms of the genes analysed in our study can be observed in table 1. The most expressed polymorphisms were the ACTN-3 R-X (56.7%) and the ECA I-D (43.3%). ACE genotypes frequencies within a group of 27 handball players found 21 players with insertion homozygous (II), five with heterozygous (ID) and one with deletion homozygous (DD)[5]. These results are in line with previous literature suggesting that RX genotype is the most frequent in handballers as Chilean[16].

Handball is an intermittent team sport that requires both the anaerobic and aerobic energy systems[17,18]. The most prevalent gene expression was the ECA I-D, associated with a higher aerobic and endurance capacity. On the other hand, RX alleles have implied a better predisposition to strength, speed, power movement[9]. In both cases, the frequency and influence of these alleles of ACE and ACTN are associated with the physical and physiological demands that characterize handball[17,18].

In other sport disciplines have been observed similar percentages of prevalence of these genes. For example, in Russian and Lithuanian professional athletes such as weightlifters, powerlifters, and throwers, the prevalence of these polymorphisms' expression was between 43% to 51% for ACE I-D and between 45% to 56% for ACTN-3 R-X[13].

ACE and ACTN are associated with physical performance in physical tests[5,8]. Nevertheless, results obtained in the present study did not evidence any significant difference among the genes expression, which coincide with results found in an Italian athletes' group, who did not present a significant correlation between ACE I/D and ACTN3 (R577X) with power capacity[3].

Other research had reported some influence of these genes on the jump capacity. In male soccer players, individuals with ACTN RR usually had better performance in jump tests than individuals with RX and XX[19]. Besides, ACTN RR and RX female soccer players groups showed a higher capacity during a CMJ test of seven continuous jumps[10]. The players with higher predisposition of these genes' expressions used gain muscle mass and strength and the development of a higher number of fibres type II, that can explain the power responses of the athletes[8].

This study included the analysis of tensiomyography responses of the leg's muscles; however, no previous investigations were found that relate muscle mechanical responses with gene expression. It is known that tensiomyography assess muscles contractile properties[20,21]. In female rugby players, a higher stiffness of vastus lateralis muscle was correlated with higher muscle power assessed by Wingate anaerobic test[20]. Likewise, vertical jump performance had shown an association with tensiomyography responses in power and endurance athletes[21].

The analysis of the changes in the tensiomyography responses and vertical jump seem not to show a significant effect on the gene's expression. However, during the young soccer short-congested fixture period, muscle stiffness of biceps femoris and rectus femoris decreased due to cumulative fatigue during the game and throughout the tournament[14]. In team sports such as handball, in which players frequently perform high-intensity activities[17], the manifestation of muscle fatigue can affect physical performance reducing the force, power, aerobics, and anaerobic capacity during the game. Another important aspect described in the literature is the association between ACTN and low muscle injury risk[9].

Authors should highlight some limitations, as the relative low sample size, to analyse and obtain solid conclusions. On the other hand, only two variables associated with physical performance were analysed, this should be extended in future studies. This could have limited the possible correlations or differences between physical capacities with gene expression like have been informed in previous literature.

Conclusion

The handball players have ACE and ACTN; however, a potentiation of effect was not found on the mechanical or functional muscle responses. According to these results, these genes it seems not to influence on these neuromuscular capacities.

More investigations will be needed to explain and understand the real influence of this gene's expression on the physical performance of handball players. It will be crucial to add other facts like nutrition, physical training experience and anthropometric within the future studies to obtain a more complete scenery about this topic. Also, to consider analysing ACE and ACTN together with physical activities during the games, knowing the influence of these genes' expression on the physical performance players when they are competing will help practitioners have a better understanding of the characteristics of this sport.

Conflict of interest

The authors do not declare a conflict of interest.

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Physical activity, physical condition and quality of life in older adults. Systematic review

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Summary

Background: The aging of the population together with sedentary lifestyle, can cause a functional deterioration that leads to the decrease of physical condition and quality of life. Promoting active aging can improve the quality of life and physical condition of our elders.
Objective: This work aims to investigate the available scientific evidence on the effect of physical activity in older adults, in terms of quality of life, physical condition, and maintenance of functional independence.
Material and method: A systematic review was performed in the WOS, SCOPUS and PubMed databases. Selection of articles: Intervention studies evaluating the quality of life and functional capacity of older adults were included. The studies were evaluated according to methodological quality with the PEDro scale.
Results: 1331 articles were found, of which 17 were included. Interventions included resistance, strength, balance, coordination, and gait speed exercises. The main findings indicated that a higher rate of physical activity was associated with less impairment of physical and cognitive functions in older adults and, therefore, with a better quality of life.
Conclusions: an active lifestyle is associated with a better quality of life, better physical condition and maintenance of functional independence. Other studies, with greater homogeneity in the data collection instruments, with greater frequency of interventions, would be convenient to define the most appropriate exercise programs and to increase the scientific evidence.

Key words:
Quality of Life. Physical condition. Physical activity elderly. Systematic review.

Actividad física, condición física y calidad de vida en los adultos mayores. Revisión sistemática

Resumen

Introducción: El envejecimiento de la población junto al sedentarismo, puede ocasionar un deterioro funcional que conduciría a la disminución de la condición física y de la calidad de vida. La promoción del envejecimiento activo puede mejorar la calidad de vida y la condición física de nuestros mayores.
Objetivo: Evaluar la evidencia científica disponible sobre el efecto de la actividad física en los mayores, en términos de calidad de vida, condición física y mantenimiento de la independencia funcional.
Material y método: Revisión sistemática en las bases de datos WOS, SCOPUS y PubMed. Selección de artículos: Se incluyeron estudios de intervención que evaluaban la calidad de vida y capacidad funcional de los adultos mayores. Los estudios fueron evaluados según la calidad metodológica con la escala PEDro.
Resultados: Se encontraron 1331 artículos, de los que se incluyeron 17. Las intervenciones incluyeron ejercicios de resistencia, fuerza, equilibrio, coordinación y velocidad de la marcha. Los hallazgos principales indicaron que un mayor índice de actividad física se relacionó con un menor deterioro de las funciones físicas y cognitivas de los mayores y, por lo tanto, con una mejor calidad de vida.
Conclusiones: Un estilo de vida activo se asocia a una mejor calidad de vida, mejor condición física y mantenimiento de la independencia funcional. Serían convenientes otros estudios, con una mayor homogeneidad en los instrumentos de recogida de datos, con mayor frecuencia de intervenciones, para definir los programas de ejercicios más adecuados y para incrementar la evidencia científica.

Palabras clave:
Calidad de vida. Condición física. Envejecimiento activo. Revisión sistemática.

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Introduction

The drop in the birth rate and rise in life expectancy have led to an ageing population, especially in developed countries, where life expectancy has increased considerably[1]. In Spain, life expectancy stands at 85.8 for women and 80.5 for men. The percentage of the population over 65 is currently 19.3% and is expected to reach 25.6% by 2031 and 34.6% by 2066[1].

At the same time, more than 50% of the population over 60 years of age is physically inactive[1,2], which can lead to a state of frailty, disability and dependency. People who do not do enough physical activity have a risk of mortality between 20% and 30% higher than those who are sufficiently active[3,4].

Physical activity is recommended to improve physical condition and health-related quality of life (HRQoL) at all stages of life. Having an active lifestyle has been shown to promote a healthier and more independent life for older people, and improve their functional and mental abilities, and, consequently, their HRQoL[4–11]. It also contributes to the maintenance of bone and muscle mass, thereby increasing functional performance and decreasing sarcopenia[12], improving coordination and dynamic and static balance, important factors to prevent the frailty process (a clinical condition involving age-related decrease in functional reserve) and the risk of falls[13–15].

Physical condition and HRQoL are closely related, contribute to maintaining an overall level of functioning and favour satisfactory ageing, the aim of which is to maintain the autonomy and independence of the elderly[16,17].

Numerous studies with very different methodologies recommend physical activity as a means to prevent the appearance of frailty, disability and dependence, and, ultimately, enhance HRQoL and achieve satisfactory ageing [2,13–17]. However, we do not know which components of physical activity or interventions may be more decisive in improvement: group or individual physical activity, multi-component exercise programmes (ones which combine endurance, strength, coordination, balance and flexibility training) or others.

The objective of this study is to update our knowledge about the effect of physical activity on the quality of life, physical condition and maintaining functional independence in the elderly by reviewing the existing studies in the field to highlight the most effective interventions and be able to enhance them; and define possible focuses for research in this area.

Material and method

Search design and strategy

A systematic review was carried out in November 2020 by means of an advanced search for original papers and reviews in the databases available through the University of Malaga: *Catálogo Jábega,* the university library's automated catalogue, and the online databases Web of Science (WOS), SCOPUS and PubMed. The following MeSH descriptors were used: *'physical activity', 'exercise', 'physical condition', 'elderly', 'quality of life', 'frail'*, with the Boolean operators AND and OR. The review was complemented by a hand search of bibliographic references in the documents found to locate studies not identified with the electronic search. Figure 1 shows the flowchart used for the selection of papers relevant to the study.

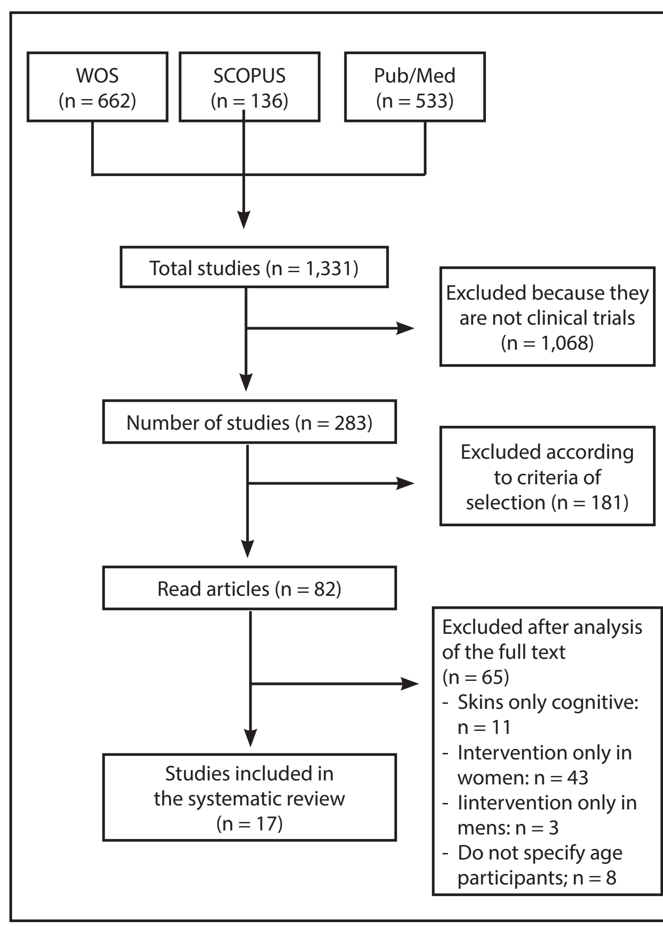
Inclusion criteria

Articles in English or Spanish published in the last 10 years. Intervention studies (clinical and quasi-experimental trials) evaluating the effect of physical activity on physical condition and HRQoL in people over 60 years of age of both sexes.

Exclusion criteria

Papers which did not meet the inclusion criteria described, papers where access to the full text was not available, duplicates and papers which did not have an explicit methodology were excluded.

Figure 1. Flowchart of the article selection process.



Selection of studies and data extraction

The papers of interest were selected independently by two reviewers who reviewed their titles and abstracts; when the abstract of a paper was not conclusive, the entire text was assessed. In the event of disagreement between the reviewers, consensus was sought.

In each original paper reviewed, information was sought on: author, year of publication, sample size, age of the subjects, characteristics of the intervention (groups, type of activity, components, duration of the programme, number of sessions and their duration, measurement instruments and results obtained).

Methodological quality assessment

The 17 studies which met the inclusion criteria were analysed. Methodological quality was scored using the Physiotherapy Evidence Database (PEDro) scale[18], which evaluates 11 items ('Yes', 'No' or 'Not reported'), of which only 10 are evaluable, the first not being scored because it refers to the external validity of the study. Items answered 'Yes' score 1 point, the rest 0.

Results

The diagram with the paper selection procedure is shown in Figure 1.

1,331 papers were reviewed. In a first screening, 1,068 papers were excluded because they were not experimental studies. Of the remaining 263, 181 were excluded according to the inclusion criteria; by population age; duplicate articles; articles relating physical exercise to specific diseases or only dealing with cognitive aspects related to exercise. The 82 resulting papers were reviewed a second time and 17 articles were finally selected.

Methodological quality

The scores obtained in the methodological assessment according to the PEDro scale ranged from 6 to 8, the mean score being 7.12. This indicates the good methodological quality of the papers selected.

Characteristics of the papers selected

The sample from the 17 papers analysed consisted of 1,910 men and women over 60 years old. As for the study environment, 16 were performed in the community[19–34] and one in a care home[35] (Table 1).

Characteristics of the interventions

Regarding the number of groups studied; 10 studies included two groups, an intervention group (IG) and a control group (CG)[19–21,23,26,30–35], and three studies included three groups (two with 2 IGs and 1 CG[22,28], and one with 3 IGs24). Two studies involved two groups, both IGs[27,29]; and one study (before-after) had no control group[25].

Type of intervention: the intervention with the control groups consisted of the usual community-level healthy lifestyle recommendations; such as staying active (walking at least 150 minutes a week) and a balanced diet[19–21,23,26,30,31,33,35].

The intervention groups did multi-component training programmes[9, 20, 25, 26, 30–35]; programmes to improve walking[21]; power training (muscle strengthening)[22]; Pilates exercises[23]; aquatic gymnastics, general gymnastics and weight training[24]; water- versus land-based exercises[27] and aquatic exercise[28,29].

Intervention period: between 8 weeks[33] and 6 months[19,25,29] with a median of 12 weeks[20–24,31,32,35].

Frequency of the interventions: most of the studies involved two[20,23–25,28,29,35] or three[27,32] weekly sessions lasting about 60 minutes.

Measurements

All the studies measured the participants at baseline and post-intervention, except one study[26], which evaluated the intervention one week after completion. Participants were followed up after the intervention in two studies: at 3 months[33] and at 12 months[21]. The rest of the studies did not involve any kind of follow-up.

Measurement of physical condition

Physical activity: Daily physical activity patterns were measured in 2 studies using accelerometers, pedometers, and the Physical Activity Scale for the Elderly (PASE) questionnaire; and observed a significant improvement in physical activity patterns and functional ability after a training programme[21,26].

Muscular strength: Significant improvement ($p<0.05$) was seen after the programme in most of the studies analysed, both in upper and lower limbs[20–22,25,29,32,35]. However, in one study which measured gripping strength in the upper limbs, no significance was found[19].

Gait speed: Gait speed was analysed in 10 studies, and a significant improvement ($p<0.05$) was obtained in all of them[19–21,25,26,28,29,32,33,35]. The tests used for measurement were the Timed-Meter Walk Test (MWT)[20.35]; the 6 min Walk Test (6MWT)[19.25.28]; and the Short Physical Performance Battery (SPPB)[33]. One study analysed walking speed using a VICON motion capture system consisting of a set of 8 cameras with sensors and motion markers on each patient, (which analysed gait speed, cadence and step length), obtaining significant improvements in physical condition and in the risk of falls after the intervention[32].

Balance: Balance was evaluated in 12 studies; different tests were used for dynamic or static balance depending on the study: the Test of Static Balance (FICSIT-4T)[35], Balance at 3 levels[20], functional capacity (SPPB)[19,33], the Berg Balance Scale[23,28], the Functional Reach Test (FRT)[29,32], TUG[30,34] and the Senior Fitness Test (SFT)[25]. Statistically significant improvements were obtained compared to the control groups in all the studies.

Flexibility was assessed through different tests, either in isolation or as a component of functional physical condition tests; the SPPB[19,33] test; the Chair Sit and Reach Test (CSAR)[25,29,34]. The study by Cichocki *et al.*[34] did not obtain a significant improvement in flexibility after the intervention.

Table 1. Characteristics of the papers selected (n=17).

Authors	Sample	Characteristics of intervention	Variables / Measuring tools	Results	PEDro
Harris *et al*. 2015[21]	n = 298; 160 women and 138 men. Age: 60 – 74	Walking programme. 3 months 2 groups: IG + CG. Intervention to increase walking, using: - Behaviour change techniques. - Individual walking plan.	- Accelerometer (ActiGraph GT3X+) to monitor physical activity. - Pedometer (step count)	The changes in mean daily step counts (CI 95%: 513-1560) and weekly MVPA in 10 min episodes (CI 95%: 40-87) were significantly higher in the IG than the CG	8/10
Sayers y Gibson, 2014[22]	n = 64; 43 women and 21 men. Age: 70.3 + 6.9	Strength exercise programme. 12 weeks. 3 groups: 2 IG: 1st: high-speed strength training 2nd: slow-speed strength training. CG: warm up and stretching.	Lower limb strength: measures of muscle performance.	High-speed strength exercises increased the speed of older adults (0.18±0.21 m/s; p<0.05), allowing improvement in functional tasks related to safety.	8/10
Tarazona-Santabalbina, 2016[19]	n = 100 54% women. Age: 79.9 + 3.8	Exercise programme. 24 weeks. 5 x 65-min. sessions/week. 2 groups: IG + CG Exercises for: - Proprioception - Endurance- aerobic. - Strength: - Flexibility. Stretching - Coordination, balance	Physical condition: - Handgrip strength; Balance and gait (Tinetti); Functional capacity (SPPB); Physical performance (PPT); Energy expenditure (PAEE). Others: - ADLs (Barthel) and IADLs (Lawton and Brody); Cognitive status (MMSE); Social support (Duke); Quality of Life (EQ-5D); Emotional status (GDS).	IG vs CG: Improvements in: - Static and walking (dynamic) balance (p=0.007) - Physical performance. Energy expended associated with exercise (P<0.001). - Functional ability ADLs, IADLs, cognitive status, emotional status, social support and quality of life (P<0.001). - Frailty: The frailty score dropped in the intervention group (P<0.001) (CI 95%: 20.3-45.0)	6/10
Ng, 2015[20]	n = 246 61.4% women. Age: 70 + 4.7 community	12 weeks. 2 x 90-min. sessions/week. 2 groups: IG + CG Multi-component training programme.	Physical condition: - Maximum dynamic strength (1RM); - Gait speed (6 min).	IG vs CG: Improvements in: - Muscle strength (leg flexion) (p<0.001) - Gait speed (p<0.001) Frailty: Reduction in frailty score (35.6% to 47.8%) (P<0.01)	8/10
Cadore, 2014[35]	n = 24 70% women. Age: 91.9 + 4.1	Exercise programme. 12 weeks. 2 x 40-min. sessions/week. 2 groups: IG + CG Maximum dynamic strength: 8-10 repetitions at 40-60% 1RM combined with balance and retraining of gait.	Physical condition: - Isometric and maximum dynamic muscle strength. - Lower limb strength (rise from a chair test); - Gait speed - Static balance. Others: - Incidence of falls; ADLs (Barthel)	IG pre-post: Improvements in: - Isometric hip flexion (P<0.05); and knee extension (P<0.01); - Gait speed (p<0.05) - Lower incidence of falls (P<0.0001); IG vs CG: Improvement in: - Isometric strength: handgrip, hip flexion and knee extension; Maximum dynamic strength: upper and lower limbs; Lower limb strength in the rise from a chair test (P<0.01) - Gait speed (p<0.05) - Static balance (P<0.05); - Lower incidence of falls (P<0.0001).	6/10

(continued)

Table 1. Characteristics of the papers selected (n=17) ***(continuation).***

Authors	Sample	Characteristics of intervention	Variables / Measuring tools	Results	PEDro
Campos de Oliveira *et al.,* 2015[23]	n = 32 100% women. Age: 63.6 ± 1	Pilates exercise programme. 12 weeks. 2 sessions/week. 60 min. 2 groups: IG + CG Pilates. Stretching	- Isokinetic torque of knee extensors and flexors - Timed Up and Go (TUG) test. - Berg balance scale. - Evaluation of the Health Survey (SF-36).	Significant improvement of all variables (p<0.05), except the Berg Balance Scale (p = 0.0509) The control group shows no changes.	6/10
Vicentini de Oliveira *et al,* 2014[24]	n = 120 100% women. Age: 60-70	Three different exercise programmes for 3 groups. 3 months. 2 sessions/week. 3 IG: - G1: Water aerobics - G2: General gymnastics - G3: Weight training	WHO Quality of Life Test: WHOQOL-OLD	Benefits for quality of life in the 3 groups, but especially in the weight-training group (P<0.001)	8/10
López Téllez *et al*. 2012[25]	n = 29 27 women. Age: >65 Community	Exercise programme. 6 months. 2 sessions/week. 60 min. - Monthly health education sessions. - 3 days of social activities. - 2 x 60-min. physical activity sessions/week.	- HRQoL: SF-36 - Functional Physical Condition: Senior Fitness Test.	Improvement in health-related quality of life (P<0.05) and increase of 11.7 points in mental summary component (p<0.001). Improvement of functional physical condition. Improvements in: - Gait: increase 62 m (p<0.001) (CI 95%: 48-76). - Strength: 73.9% (CI 95%: 56-92) - Dynamic balance: 86.4% (CI 95%: 74-99); - Flexibility: 69.6% (CI 95%: 51-88).	7/10
de Roos *et al.* 2018[26]	n = 52; 34 women and 18 men. Age: 70.2 + 9.5	Combined exercise training and walking programme. Duration: 10 weeks.	- Accelerometry (to measure daily physical activity) - PASE questionnaire - 6 MWT - CVRS questionnaire (CRQ)	The increase in functional capacity between the groups was clinically relevant (CI 95%: 2.3 to 65.6) in favour of the intervention group.	7/10
Oh *et al.* 2015[27]	n = 66 Age: >65	Exercise programme. 10 weeks. 3 sessions/week. 2 IG: - land environment and - water environment.	- SF36 - M-FES questionnaire. (modified falls efficacy scale). - Measuring instruments: Hand dynamometer, Sit and Reach, hip strength in flexion, ext, abd and add; TUG (Timed Up-and-Go).	Improved hip abduction (p=0.001) and adduction strength (p=0.007). Significantly different quality of life improvement between the two groups (p < 0.001). Significant improvement in the risk of falls in both groups (p = 0.040) (CI 95%).	8/10
Arnold *et al.* 2010[28]	n = 79 Age: >65	Aquatic exercise and education programme. 11 weeks. 2 sessions/week. 3 groups: 2 IG + CG - 1st Aquatic exercise: stretching, postural control and balance. - 2nd Aquatic Exercise + education class: Same as above + education class. - Control G.	- Balance. Berg Balance Scale. - Falls. ABC scale. - Functional performance. (30s-CST) - Walking. 6MW	The combination of aquatic exercise and education is effective in improving risk factors for falls in older adults (p = 0.038).	8/10

(continued)

Table 1. Characteristics of the papers selected (n=17) ***(continuation).***

Authors	Sample	Characteristics of intervention	Variables / Measuring tools	Results	PEDro
Sato *et al*. 2011[29]	n = 35 Age: ≥65	Aquatic exercise programme. 6 months. 2 IG: 1st group: 1 session/week. 2nd group: 2 sessions/week. Gymnastic exercises in the pool, with 10 min of warm-up and stretching out of the water.	- Lower limb muscle strength. - Flexibility. - Balance (FRT). - Falls.	Improvements after intervention in muscle strength, balance and flexibility. In the mobility test (TUG) for the risk of falls, no significant differences were found in the tests before and after the intervention. Significant improvements were found in ADLs (p<0.05).	6/10
Siegrist *et al*., 2016[30]	n = 378; 285 women. Age: 65-94	16 weeks. 1 hour/week. Multi-component exercise programme: strength training, balance, walking and functional training.	- Balance. Timed Up-and-Go (TUG) - Functional performance. (30s-CST) - Falls. Falls Efficacy Scale; Romberg's Test.	Patients in the intervention group showed significant improvements in: Falls (CI 95 %:0.35; 0.84), p=0.007. Balance (p=0.014)	8/10
Oh *et al*. 2012[31]	n = 65 Age: ≥65	12 weeks. 2 groups: IG + CG Multi-component exercise programme: strength training, balance, agility, flexibility, muscular endurance.	- ABC scale. - SF-8	Reduces fear of falling (p=0.02), improved balance (5.84 ± 1.62) (p=0.003), flexibility (4.14 ± 0.73) (p<0.001) and muscle strength (7.42 ± 1.98) (p=0.004). Also improved quality of life (11%).	7/10
Zhuang *et al*., 2014[32]	n = 56 (36 women) Age: 60-80	Multi-component exercise programme + Tai chi. 12 weeks. 3 sessions/week. 60 min. 2 groups: IG + CG - Strength and balance exercise programme. - Tai chi (8-form T'ai chi ch'üan).	- Functional performance. (30s-CST) - Balance and falls. Timed Up-and-Go (TUG); - (FRT); Star Excursion Balance Test (SEBT) - Isokinetic strength of the knee and ankle extensors. Dynamometer. - Three-dimensional gait analysis. VICON system	After the intervention, significant improvements were found in all the variables (p<0.001; d=0.36), improving physical condition and reducing the risk of falls.	7/10
Cichocki *et al*., 2015[34]	n = 222 88% women. Age: 72-99	20 weeks. 1 session/week. 60 min. 2 groups: IG + CG. Multi-component exercise programme: strength training, walking, balance, dancing, stretching and yoga.	- Quality of life. EQ-5D. - Balance. Timed Up-and-Go (TUG); - Flexibility. Chair Sit and Reach (CSAR); Back Scratch Test (BS); Lower Back Scratch and Neck Reach Test. - Assessment of cognitive status. Mini-Mental State Examination (MMSE).	Improvements in HRQoL after intervention (p=0.001). No significant results were found in the flexibility and balance tests.	7/10
Otones *et al*., 2020[33]	n = 44 78.1% women. Age: ≥65 Pre-frail with chronic pain (SHARE). Community	Multi-component exercise programme + Education prog. 8 weeks (1 session/week). 60 min. 2 groups: IG + CG.	- Quality of life (EQ-5D). - VAS (Chronic Pain) - SHARE (frailty index) - Functional capacity (SPPB: balance, gait speed and leg strength. - ADLs (Barthel).	Significant improvements in: Quality of life (CI 95%:– 0.33-0.04) and Functional capacity (p<0.01)	6/10

1RM: 1 repetition maximum (test); 6MWT: 6 Min Walk Test; 30s-CST: Test 30s Chair Stand Test; ADLs: Activities of Daily Living: IADLs Instrumental Activities of Daily Life; CRQ: Chronic Respiratory Questionnaire; HRQoL: Health-related Quality of Life; EQ-5D: Euroqol Quality-Of-Life Scale questionnaire; ABC scale: Activities specific Balance Confidence; FRT: the Functional Reach Test; MMSE: Mini-Mental State Examination; PAEE: Physical Activity Energetic Expenditure; PASE: Physical Activity Scale for the Elderly; PPT: Physical Performance Test; SF-8: Abbreviated version of the SF-36 questionnaire; VICON system: motion capture system consisting of cameras, markers and motion sensors; SPPB: Short Physical Performance Battery; TUG: Timed Up and Go; WHOQOL-OLD: World Health Organization Quality of Life-Old.

Measurement of HRQoL: Nine studies specifically measured HRQoL[19,23–27,31,33,34] and positive results (p<0.05) were obtained in all of them after the intervention. The measuring tools used were the Euroqol Quality-Of-Life Scale (EQ-5D) questionnaire[19,33,34], the SF-36 questionnaire[23,25,27], the SF-8 questionnaire (abbreviated version of SF-36)[31]; the Chronic Respiratory Questionnaire (CRQ)[26]; and WHOQOL-OLD (World Health Organization Quality of Life-Old)[24], a test developed by the World Health Organization to specifically assess the quality of life of the elderly.

Effect of physical exercise on other variables:

Falls: Seven papers assessed the risk of falling in their studies[27–32,35]. The measuring tools used were: the Falls Efficacy Scale[30]; Romberg's test[30], the Modified falls efficacy scale (M-FES) questionnaire[27]; the ABC (Activities-specific Balance Confidence) scale[28,31]; and the Timed Up-and-Go (TUG) test, widely used to assess dynamic balance, which is closely related to the risk of falls and, therefore, a reliable indicator of frailty in the elderly[19,27,29,30,32,34,35]. All the studies found a reduction in the incidence of falls after the intervention.

Frailty: Two articles evaluated the effects of physical exercise on frailty[19,20], both showing a statistically significant reduction in frailty test scores (p<0.05).

Four papers analysed the effect of physical activity on disability[19,29,33,35], obtaining an improvement in basic activities of daily living (ADL), evaluated with the Barthel scale[19,33] and with the disability indicator FIM (Functional Independence Measure)[29]. The study by Tarazona-Santabalbina et al also evaluated Instrumental Activities of Daily Life (IADLs) using the Adelaide Activities Profile (AAP) and the Lawton and Brody scale, obtaining an improvement in disability (p<0.05).

Two studies analysed the effects of exercise on cognitive status using the Mini-Mental State Examination (MMSE)[19,34]; only the study by Tarazona *et al.* described improvement after exercise, with a 9% increase in MMSE (p=0.025); they also observed improvements in emotional status and social support, measured with the Geriatric Depression Scale (GDS) (p =0.043) and the Duke scale (p < 0.001), respectively.

Discussion

The objective of this review is to update our knowledge about the effect of physical activity on active ageing in order to define possible focuses for research in this area in the future. The results obtained show the benefit of physical activity on the quality of life, physical condition and maintenance of functional independence of older adults through selected experimental studies. Most of the studies included indicate that physical activity improves the different components of physical condition and HRQoL in older people.

We found that most of the 17 studies analysed were carried out in the community, applied a multi-component intervention and lasted between 8 weeks and 6 months. In general, despite the methodological differences between the different studies, the results of this review demonstrate a statistical association between physical activity and the improvement of physical condition and HRQoL.

The intervention programmes and tests used to assess HRQoL and physical condition were heterogeneous, although all the tests are validated. Some are generic instruments, which have different components or scales; others are more specific, aimed at aspects of interest (illness, frailty, elderly, etc.) or at certain components of physical condition (endurance, strength, flexibility, balance or coordination).

Among the questionnaires used to evaluate HRQoL, the SF36 stood out due to its ready availability in several languages, reliability, validity and sensitivity, together with its reduced version, SF8. Other questionnaires used were: the Euroqol Quality-Of-Life Scale (EQ-5D), the WHOQOL-OLD (World Health Organization Quality of Life-Old) questionnaire and the Chronic Respiratory Questionnaire (CRQ). To analyse functional ability and performance, the following were used: Short Physical Performance Battery (SPPB), the 30s Chair Stand Test (30s-CST), the Functional Reach Test (FRT), the Physical Performance Test (PPT), the Senior Fitness Test (SFT) and the Functional Independence Measure (FIM). All are validated tests widely used with the elderly population and easy to carry out. However, the diversity of scales and the absence of population reference values could hinder the comparability of the studies[15,17].

The type of intervention was different in the 17 papers analysed, although they all sought the same objective: to maintain or improve the physical condition and quality of life of the elderly. Most of the studies involved multi-component training programmes[19,20,25,26,30,31,33–35] or a combination of programmes of this type with a more specific intervention in water exercise[24,27] or Tai chi[32]. The latter consisted of multi-component training exercises combined with T'ai chi ch'üan exercises (8-form Tai chi: movements involving weight changes, body alignment and coordinated movements carried out in a slow, continuous, circular and fluid manner). Only five studies focused intervention on a single type of activity or sport[21–23,28,29].

Interventions with physical activity programmes appear to be effective in achieving improvements in HRQoL and show improvements in the physical condition and functional independence of older adults[13,14,17].

We believe that, despite the difficulty that their implementation may entail, varied activities with different components are more satisfactory for the elderly, provide greater benefits; and favour adherence to the programme, reducing the dropout rate. However, there is also the disadvantage of not knowing which components are the most decisive in any improvement when an overall assessment is made. Based on the results of the studies, including multi-component programmes with exercises centring on strength, gait, balance and flexibility brings benefits in the prevention of disability[15,19,29,34,35], favours functional independence[28,30,32], improves physical condition[19,20,24-27,30-32,34,35] and reduces the risk of falls[27–32,35].

In addition, improvements have been observed in the performance of activities of daily living[19,29,33,35], as have decreases in cognitive impairment[19,34], decreases in frailty[19,20] and improvements in HRQo[19,24–27,31,33,34].

The rest of the studies, in which specific exercises focussing on gait[21], strength[22], Pilates[23] or exercise in water[28,29] were carried out, also obtained significant improvements in terms of physical condition[21–23,28,29], functional independence[22,23,28,29] and quality of life[23].

All the exercise programmes involved exercises to improve balance and develop muscle strength because they enhance postural stability and, therefore, lead to a reduction in falls[27–32,35–37]. Equilibrium and walking speed have been determined as indicators of frailty in the elderly 38 and are directly related to the risk of falls in this population[39,40]. The studies analysed demonstrate the effectiveness of exercise programmes to improve the physical condition of the elderly and delay and prevent disability caused by ageing[19,29,34,35,41–44].

Regarding the limitations of the studies selected, there is variability in the number of participants, and the different types of interventions and measuring instruments. We believe that studies which obtain a standard reference value are necessary to facilitate the comparability of the measurements, as are studies which indicate the ideal exercise programmes for this population, those which provide the greatest benefits and those which favour continuity and permanence over time. Although most of the interventions identified described positive results in their evaluations, design limitations (small number of participants, small scopes, difficulty in masking participants or researchers) could limit their extrapolation.

In this review, the articles finally selected were those that best met the inclusion criteria; studies carried out in our setting were also included, which could favour the extrapolation of their results to our population. There is possibly a publication bias of studies with positive results, so there could be studies with negative results which have not been published. One aspect to highlight is that most of the studies were carried out in the community, which would facilitate their extrapolation; although this does mean future focuses of research in care homes and hospitals should be considered.

It is necessary to carry out studies to assess which types of programmes are most effective and applicable, with greater homogeneity in the data collection instruments, in order to facilitate the comparability of the measurements and their applicability to the elderly population, and to increase the degree of scientific evidence.

Conclusions

This systematic review shows that, despite the methodological differences in the studies, an active lifestyle with the performance of multi-component, group or community activities is beneficial for older adults and is associated with better HRQoL, physical condition and maintenance of functional independence, and a reduction in the risk of falls.

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Conflict of interest

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

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Campaña de aptitud física, deporte y salud

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

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

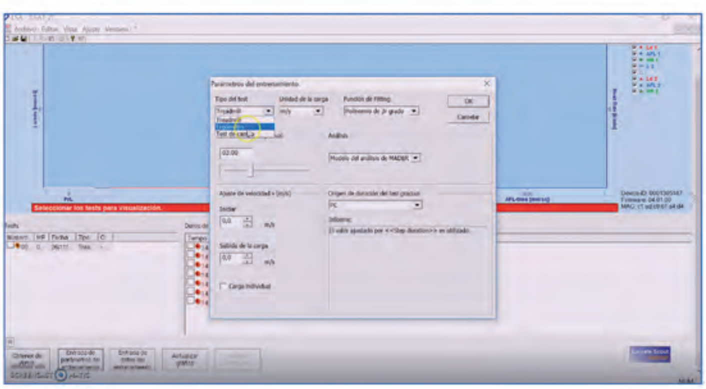
ANALIZADOR PORTÁTIL DE LACTATO
Lactate Scout 4

- Volumen de muestra: 0.2 μl.
- Resultados en 10 segundos
- Calibración automática
- Conexión PC vía Bluetooth (en presentaciones Start y Maletín)
- Software de análisis Lactate Scout Assistant (en presentaciones Start y Maletín)
- Memoria de hasta 500 resultados
- Pantalla e-paper para facilitar la visualización
- Diseño más pequeño, más ligero, más robusto
- Gran Conectividad, Conexión a monitores de ritmo cardíaco compatibles

1 Sacar la tira reactiva e introducirla en el Lactate Scout 4

2 Poner la muestra de sangre en el sensor de la tira reactiva

3 Se mostrará el resultado en 10 segundos



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