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COVID-19: a challenge for exercisers and, an opportunity for non-exercisers?

COVID-19: un desafío para los exercisers *y, ¿una oportunidad para los* non-exercisers*?*

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Coronavirus (COVID-19) is a pandemic that has infected more than 1,500,000 people (10.1% in Spain) and caused more than 89,900 deaths worldwide (16.9% in our country)[1]. The Spanish Government decreed a national state of alert from 14 March to 26 April 2020 with the possibility of an extension based on the actual conditions at that time. As a result, the majority of the population was forced to remain at home in order to stop the spread of the virus, stem the flow of infections and prevent the saturation of the healthcare system.

However, although lockdown is extremely necessary in order to reverse the current situation, it can also be harmful to health, specifically with regard to those in a vulnerable situation (older people or those with chronic pathologies). The Morris studies in the fifties were pioneers in reflecting the negative impact that the habits of a sedentary lifestyle have on health and, even today, cardiovascular disease is the leading cause of death in the world (31%). In this respect, there is strong evidence that relates physical inactivity with an increase not only in the occurrence and aggravation of chronic diseases but in the mortality rate[2]. Despite this, globally, 27.5% of the adult population and 80% of young people are insufficiently active, a situation that has been named "physical inactivity pandemic", with a mortality rate that has reached 6%[3]. Due to the exceptional state of isolation proposed as a result of COVID-19, Google® made a report based on location history data from mobile devices in which it shows a drop in the movement trends of the Spanish population in a range from 64 to 94%[4]. Looking at these statistics, it is obvious that the impact of the current lockdown period could lead to an even more sedentary lifestyle.

While some evidence is already available on the cell and molecular mechanisms by which the regular practice of physical exercise is beneficial, it is evident that muscle contraction is in itself a determining factor in molecular signalling. Thus, the skeletal muscle behaves as an endocrine organ generating molecules (myokines) capable of acting on a large number of organs and tissues while modulating their functions, directly intervening in the progression of certain pathologies. Moreover, the release of myokines is closely related to the amount of muscle mass involved.

It is more than likely that those subjects who were training regularly before lockdown will continue to maintain these habits. It is therefore reasonable to think that professional and leisure athletes, and even weekend warriors, will be able to adapt their exercise workouts to their home settings, following the routines guided by sports physicians, physical education instructors or else turning to virtual training platforms such as the social media. Moreover, subjects with previous training can count on a powerful ally: muscle memory. This concept was coined to describe the fact that the trained skeletal muscle takes less time to return to its original structure after being subject to a re-training workout following a period of physical deconditioning. It has thus been observed that the micronuclei formed in response to an exercise workout, keep their number despite the training cessation period, irrespective of the reduction in the muscle cross-sectional area. This factor is fundamental once a person starts to exercise again, given that it accelerates the re-adaptation process to the training tables. In this respect, it has been estimated that the muscle memory mechanism could remain latent even over decades. It therefore does not appear to be necessary to get worried about maintaining the same exercise levels during lockdown. However, those persons previously considered to be physically inactive (< 150 minutes of moderate physical activity or < 75 minutes of intense physical activity a week) are the ones who need to take exercise as a necessary instrument to counteract the periods of inactivity, particularly at this present time (Figure 1). The main arguments associated with a little physical activity are a lack of time and motivation. If we start from the premise that, in terms of exercise, "something is always better than nothing" and taking into account the fact that 36% of the Spanish population reports that it spends its leisure time in a way that is almost completely sedentary, we can assume that it is not due to lack of time (and even less so at present) but due to a lack of motivation, the most important obstacle for doing physical exercise. Although it has been

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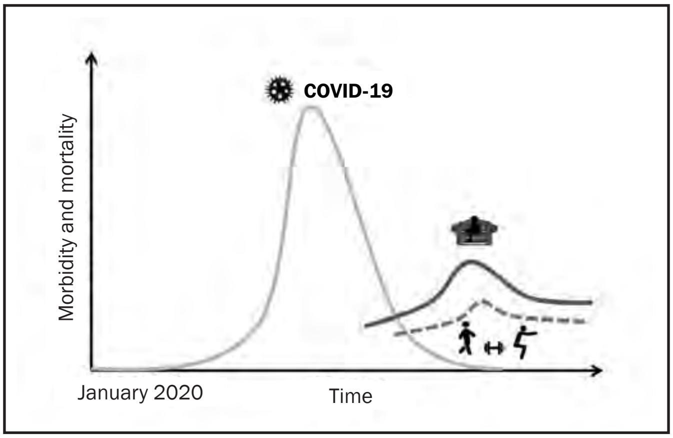
Figure 1. Estimate of the morbidity and mortality based on the practice of physical exercise during the lockdown period caused by COVID-19, for vulnerable people.



reported that the practice of vigorous physical exercise (60-75 minutes a day) is able to counteract the greater risk of death associated with long periods of a sedentary lifestyle, those persons unaccustomed to physical activity are not advised to start intensive workouts right from the outset. An alternative to the traditional training workouts could be to include frequent periods of physical exercise in order to transition from sedentary behaviour. This habit is able to produce a significant drop in the postprandial glucose levels, as well as in insulin and triglyceride levels. However, there has been no definition of the amount, duration, intensity or type of exercise to be made during these active periods. In fact, positive effects are likely to be obtained regardless of the exercise model used, provided that this involves a large muscle mass (from walking at a light pace to doing strengthening exercises with one's own body weight)[5].

According to a report by Eurostat, Spanish homes have an average size of 90 m^2 in urban areas and 115 m^2 in rural areas[6].

In principle, it may appear to be advantageous to have more space, as well as terraces or gardens. However, putting these advantages to one side, a spacious area to exercise is not strictly necessary. In this way, many of the leading healthcare institutions have put forward physical exercise workouts that are specifically directed at those with the least experience in this area and those vulnerable populations, not only those who are elderly but also those with chronic pathologies[7]. Although these initiatives are directed at getting the population to do physical exercise during this lockdown period, their real value goes beyond the present situation and could serve to create physical exercise guidelines that go beyond present requirements. Moreover, the inactive population, although to a lesser extent, does also have some advantages. On the one hand, an untrained person requires less stimulus or training load to achieve adaptations, and therefore improvements will be observed right from the outset. On the other hand, it is good to remember that "it's never too late" to obtain the benefits resulting from doing physical exercise, as has already been demonstrated in the elderly population.

Despite all the prejudices on the quality of life with regard to the period in which we are living, it could be a good time to look for positive things and to create long-lasting healthy habits. Therefore, people should be made aware of the advantages of doing frequent physical exercise and, although today it may appear to be a challenge or a simple hobby, it may have unimaginable benefits in the not-too-distant future.

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Original article

Reliability of heart rate recovery indexes after maximal incremental tests

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Summary

Introduction: The relationship between heart rate (HR) recovery (HRR) and cardiovascular diseases (CAD) is well stablished, being that slower HRR is associated with an increased risk of sudden death and overall death, and it has been demonstrated to be independent predictor for both healthy and cardiac diseases individuals. However, it is not clear about which indexes from fast and slow phase of HRR have greater reliability after maximal exercise. This study aimed to verified which of the HRR indexes (T30 and ΔHR60s for fast phase of recovery; ΔHR300s and HR off-kinetics for slow phase) have better reliability in adults after maximal exercise test.

Material and method: Twelve healthy and moderate physical active young men without heart diseases performed three maximal treadmill tests with an interval of at least 48 h. Treadmill test started with speed of 4 $km.h^{-1}$, with increase of 1 $km.h^{-1}$ every minute until exhaustion. Beat-to-beat HR was recorded during exercise and 5 min of seated recovery to verify relative and absolute reliability of the T30, ΔHR60s, ΔHR300 and HR off-kinetics.

Results: It was found very high reproducibility in T30 (ICC = 0.91; SEM = 17.19s; CV = 13.51%), ΔHR60s (ICC = 0.91; SEM = 2.40 bpm; CV = 9.08%), ΔHR300s (ICC = 0.90; SEM = 2.69 bpm; CV = 5.42%) and HR off-kinetics parameters (ICC = 0.91-0.94; SEM = 2.43-3.63; CV = 4.06-8.10%), without difference for the variables among the tests ($p > 0.05$).

Conclusion: The ΔHR60s presented better reliability (higher ICC and lower CV) when compared to the T30, being both for fast phase of recovery. For slow phase, ΔHR300s and HR off-kinetics presented equivalent reliability.

Key words:
Cardiovascular diseases. Post-exercise recovery. Autonomic nervous system.

Reproducibilidad de los índices de recuperación de la frecuencia cardiaca después de las pruebas de esfuerzo máximas

Resumen

Introducción: La relación entre la recuperación de la frecuencia cardíaca (RFC) y las enfermedades cardiovasculares está bien establecida, siendo que la RFC más lenta se asocia con un mayor riesgo de muerte súbita y muerte en general, y se ha demostrado que es un factor predictivo independiente tanto para las personas sanas como para las personas con enfermedades cardíacas. Sin embargo, no está claro qué índices de la fase rápida y lenta de la RFC tienen mayor confiabilidad después del ejercicio máximo. Este estudio tuvo como objetivo verificar cuál de los índices de RFC (T30, ΔFC60s, ΔFC300s y cinética de FC) tienen mayor confiabilidad en adultos después de las pruebas máximas de ejercicio.

Material y método: Doce hombres con actividad física saludable y moderada sin enfermedades del corazón realizaron tres pruebas máximas en cinta rodante con un intervalo de al menos 48 h. La prueba en cinta rodante comenzó con una velocidad de 4 $km.h^{-1}$, con un aumento de 1 $km.h^{-1}$ cada minuto hasta el agotamiento. La FC de latido a latido se registró durante el ejercicio y 5 minutos de recuperación sentada para verificar la confiabilidad absoluta y relativa del T30, ΔFC60s, ΔFC300s y cinética de FC.

Resultados: Se encontró una reproducibilidad muy alta en T30 (CCI = 0,91; SEM = 17,19 s; CV = 13,51%), ΔFC60s (CCI = 0,91; EEM = 2,40 lpm; CV = 9.08%), ΔHR300s (CCI = 0,90; EEM = 2.69 lpm; CV = 5.42%) y los parámetros de cinética de FC (CCI = 0,91-0,94; EEM = 2,43-3,63; CV = 4,06-8,10%).

Conclusión: Los ΔFC60s presentaron mejor confiabilidad (mayor ICC y menor CV) en comparación con el T30 para una rápida fase de recuperación. Para la fase lenta, ΔFC300s y la cinética de FC fueron equivalentes.

Palabras clave:
Enfermedades cardiovasculares. Recuperación post ejercicio. Sistema nervioso autónomo.

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Introduction

Heart rate (HR) recovery (HRR) is a non-invasive tool to evaluate fast and slow phase of cardiac autonomic control after exercise[1]. The autonomic imbalance[2-5] is associated with increased risk of cardiovascular disease (CAD), sudden death and all-cause mortality[2,4-7]. At onset of exercise occurs vagal withdrawal and sympathetic increase activity, enhancing HR. After exercise, occurs fast parasympathetic reactivation, followed by sympathetic activity withdrawal, making a decreased of HR[8-10]. Previous studies have proposed different indexes with the purpose to monitor the HRR in different populations, and training effect[8,11,12].

Slower HRR is associated with an increased risk of CAD[1,4,13] and it has been demonstrated to be independent predictor for both healthy and cardiac diseases individuals[2,4,5,6,12]. For evaluation of HRR after maximal exercise, the main indexes used are T30, the difference between HR registered at the end of exercise and after sixty seconds (ΔHR60s) and after three hundred seconds (ΔHR300s) and nonlinear regression on the first 300s of the recovery phase (HR off-kinetics). T30 and ΔHR60s are indexes that evaluate fast recovery phase, determined by vagal reactivation, while Δ300s and HR off-kinetics covers both fast and slow recovery phase, determined by vagal reactivation and sympathetic withdrawal[7,8].

Some studies have demonstrated divergent results about HRR reliability using different indexes. This inconsistence may be due the different experimental protocols, such as: type of effort (maximum or submaximal)[14,15], type of recovery (active, passive or mixed)[16-18], interval between each test[19,20] and level of physical activity (sedentary, physically active or athletes)[17,21-23]. In this manner, this study aimed to verified which fast and slow HRR indexes (T30 and ΔHR60s for fast phase of recovery; ΔHR300s and HR off-kinetics for slow phase) have stronger reliability in young adults after maximal incremental tests.

Material and method

Subjects

Twelve healthy and moderate physical active young men (age = 24.6 ± 5.2 yr) without heart diseases took part of this study. The procedures were approved by the local Human Research Ethics Committees and all participants were informed about the aim and study protocols and signed an informed consent form.

Experimental design

In first session, the participants were submitted to anthropometric, body composition and blood pressure assessment. Later, they performed three maximal treadmill incremental tests with an interval between each other for at least 48 h. Participants were instructed to avoid caffeine and alcohol intake and strenuous exercise in the 24 h before the tests.

Anthropometric and blood pressure measurements

Weight (kg) was evaluated in digital scale (Tanita, UM-080) and height (cm) was measured with a stadiometer and, posteriorly, body mass index (BMI) was calculated according to equation (kg/m^2). The body fat (%) was assessed by tetrapolar bioelectric impedance analysis device (Maltron, BF906).

Blood pressure (mmHg) was measured by automatic device (Omron, HEM-7113), with standard cuff for adults, being considered the mean between two consecutive measurements with maximum differs of 4 mmHg, with two minutes interval between each other.

Exercise testing

Maximal exercise test started with speed of 4 $km.h^{-1}$, with increase of 1 $km.h^{-1}$ every minute until exhaustion and fixed treadmill slope of 1% throughout the test. Rating of perceived exertion (RPE) was measured at final of each stage (last 10 seconds of each minute) from the incremental test using Borg scale 6-20. The test was considered maximal when the following variables were reached: 95% of HRmax predicted for age (220-age), rating of perceived exertion (RPE) ≥19 and voluntary exhaustion. Immediately after test, the subjects sat on a chair during 5 minutes of passive recovery and minimum movement. Beat-to-beat HR was recorded during exercise and recovery period by Polar V800 HR monitor to evaluate T30, ΔHR60s, ΔHR300s e HR kinetics.

HR data analysis

T30 was the negative reciprocal of the slope of the regression line between the natural logarithm of heart rate and elapsed time from the 10^{th} to 40^{th} second of exercise[24]. ΔHR60s was obtained through of numerical difference between HR immediately at the end of exercise and HR one minute after the end of test[2] and ΔHR300s after five minutes of end-test[25]. HR off-kinetics was adjusted by the following monoexponential function[26]:

$$HR = HRmin + A_{off} * \exp[-(time- \tau)/T]$$

Where HRmin is the asymptotic value of HR; A_{off} is the amplitude of the HR response; T is the time of the recovery onset; and τ is the time constant to reach 63% of the HR decline.

Statistical analysis

Data are present as mean and standard deviation (SD). Normality of distribution was checked with the Shapiro-Wilk test. Three tests were compared by repeated measures ANOVA for normally distributed data and Friedman test for non-normally distributed. Relative reliability was assessed with intraclass correlation coefficient (ICC) and absolute reliability with the standard error of measurement (SEM) and the coefficient of variation (CV). Significance level was set at $p < 0.05$.

Results

Participants characteristics are presents in Table 1 (mean ± SD) (Table 1).

The maximum speed, duration of the tests, HRmax (bpm), HRmax (%) and RPE in three treadmill incremental tests were not significant different ($p > 0.05$). Table 2 shows the data of each test (Table 2).

Table 3 shows data of T30, ΔHR60s, ΔHR300s and HR kinetics of each test and the reliability values. High reliability was found in T30 (ICC =

Table 1. Characteristics of the subjects (n=12).

Characteristics	Values
Age (years)	24.6 ± 5.2
Weight (kg)	75.7 ± 14.0
Height (cm)	174.2 ± 6.9
BMI (kg/m²)	25.0 ± 4.3
Body fat (%)	23.0 ± 8.7
SBP (mmHg)	121.0 ± 9.4
DBP (mmHg)	65.6 ± 7.8

Values in mean ± standard deviation. BMI: body mass index; SBP: systolic blood pressure; DBP: diastolic blood pressure.

Table 2. Maximal treadmill test data.

Variable	Test 1	Test 2	Test 3
Maximum speed (km.h⁻¹)	15.9 ± 1.7	15.9 ± 1.4	15.8 ± 1.5
Duration (s)	793.8 ± 86.3	787.6 ± 78.0	783.9 ± 82.6
HRmax (bpm)	192.5 ± 6.3	193.4 ± 7.9	191.6 ± 7.7
HRmax (%)	104.0 ± 3.7	104.5 ± 5.0	103.5 ± 3.9
RPE (a.u.)	19.3 ± 1.2	19.1 ± 1.2	19.2 ± 1.3

Values in mean ± standard deviation. Duration: incremental test duration; HRmax: maximum heart rate; RPE: rating of perceived exertion.

Table 3. Reliability of HRR indexes after maximal treadmill test.

	Test 1	Test 2	Test 3	ICC	SEM	CV (%)
T30 (s)	232.0 ± 56.6	214.1 ± 60.4	220.1 ± 73.9	0.91	17.19	13.51
ΔHR60s (bpm)	44.3 ± 8.9	43.6 ± 9.2	47.7 ± 12.2	0.91	2.40	9.08
ΔHR300s (bpm)	85.03 ± 9.81	85.30 ± 9.54	86.16 ± 11.79	0.90	2.69	5.42
HRmin (bpm)*	104.1 ± 9.2	104.2 ± 11.8	101.5 ± 12.3	0.91	2.43	4.06
Aoff (bpm)*	89.6 ± 15.5	91.0 ± 14.2	90.1 ± 12.2	0.92	3.39	6.44
τ (s)*	77.6 ± 13.4	79.2 ± 18.8	77.0 ± 21.3	0.94	3.63	8.10

Values in mean ± standard deviation. ICC: intraclass correlation coefficient; SEM: standard error of measurement; CV: coefficient of variation; T30: time constant of fast stage of HRR; ΔHR60s: difference between maximum and minimum heart rate one minute post exercise; ΔHR300s: difference between maximum and minimum heart rate five minutes post exercise; HRmin: minimum heart rate after five minutes of recovery; A_{off} : amplitude of heart rate; τ: time constant. *HR kinetics indexes.

0.91; SEM = 17.19 s; CV = 13.51%) and ΔHR60s (ICC = 0.91; SEM = 2.40 bpm; CV = 9.08%). Both variables evaluate fast recovery phase, where there is mainly vagal reactivation.

ΔHR300s (ICC = 0.90; SEM = 2.69 bpm; CV = 5.42%) and HR kinetics (ICC = 0.91-0.94; SEM = 2.43-3.63; CV = 4.06-8.10%) also presented high reliability. They evaluate both fast and slow recovery phase, with vagal reactivation and sympathetic withdrawal.

Discussion

This study aimed verify the reliability of HRR indexes after maximal treadmill tests in adults. The indexes evaluated were T30 and ΔFC60s for vagal reactivation (fast recovery phase) and ΔFC300s and HR kinetics for vagal reactivation and sympathetic withdrawal (fast and slow recovery phase together)[7,8].

ICC is a classical measure of relative reliability which permits estimation of the percentage of the observed score variance that is attributable to the true score variance[14,16,27], being the higher value, greater the relative reliability. SEM provides an index of the expected trial-to-trial noise in the data, and CV is a measure of the discrepancy and expresses error as a percentage of the mean[14,16,21,27], with the lower value considered greater absolute reliability.

Considering T30, previous studies have showed low-to-moderate reliability (ICC = 0.12-0.56 s; SEM = 52.0-149.5 s; CV = 50.0-75.3%)[14,15,21]. This index presents limitations, such as: complex mathematical equation susceptible to artefact or arrythmias and required register HR on a beat-to-beat[8]. Another limitation is related to time frame used. Initially, the studies evaluated the first thirty seconds, but in the 10 initial seconds of recovery, the HR present a plateau or higher values compared to exercise HR. Thus, currently it has been encouraged to analyze the HR from 10th to the 40th seconds[8,12,14], which it present higher reliability (ICC = 0.12 to 0.56 vs 0.62 to 0.77, respectively). Conversely to other studies, this study showed high reliability of the T30 (ICC = 0.91; SEM = 17.19 s; CV = 13.51%). Our hypothesis is related to methods used, since the majority studies used submaximal tests[15,19]. However, Dupuy *et al.*[14] observed low reliability with method similar to the present study (maximum exercise), but with short period of the test, demonstrating that the effort duration may influence reliability values.

The present study showed high relative and absolute reliability of ΔHR60s (ICC = 0.91; SEM = 2.40 bpm and CV = 9.08%). Others studies have presented inconsistent reliability of ΔHR60s after submaximal exercise (ICC = 0.15-0.99; SEM = 1.6-11.4 bpm; CV = 0.9-25.7%)[14-17,19,20,22], but moderate to high reliability after maximum exercise tests (ICC = 0.58-0.92; SEM = 3.0-10.2 bpm; CV = 10.8-23.3%)[14,15,17,18,21], suggesting that ΔHR60s reliability may be exercise intensity dependent. Cole *et al.*[2] described that HRR, in active recovery, lower than 13 bpm in first minute after exercise is a powerful predictor of overall mortality. Later, Jouven *et al.*[4] showed in passive recovery that ΔHR60s less than 25 bpm is a predictor of sudden death. All subjects of the present study presented ΔHR60s > 25 bpm, indicating a good cardiovascular health.

As well as ΔHR60s, ΔHR300s also presented better reliability in maximal exercise tests in comparison to submaximal exercise. Several studies have found moderate to high relative (ICC = 0.71-0.93) and absolute (SEM = 3.4-5.6 bpm; CV = 7.0-8.6%) reliability after maximal exercise[16,17,20], while there were inconsistent results after submaximal exercise (ICC = 0.37-0.82; CV = 6.90-10.1%)[15,16,18]. Among men with diabetes, ΔHR300s is independently predictor of cardiovascular and all-cause death, with cut-off value <55 bpm[24].

HR kinetics also seems to present an association with effort intensity. Submaximal test showed low to moderate reliability (τ ICC = 0.36-0.64; SEM = 11.0-35.7 s; CV = 29.8-32.1%)[14,15,16,19,21] while, maximal treadmill tests presented moderate to high reliability (τ ICC = 0.71-0.84; CV = 11.5-13.3%)[14,16,20]. However, Al Haddad *et al.*[21] evaluated HR kinetics in cycle ergometer and obtained low reliability (τ CV = 24.3%), which it may suggest that this index can be influenced by the type of exercise.

In our study, despite the subjects were health and moderate physical active, they had different body mass index (eutrophic or overweight). Notwithstanding, Rezende *et al*.[28] evaluated young adults with normal weight and overweight and they did not find differences in vagal reactivation at short-term after a maximal incremental exercise test. In addition, the level of physical activity and interval between each test do not appear to be a determining factor in the variation of reliability. Previous studies[15,17] have showed large variation between the test periods (1-21 days) without any tendency to improve or worst reliability.

The main limitations of the study were small sample size and not breathing pattern recovery control. However, other studies have observed reliability of HR parameters with similar sample size and without breathing frequency control[19,21]. Additionally, this study was limited to healthy subjects, thus these results cannot be extrapolated to other populations.

Conclusion

All indexes of HRR showed high reliability after three maximal treadmill tests in adult men. However, for clinical practice, ΔHR60s is more recommended for evaluation of the fast recovery phase, because it presents higher relative and absolute reliability when compared to the T30. In addition, ΔHR60s has established prognostic values in previous studies. ΔHR300s and HR kinetics had similar reliability, and both can be used for clinical evaluation of both fast and slow recovery phase after maximal exercise.

Conflict of interest

The authors do not declare a conflict of interest.

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Original article

Strength training and blood pressure in normotensive women: the effects of the conjugate method

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Summary

Objective: Analyze the effect of conjugated strength training method for lower limbs exercises on arterial blood pressure of normotensive women.
Material and methods: Experimental study attending 10 normotensive women (30.2±5.2 years old; 68.4±5.5 kg, 1.65±0.04 m, BMI 25.04±2.63, systolic blood pressure at rest: 121±5.2 mmHg; dyastolic blood pressure at rest: 74.8±6.5 mmHg). After anthropometric evaluation, 10 repetition maximum tests, volunteers were submitted to training, composed by 3 conjugated sets, respectively at Leg Press 45º, Knee flexion machine, knee extension machine, with load of 70% of 10 repetition maximum. The speed of concentric and excentric phases was of 2" in each exercise, and rest interval of 3' between sets'. Arterial blood pressure admeasurement were held through the auscultatory method at distinct moments: after 10' resting; immediately post-exercise; and every 20' post-exercise for 60'.
Results: Changes were observed for systolic blood pressure with increase between resting and post-exercise and reduction between moments 20', 40' and 60' (F= 66.654; p= 0.0001). There were changes also for diastolic blood pressure between resting and post-exercise moment (F= 15.258; p= 0.0001), however without changes when comparing moments 20', 40' and 60' and post-exercise.
Conclusion: The conjugate method was able to generate post-exercise hypotension only for systolic blood pressure.

Key words:
Physical exercise. Blood pressure. Post-exercise hypotension and strength training.

Entrenamiento de fuerza y presión arterial en mujeres normotensas: efectos del método conjugado

Resumen

Objetivo: Analizar el efecto del método conjugado de entrenamiento de fuerza en ejercicios para miembros inferiores sobre la presión arterial de mujeres normotensas.
Material y método: Se realizó un estudio experimental en el cual participaron 10 mujeres normotensas (30,2 ± 5,2 años, 68,4 ± 5,5 kg, 1,65 ± 0,04 m, IMC 25,04 ± 2,63, presión arterial sistólica en reposo: 121 ± 5,2 mmHg, presión arterial diastólica en reposo: 74,8 ± 6,5 mmHg). Después de la valoración antropométrica y los test de 10 repeticiones máximas, las voluntarias fueron sometidas al entrenamiento que consistió en 3 series conjugadas, respectivamente, entre los ejercicios de máquina Leg Press 45º, Leg Extension y Leg Curl, con sobrecarga de 70% en 10 repeticiones máximas. La velocidad de ejecución de las fases concéntricas y excéntricas fue de 2" en cada ejercicio, y los intervalos entre las series fueron de 3'. Las mediciones de la presión arterial se realizaron por medio del método auscultatório en distintos momentos: después de 10' en reposo; inmediatamente después del ejercicio; y cada 20' después del ejercicio durante 60'.
Resultados: Se observaron cambios en la presión arterial sistólica con elevación entre los momentos de reposo y post-ejercicio y reducción entre los momentos 20', 40' y 60' (F= 66,654; p= 0,0001). Se observaron cambios en la presión arterial diastólica entre el momento de reposo y el momento post-ejercicio (F= 15,258, p= 0,0001), pero sin alteración de la variable en la comparación entre los momentos 20', 40' y 60' y el momento post-ejercicio.
Conclusión: El método conjugado fue capaz de generar la hipotensión post-ejercicio sólo para la presión arterial sistólica.

Palabras clave:
Ejercicio físico. Presión arterial. Hipotensión post-ejercicio. Entrenamiento de fuerza.

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Introduction

Hypertension (HT) is a multifactorial clinical condition characterised by persistently high arterial blood pressure (BP). It is often associated with functional and/or structural damage to the target organs (heart, brain, kidneys and blood vessels), with the consequent increase in the risk of fatal and non-fatal cardiovascular events[1].

HT is a highly prevalent disease, considered a global public health problem due to the difficulty involved in controlling it. Some cases are asymptomatic, meaning that it is often neither diagnosed nor treated[2].

Reducing BP can prevent cardiovascular diseases, thereby improving the quality of life of the population[3]. Regular exercise is recommended to prevent and treat these and the risk factors for them, as well as other chronic diseases[4].

One common type of exercise is strength training (ST), where adaptation of the methodological variables prescribed, such as the order of the exercises, the interval between sets and exercises, the number of sets and repetitions, the overload and the training method, can trigger different physiological responses which can affect BP behaviour after a training session[5].

One of the numerous methods available is the conjugate method, which consists of performing more than one exercise for the same muscle group or different muscles groups in sequence and without a recovery interval in between during a set in order to increase the time during which the target muscles are under tension[6].

A single ST session can reduce BP for a number of hours[7]. This effect is known as post-exercise hypotension (PEH). The blood pressure levels during recovery are lower than those obtained at rest before starting training[8] or those registered on days without any physical exercise[9].

There is evidence to suggest that long-term BP reductions resulting from exercise programmes are due to the sum of the acute hypotensive effects of training sessions[10]. However, doubts remain about the methods used in ST regarding the occurrence and duration of the response, and the physiological mechanisms associated with PEH[11].

Of the different types of ST available, the evidence focusing on the hypotensive responses observed is limited when it comes to the conjugate methods, these normally being used to enhance strength or muscle hypertrophy.

In view of the paucity of data on the PEH induced by the conjugate method, research into the hypotensive effect of ST involving the method in question is more than warranted. The present study, therefore, aims to analyse the effect of the conjugate ST method for lower limbs on the BP of normotensive women.

Materials and method

Sample

Ten female volunteers (30.2 ± 5.2 years old) who met the following inclusion criteria: normotensive without the use of beta-blockers, angiotensin converting enzyme (ACE) inhibitors, diuretics, corticosteroids or Ca^2 + channel blockers, who had done ST sessions lasting over 60 minutes at least five days a week for over 6 months or with a suitable Physical Activity Questionnaire Readiness (PAR-Q)[12] result; and the following exclusion criteria: sufferers from degenerative or metabolic diseases, those with musculoskeletal injuries preventing them from performing the exercises, those with cardiovascular dysfunctions and users of ergogenic substances.

The *Free and Informed Consent* document (TCLE) for participation in research involving human beings was signed, in accordance with Resolution 466/2012 of the National Health Council (Brazil). The project for this study was submitted to the Research Ethics Committee of the Naval Hospital Marcilio Dias / Rio de Janeiro / Brazil and was approved under protocol number 1581498/2016.

Experimental development

Each volunteer came three times with a minimum interval of 48 hours between each visit. In the first session, the participants were informed about the data collection procedures and the intervention, answered the PAR-Q, were measured anthropometrically and did the 10RM tests. In the second session, they did the 10RM retests. In the third session, they did the ST and their haemodynamic responses were compared before and after it.

Height was measured using a Sanny® ES2020 stadiometer (Brazil) with a maximum measurement of 2.1 m and 0,001 m precision. Body mass (BM) was registered with 110CH Welmy® mechanical scales (Brazil) with a 150 kg limit and 100 g precision. The body mass index (BMI) was calculated using the ratio between BM and the square of height. The anthropometric measurements were taken following the recommendations of the International Standards for Anthropometric Assessment (ISAK)[13].

10RM tests were chosen to prescribe the ST intensity[14]. These were conducted on the same day on a Technogym® 45º Leg Press (Italy) and Life Fitness® Leg Extension and Leg Curl equipment (USA).

The warm-up consisted of 15 repetitions with 50% overload, estimated according to the training weight. Three minutes later, the first of the three attempts at each movement was carried out. The initial overload was estimated according to the overload used in the volunteers' training sessions.

The tests stopped when voluntary concentric failure occurred at 10RM. The movement execution speed was 2 seconds for each phase (concentric / eccentric) without any interval allowed in between these.

If the overload for 10RM was not reached after 3 attempts, the test was cancelled and performed on a non-consecutive day. The intervals between attempts for each exercise were set at 5 minutes to recover. After 3 attempts at an exercise at 10RM, 10 minute recovery intervals were set before moving on to the test for the next exercise in order to minimise premature fatigue.

Following the same protocols, the volunteers were subjected to strength retests for the same exercises in order to verify the reproducibility of the overloads obtained[15] with a minimum interval of 48 hours.

The greatest overload reached in the two tests with a difference of less than 5% between them was taken as 10RM. If the difference exceeded that percentage, new tests and retests were scheduled.

Participants were asked not to exercise or consume stimulants in the 24 hours preceding the training session and data collection. The tests and retests were held at times similar to those at which the volunteers usually trained.

In the ST session, the participants warmed up with 15 repetitions on the 45º Leg Press with an overload of 50% 10RM. 3 sets were completed in the three minutes following warm-up, consisting of the 45º Leg Press, Leg Curl and Leg Extension with an overload of 70% 10RM and without recovery intervals between them, avoiding the Valsalva manoeuvre. The movement execution speed was the same as in the tests and retests. The intervals between each set lasted 3 minutes. In the third set, the cuff of a sphygmomanometer was fitted onto the volunteer's left arms to do the exercise on the equipment.

BP was recorded using a digital Microlife® 3BTO BP-A sphygmomanometer (Switzerland), approved by both the British Hypertension Society (BHS) and the American Heart Association (AHA).

BP was measured at different times: at rest before the ST (in an empty room after being in supine position for 10 minutes); post-exercise (immediately after the third set of ST on the Leg Extension equipment itself with feet uncrossed and hands supine); and at rest after the exercise (20, 40 and 60 minutes after the training session in the same place and in the same positions in which the BP measurements were taken at rest before the exercise).

Statistical analysis

The descriptive statistics focus on the measures of central tendency and dispersion, and the Shapiro-Wilk test. The results obtained were subjected to a One-way ANOVA, followed by Tukey's post-hoc test. The data were processed using the Statistical Package for Social Sciences (SPSS 18.0, Chicago, USA). The level of significance was set at p≤0.05.

Results

Table 1 shows the volunteers' anthropometric characteristics and the results of the Shapiro-Wilk test for the variables.

Figure 1 shows the participants' systolic blood pressure (SBP) and diastolic blood pressure (DBP) at different times: at rest before the ST, immediately after the ST session (post-exercise) and over the next 60 minutes (20', 40' and 60' after the session).

Changes were observed in SBP (F= 66.654, p= 0.0001), which rose between at rest before exercise and immediately after exercise, and then dropped 20', 40' and 60' afterwards compared to both.

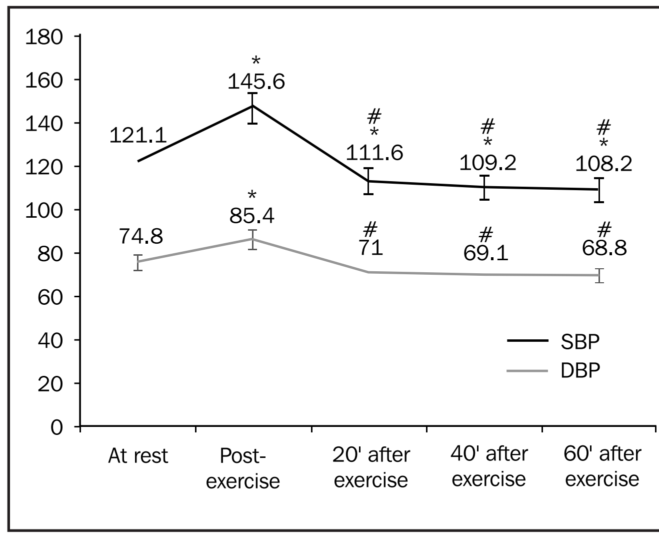
DBP changed (F = 15.258, p = 0.0001) between at rest before exercise and immediately after exercise, but no significant drop in the variable was noted on comparing 20', 40'and 60' post exercise with at rest beforehand.

Table 1. Anthropometric characteristics.

n = 10	Age (years)	TBM (kg)	Height (m)	BMI (kg/m²)
Mean	30.2	68.4	1.65	25.04
sd	5.2	5.5	0.04	2.63
Minimum	22	61.7	1.60	22.12
Maximum	38	76.3	1.74	28.98
SW (p-value)	0.75	0.26	0.34	0.10

TBM: total body mass; BMI: body mass index; sd: standard deviation; SW (p-value): Shapiro-Wilk normality test.

Figure 1. Analysis of SBP and DBP at rest and after exercise.



SBP: systolic blood pressure; DBP: diastolic blood pressure; * significant difference in relation to rest (p <0.05): # significant difference in relation to post-exercise (p <0.05).

Discussion

The present study aimed to analyse the effect of the conjugate ST method for lower limbs on the BP of normotensive women. ST stimulates the production of substances which regulate the body, including nitric oxide, which is secreted in the endothelium and is responsible for vasodilation, improving blood circulation and the metabolic functions needed to recover from exercise[16].

The increased vasodilation after training leads to a drop in BP, acting for up to 24 hours in hypertense individuals. This means that long-term exposure to PEH can reduce BP at rest by diminishing peripheral vascular resistance, that is to say, continuous dilation of the blood vessels, thereby facilitating blood circulation[8].

In addition to nitric oxide, other substances with a hypotensive effect are also released through exercise, such as prostaglandins, adenosine, potassium, lactate, bradykinin and vasopressin[17].

This research saw an increase in both SBP and DBP immediately after exercise compared to at rest beforehand. This can be explained by the variables which contribute to increasing BP and manifest themselves during high-intensity exercise, such as the activation of chemoreceptors as a result of peripheral fatigue[18].

However, the results showed a drop in SBP as of 20 minutes post-exercise which lasted until 60 minutes later. The hypotensive effect for DBP was not reached in the 60 minutes after exercise. Kelley and Kelley[19], however, saw drops of approximately 3 mmHg in the group participating in their ST programme. These reductions were equivalent to reductions of 2% and 4% for SBP and DBP, respectively. Although they may appear modest, from a clinical standpoint such modifications in hypertensive individuals are sufficient to reduce the risk of heart disease by 5-9%, the risk of stroke by 8 to 14% and the risk of death by 4%.

Kenney and Seals[20] reported that BP responses may be differ between normotensive and hypertensive individuals, since PEH may be associated with the health status of the individual. They showed that blood pressure fell more in hypertensive patients, in whom the drop in SBP and DBP after exercise varied from 18 mmHg to 20 mmHg and from 7 mmHg to 9 mmHg, respectively. In normotensive individuals, the reduction of the levels of the variables was less relevant (SBP: 8 mmHg to 10 mmHg; DBP: 3 mmHg a 5 mmHg), similar to the results obtained in this study.

In line with the findings of this research, O'Connor *et al*.[21], who analysed the blood pressure responses of 14 female volunteers between 30 minutes and 2 hours after an ST session consisting of 3 sets at varying intensities on leg extension, leg curl, pull down, chest press, shoulder press and abdominal curl equipment, observed higher SBP values, but no reduction in DBP.

The experiment conducted by Granados and Herrera[22] analysed the hypotensive effect of completing two 30-minute aerobic exercise sessions on a treadmill (one at an intensity of 50% HRreserve and the other at 70% HRreserve) on 10 men. PEH in SBP for 50% HRreserve was reached and maintained for the first 30 minutes, while PEH was observed as of 10 minutes until 60 minutes for 70% HRreserve. No significant difference, however, was observed for DBP.

According to Brum *et al*.[23] PEH in normotensive subjects after ST is due to the drop in cardiac output as a result of the decrease in systolic volume, the drop not being compensated for by increased peripheral vascular resistance. This mechanism would seem to be the same for both low- and high-intensity exercise, but when a longer period after high-intensity exercise is considered, peripheral vascular resistance at the start of recovery partially compensates for the drop in cardiac output, preventing reduction in DBP, but not in SBP.

Meanwhile, investigating the blood pressure responses of 6 physical education students after ST consisting of 3 sets at 70% 10RM with free weights, Hill *et al*.[24] saw a significant drop in DBP after exertion over 60 minutes without noting any change in SBP.

The results appear contradictory, maybe because there is not a single benchmark for the way in which ST is prescribed. According to Lizardo and Simões[25], there is still not enough information on intensity, the muscle groups involved, body segments and the magnitude and duration of PEH, indicating the need to define the characteristics of exercise, the method used and under what circumstances the phenomenon may occur, thereby justifying future studies.

In conclusion, the ST session using the conjugate method as prescribed for this study led to a drop in SBP in the period monitored following exercise. This was not true for DBP.

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Conflict of Interests

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

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Original article

Lower extremity injuries and key performance indicators in professional basketball players

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Summary

In basketball, the most injured part of the body is the anatomical region that comprises the lower extremities. The aim of this study was to analyse the relationships among the occurrence of lower extremity injuries and Key Performance Indicators (KPIs) of professional basketball players. Statistical variables of 554 professional basketball players (age: 26.97±4.86 years, height: 199.23±8.80 cm, minutes per season: 441.18 ± 301.41) in ACB competition were analysed for two seasons (2012-13 and 2013-14). In addition, injury reports were registered and injuries were categorized taking into account OSICS-10 classification. The players who played the most minutes during the season were more likely to suffer ankle (P<0.001) and knee (P<0.05) injuries. The players injured in the ankle had better means, per minute played, in points, field goals made, free throws made and attempted, assists, fouls received and ranking (P<0.05). The players injured in the knee obtained better average in most variables related to a positive performance: points, 2 points made and attempted, field goals made and attempted, free throws made and attempted, offensive rebounds, defensive rebounds, total rebounds, blocks made, dunks, received fouls, +/- statistic and ranking (P<0.05). The players injured in the leg had better means per minute in 3 points made and attempted, and 2 points attempted (P<0.05). Significant relationships were also found between injuries in the thigh and performance (better means in assists and steals, P<0.05) and the foot injuries (defensive and total rebounds, dunks and fouls, P<0.05). Higher performance in basketball involves a higher risk of injury in the lower extremities and this information could be useful to design injury prevention strategies.

Key words:
Basketball. Injuries. KPI. Performance.

Lesiones de miembro inferior e indicadores clave de rendimiento en jugadores profesionales de baloncesto

Resumen

En el baloncesto, la región anatómica más lesionada es el miembro inferior. El objetivo de este estudio fue analizar la relación entre la ocurrencia de lesiones en el miembro inferior y los factores de rendimiento clave (*Key Performance Indicators,* KPIs) en jugadores profesionales de baloncesto. Se ha analizado la información estadística de 554 jugadores de baloncesto profesional (edad: 26,97±4,86 años, estatura: 199,23±8,80 cm, minutos por temporada: 441,18±301,41) en la liga regular ACB durante dos temporadas (2012-13 y 2013-14). Además, se han recogido los partes médicos de cada jornada y categorizado las lesiones según el sistema OSICS 10. Los jugadores que jugaron una mayor cantidad de minutos durante la temporada fueron más propensos a sufrir lesiones de tobillo (P<0,001) y rodilla (P<0,05). Los jugadores lesionados en el tobillo tuvieron mejores promedios, por minuto jugado, en puntos, tiros de campo intentados, tiros libres anotados e intentados, asistencias, faltas recibidas y valoración (P <0,05). Los jugadores lesionados en la rodilla obtuvieron un mejor promedio en la mayoría de las variables relacionadas con un rendimiento positivo: puntos, tiros de 2 anotados e intentados, tiros de campo anotados e intentados, tiros libres anotados e intentados, rebotes ofensivos, rebotes defensivos, rebotes totales, tapones realizados, mates, faltas recibidas, estadística +/- y valoración (P <0,05). Los jugadores lesionados en la pierna tuvieron mejores promedios por minuto en triples convertidos e intentados, y tiros de 2 intentados (P <0,05). También se encontraron relaciones significativas entre las lesiones en el muslo y el rendimiento (mejor promedio de asistencias y robos, P <0,05) y las lesiones del pie (rebotes defensivos y totales, mates y faltas, P <0,05). Un mayor rendimiento en el baloncesto implica un mayor riesgo a lesionarse en el miembro inferior y esta información podría ser útil para diseñar estrategias de prevención de lesiones.

Palabras clave:
Baloncesto. Lesiones. KPI. Rendimiento.

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Introduction

In basketball, the most injured part of the body is the anatomical region that comprises the lower extremities[1]. Several studies identify the joints as the most damaged in sports injuries, with the knee and the ankle being the most affected in basketball[2]. Injuries can produce a lower performance, the absence of competition and adverse psychological effects among athletes[3]. In addition, some studies have reported persistent symptoms for months or even years, among patients with injuries[4].

Ligamentous distension of the ankle is the most common injury in sports population[1, 4-6]. As for professional athletes, ankle injuries were recorded in 14.9% of the NBA games played between 1988 and 2005[6]. Ankle sprains occur much more frequently during matches than during training[7-9], up to 23 times more often in basketball[10]. In general, the greater intensity in the activity during the matches is a factor that contributes to this difference in different sports[1].

Knee injuries are among the most common as well[11]. The nature of basketball, with continuous jumps, sprints, accelerations, decelerations and crossovers, makes the knee suffer even more injuries than the ankle, according to previous research in NBA[12]. Some studies even reported a damaged knee cartilage in asymptomatic professional basketball players[13] and college players[14]. Moreover, the recovery period is the longest among NBA players (9.5 games and 20.6 days in average)[5,16]. Anterior Cruciate Ligament (ACL) injuries are among the most reported and the worst in terms of performance decrease in NBA[17,18].

OSICS classification 10[19] associates the code "Q" with the anatomical region between the joints of the ankle and the knee. In this anatomical region, the typical injuries are: stress osseous lesions, cramps, muscle inflammation and injuries of the soft tissues. Bone stress fractures that occur under the knee often affect the tibia or the distal fibula[11]. Some studies have reported a 7,6% of incidence of leg injuries in this area in NBA[12,15] and 4% in shorter competitions (Olympic Games)[20].

Some common foot injuries in basketball are: fractures of the navicular bone and the base of the fifth metatarsal, in addition to tears of the short extensor muscle of the fingers in their insertion with the calcaneus[11]. Foot injuries do not usually exceed 8% of total injuries and are generally less common than those of ankle and knee in both occurrence[12,15] and recovery[16]. The thigh is probably one of the anatomical areas most prone to muscle contusions[21], but occurrence (5%) tends to be lower than in the other anatomical regions[12,15,16], analysed according to OSICS 10.

Epidemiology of basketball injuries have been widely studied, according to injuries per hour of exposition in both practices and games[1,10,16,22], different competitive levels[6,10,23], anatomical region or type of injury (muscular, concussion, ligamentous distension, etc.)[1,15,16], biomechanical reason and anthropometry[10,12,15,23,24].

However, not many researches have studied the relationship between the occurrence of injuries and the performance of players in games. The studies that exist have been conducted mostly in the United States (NBA) and have studied differences in performance after suffering long-term injuries or that have required surgery[17,18]. Studying the relationships between Key Performance Indicators (KPIs) and occurrence of injuries can offer information of interest to coaches and physical trainers to promote a specific preventive work with the profiles of players most susceptible to injury. In addition, this information could help to make decisions about the evolution of the regulation in this sport, with the intention of reducing the occurrence of injuries.

Therefore, the objective of the study is to analyse the occurrence of lower extremity injuries and the relationship with KPIs in basketball players of the ACB professional competition.

Material and method

Design

To analyse the injuries of basketball players in the ACB league, a transversal, descriptive and retrospective methodology was used to study the injuries and the performance of the players, based on the information provided by the official website of the ACB league[25] in each of the injury parts prior to each regular league day of the 2012-13 and 2013-14 seasons.

Participants

The sample was the total number of ACB players during the 2012-13 and 2013-14 seasons. It was established as a requirement to be included in the study: i) to have played at least one match of the ACB league and ii) not to have played on another team of the same competition during the season. They fulfilled both requirements and therefore a sample of 554 players from the ACB league during the 2012-13 and 2013-14 seasons is included in this study.

Procedure

We reviewed the information of "News and Medical Party" on the official website of the ACB Basketball League[25], corresponding to the Regular Season of 2012-13 and 2013-14, adding a total of 68 registered matches. All the injury parts of all the disputed days were obtained. From this information, it was identified which players of the competition had suffered each type of injury, registering the anatomical place of the same. The OSICS classification was used for the categorization of injuries[26].

Subsequently, the total individual statistics of each player were obtained for each of the two seasons[25]. The statistics collected the performance of the players for each variable in absolute values (total of the season) and per game played. As the risk of injury increases with minutes of exposure in matches[7], from the original data the individual statistics per player minute were calculated. In this way, the effect of time on the existing correlation between actions and game time was eliminated (the longer the game, the more actions performed).

Statistical analysis

For the analysis of the qualitative variables, absolute frequencies and percentages were used. To analyse the relationship between qualitative variables, contingency tables were used with the Pearson χ^2 statistic.

For the quantitative variables, the normality of the variables was checked with the K-S test for a sample. The data are shown as mean ± standard deviation. To determine if there are significant differences between the players who suffered a type of injury during the season and those who did not, in the different performance variables during the matches, a contrast of means was made using the t test in the case of variables with normal distribution and the Mann-Whitney U statistic for those nonparametric variables. The level of significance was established at P <0.05 for all cases.

The statistical program PASW Statistics 18 was used to carry out the statistical analysis.

Results

Table 1 shows the statistical performance variables that show significant differences between players injured and not injured in the ankle.

Statistically significant differences have been found, relative to the minutes of exposure in the games (total minutes played), between the set of players that presented an ankle injury and the group that did not (P = 0.000). The group of injured players in the ankle played 156 minutes more than average during the regular season.

Significant differences have also been found regarding the points; the field goals converted; the free throws attempted and converted; the assists; the faults received and the ranking (all of them, per minute of exposure). The group of players with ankle injury performed more actions of that type (P <0.05).

No significant differences were found in the case of attempted and converted three point shots; the shots of two points attempted and converted; field shots attempted; the offensive, defensive and total rebounds; the steals; the losses; the blocks made and against; the faults committed; dunks and +/- statistic (all of them, per minute of exposure).

In the case of the two-point shots converted, a trend towards significance was found (P = 0.05), with injured ankle players having the highest average in this variable.

Table 2 presents the statistical performance variables that present significant differences between players injured and not injured in the knee.

Statistically significant differences have been found, relative to the minutes of exposure in the matches (total minutes played), between the set of players who presented a knee injury and the group that did not (P = 0.033). The group of injured players in the knee played 97.42 more minutes on average during the regular season.

Significant differences have also been found regarding the points; the shots of two points attempted and converted; the field goals converted; the free throws attempted and converted; the offensive, defensive and total rebounds; the blocks made, the faults received; dunks, +/- statistic and ranking (all of them, per minute of exposure). The group of players with knee injury carried out more actions of that type (P <0.05).

No significant differences were found in the case of attempted and converted three point shots; field shots attempted; the steals; the assistance; the losses; the plugs to against and the faults committed (all of them, per minute of exposure).

Regarding leg injuries (between the ankle and knee), the relevant statistical performance variables are presented to compare the differences between injured and uninjured players in the body area between the ankle and knee joints (Table 3).

No statistically significant differences were found, related to the minutes of exposure in the matches (total minutes played), between the set of players who presented a leg injury and the group that did not (P = 0.590). As with ankle and knee injuries, the group of injured players in the leg played more minutes on average during the regular season (specifically 33.21 minutes more). But unlike in ankle and knee injuries, this fact has not been statistically significant.

However, significant differences have been found with respect to three-point shots (attempted and made), and two-point shots attempted (all of them, per minute of exposure). The group of players with a leg injury made and scored more three-point shots, but attempted fewer two-point shots (P <0.05).

Table 1. Significant KPIs in ankle injury occurrence.

KPIs (per minute)	Ankle injury	N	Mean	Standard Deviation	*P*
Total minutes	No	477	419.48	303.10	.000*
	Yes	77	575.64	253.76	
Total points	No	473	.360	.243	.002*
	Yes	77	.396	.094	
Field goals made	No	473	.128	.074	.005*
	Yes	77	.143	.039	
Free throws made	No	473	.069	.133	.000*
	Yes	77	.073	.028	
Free throws attempted	No	473	.092	.139	.007*
	Yes	77	.093	.034	
Assists	No	473	.063	.059	.009*
	Yes	77	.070	.042	
Fouls received	No	473	.098	.080	.006*
	Yes	77	.107	.033	
Ranking	No	473	.323	.401	.008*
	Yes	77	.390	.151	

KPIs: Key Performance Indicators.

Table 2. Significant KPIs in knee injury occurrence.

KPIs (per minute)	Knee Injury	N	Mean	Standard Deviation	*P*
Total minutes	No	502	432.04	303.26	.033*
	Yes	52	529.46	269.97	
Points	No	498	.359	.237	.000*
	Yes	52	.417	.112	
2 points made	No	498	.093	.072	.002*
	Yes	52	.117	.063	
2 points attempted	No	498	.192	.110	.019*
	Yes	52	.216	.083	
Field goals made	No	498	.128	.072	.000*
	Yes	52	.153	.051	
Free throws made	No	498	.069	.130	.002*
	Yes	52	.075	.033	
Free throws attempted	No	498	.091	.135	.004*
	Yes	52	.101	.049	
Offensive rebounds	No	498	.045	.040	.017*
	Yes	52	.056	.036	
Defensive rebounds	No	498	.110	.089	.002*
	Yes	52	.126	.048	
Total rebounds	No	498	.155	.105	.005*
	Yes	52	.182	.075	
Blocks made	No	498	.013	.019	.013*
	Yes	52	.018	.020	
Dunks	No	498	.010	.018	.001*
	Yes	52	.017	.028	
Received fouls	No	498	.098	.078	.006*
	Yes	52	.111	.039	
+/- statistic	No	498	-.087	.534	.034*
	Yes	52	.011	.242	
Ranking	No	498	.321	.391	.000*
	Yes	52	.441	.169	

KPIs: Key Performance Indicators.

Table 3. Significant KPIs in leg injury occurrence.

KPIs (per minute)	Leg injury	N	Mean	Standard Deviation	*P*
Total minutes	No	520	439.14	302.06	.590
	Yes	34	472.35	293.90	
3 points made	No	516	.034	.036	.006*
	Yes	34	.046	.026	
3 points attempted	No	516	.104	.098	.014*
	Yes	34	.129	.061	
2 points attempted	No	516	.197	.109	.048*
	Yes	34	.160	.075	

KPIs: Key Performance Indicators.

The statistical performance lesions relevant to the occurrence of thigh injuries are reflected in the Table 4.

No statistically significant differences were found, related to the minutes of exposure in the matches (total minutes played), between the set of players that presented a thigh injury and the group that did not (P = 0.131). As with all injuries seen previously, the group of injured players in the thigh played more minutes on average during the regular season (specifically 101.01 minutes more). But unlike in the ankle, knee and hand injuries, this fact has not been statistically significant.

However, significant differences have been found regarding attendance and recoveries (all of them, per minute of exposure). The group of players with thigh injury performed more assists and recoveries per minute during the season (P <0.05).

The statistical performance lesions relevant to the occurrence of foot injuries are shown in the Table 5.

No statistically significant differences were found, related to the minutes of exposure in the matches (total minutes played), between the set of players that presented a thigh injury and the group that did

Table 4. Significant KPIs in tight injury occurrence.

KPIs (per minute)	Tight injury	N	Mean	Standard Deviation	*P*
Total minutes	No	531	436.99	303.032	.131
	Yes	23	538.00	247.373	
Assists	No	527	.063	.057	.038*
	Yes	23	.083	.056	
Steals	No	527	.033	.021	.042*
	Yes	23	.039	.014	

KPIs: Key Performance Indicators.

Table 5. Significant KPIs in foot injury occurrence.

KPIs (per minute)	Foot injury	N	Mean	Standard deviation	*P*
Total minutes	No	535	441.89	303.721	.748
	Yes	19	421.32	232.481	
Defensive rebounds	No	531	.110	.087	.041*
	Yes	19	.133	.056	
Total rebounds	No	531	.156	.103	.036*
	Yes	19	.194	.081	
Dunks	No	531	.010	.018	.021*
	Yes	19	.028	.036	
Fouls	No	531	.121	.107	.004*
	Yes	19	.141	.057	

KPIs: Key Performance Indicators.

not (P = 0.748). On the contrary that it happened with all the injuries seen previously, the group of players injured in the foot disputed less minutes of average during the regular season (concretely 20.67 minutes less). However, this fact has not turned out to be statistically significant.

Yes, significant differences have been found regarding defensive rebounds, total rebounds, mates and fouls committed (all variables, calculated per minute of exposure). The group of players with foot injuries made more defensive rebounds, defensive rebounds, dunks and fouls committed per minute during the season (P <0.05).

Discussion

The aim of the present research was to study the occurrence of injuries and the relationship with Key Performance Indicators (KPIs) of the players of the professional basketball competition ACB.

Numerous studies indicate that the most common mechanism of ligamentous distension injury is the performance of a jump[10,11,27]., rather than sudden accelerations towards the basket[10]. The injury is caused by a slight plantar flexion, typically caused by falling on the foot of another player turning the ankle inward or when a player falls awkwardly after a jump[11].

According to previous research, players who had more minutes of playing exposition in games had more ankle injuries[1,9]. It was unexpected the absence of relationship between KPIs which requires a jump and more injury prevalence, such as: 2 point shots, 3 point shots, rebounds (total, offensive, defensive), blocks made and against.

Offensive KPIs have been traditionally identified as crucially influential in the occurrence of ankle injuries[10], which agrees with our results. Better players in points, field shots made, free throws made and attempted, assists, fouls received and ranking, suffered an ankle injury. This player profile, due to his ability to score, would increase the level of contact with the defence.

In the case of fouls received, the contact between players has been considered a variable especially susceptible to predict injuries. Our results shows that players injured in the ankle suffered more fouls per minute played, which agrees with previous research in both NCAA[1] and European competitions[10]. The incidence of free throws in the occurrence of ankle injuries can be surprising, since it is an action in which there is no jump or contact. However, it must be borne in mind that in order to shoot a free throw it is necessary to have previously received a foul (which implies a contact) and in many cases, to be simultaneously making a shot to the basket (which implies a jump).

The assists have been identified as a determining factor in the occurrence of ankle injuries, although passing and receiving the ball is not considered as decisive as jumping to produce this type of injury[10]. However, it must be taken into account that many of the assists are made in jump to pass the ball when receiving a defensive help.

It was to be expected that injured players in the knee had significantly more minutes of exposure in matches, as other studies point to the importance of playing time as a cause related to the frequency of knee injuries[1,9,11].

There is consensus in several studies to indicate that knee injuries are caused by overuse and that an important factor of its incidence in basketball is the continuous requirement of jumps[11,27]. Thus, previous research agrees with the KPIs identified as key to suffer a knee injury: dunks, blocks made, rebounds (total, defensive, offensive).

The contact has been pointed out by several authors as a trigger factor for knee injuries[1,10,16]. This assessment coincides with the results obtained in this study, since the players injured in the knee suffered more fouls than the non-injured players, per minute of exposure in the matches. In the case of attempted and converted free throws, the reflection made on ankle injuries is still valid: performing an action of this type implies in most cases having received a foul (contact) in the performance of a shot to the basket (jump).

Finally, an offensive profile has been detected in players who have suffered this type of injury. Significantly higher means were obtained in valuation, plus-minus valuation, points scored, shots of two converts and field goals converted. These results show that, as in ankle injuries, players with an offensive cut are more likely to suffer knee injuries.

Unlike the data reflected in the scientific literature[9,10], the occurrence of leg injuries has turned out to be independent of the exposure time in matches.

This fact suggests that leg injuries may be more related to minutes of exposure in training than in games. In fact, the injuries that occur when playing basketball in this anatomical area have to do with bone injuries due to these, and inflammation in the muscles and soft tissues[11], which are likely to occur due to the existence of an excessive training load. In this sense it is necessary to analyse in the future the exposure of players in training to draw better conclusions about this type of injury.

In addition, players injured in this anatomical region are significantly more likely to throw and score three pointers, but fewer two-point shots. The tendency to specialize in elite players suggests that those who do not have very powerful limbs and are more likely to throw more from long distance (three-point shots) and less from close range (two-point shots). This type of player, typically with the less developed lower train, may be more likely to suffer muscle-type injuries due to excessive training load on the legs. Regarding bone injuries due to stress, there does not seem to be any relationship between this player profile and this type of injury. However, these aspects are difficult to justify scientifically and should be studied in greater depth in the future, since the only objective data available is that players who suffer this type of injury have a profile of long-distance shooters.

Players who perform more steals and assists are more likely to suffer thigh injuries. These relationships can be associated with the participation of the quadriceps and the femoral biceps in jumping actions (such as those performed when doubling the passes in many assists near the rim) and of defensive basic position when stealing the ball (with the knees bent and the straight trunk).

However, practically all actions related to basketball involve the participation of these muscles, so the associations found should serve as a guide to establish relationships in future prospective studies[7] and analyse these relationships again with a greater record of thigh injuries.

In summary, we can conclude that thigh injuries have been suffered by players who perform more assists and more recoveries per minute.

Players injured in the foot, captured more defensive and total rebounds than the non-injured. This results agrees with previous studies[11] that gives as a typical example of foot injury in basketball, catching a rebound and the subsequent landing on the foot of another player. However, it is curious that the capture of offensive rebounds has not been found significant, since it is a very similar action. The highest performance of dunks has also been found significant. This fact also makes sense, since this action requires a jump very close to the basket, in an area where the density of players is usually high.

It is interesting to note that fouls committed per minute have turned out to be a significant performance variable only for foot injuries (no significant relationships have been found between this performance variable and the rest of the injuries). Basketball players usually make fouls when they have been overtaken by a player with a ball, when a player makes a shot near the rim or when they are fighting for the position in rebound or pass reception situations. In all these actions, there is a risk of injury to the foot both for the player who performs the fault and for the one who receives it.

As limitations of the present study, on the one hand, the reasons why the injuries have occurred (contact, non-contact, jumps, accelerations, etc.), nor the types of injury (muscular, bone, tendon, ligament, etc.) have not been recorded, which would allow a deeper analysis of injuries in professional basketball. On the other hand, there has been no access to the minutes of exposure in training of each player, so that only exposure to injuries in competition is taken into account. These limitations are due to the design of this investigation. However, we believe that the information provided may be of interest to advance the knowledge of injuries in professional basketball in Spain, by collecting the injuries produced in all teams of the highest competition for two full seasons, providing a new way of study injuries and relate them to KPIs. It would be convenient to conduct studies prospectively, although it would be difficult to perform with reliable data from all the teams involved.

Conclusion

The players who played the most minutes during the season were more likely to suffer ankle and knee injuries. The players injured in the ankle had better means, per minute played, in offensive type actions. The players injured in the knee turned out to be very complete players: they obtained better average in most variables related to a positive performance. The players injured in the leg presented a performance profile of long distance shooters. Significant relationships were also found between injuries and performance in the case of injuries of the thigh and foot. Higher performance in basketball involves a higher risk of injury.

Conflict of interest

The authors do not declare a conflict of interest.

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Original article

Anthropometric profile of young triathletes and its association with performance variables

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Summary

The different nature of each discipline in triathlon makes consensus difficult for optimal anthropometric factors for a high global performance, especially in young people. The aim was to analyse the correlation of the cineanthropometric factors with the performance observed in the different test. Young triathletes (44 male and 20 female) were subjected to a full anthropometric measurement as well as to the performance assessment (100 m and 400 m in swimming, cycling critical power and 1000 m run). Variables were subject to a normal test (Shapiro-Wilk) and correlational analysis (coefficient of Spearman). The results show that both in the 100 m and 400 m test, basic body measures, Biacromial and Biiliocrestal diameters, as well as arm perimeters, thigh and chest (perimeters only in girls) have the highest correlations with performance. The cycling test shows a moderately significant and negative correlation ($p = .556$) between the leg fold and the relative critical power only in girls. Finally, run correlated negative to the percentage of fat mass in both sexes (boys: $p = -.323$; girls: $p = -.646$). Results indicate that arm span and height should be taken into account in swimming performance, as well as the fat tissue in career performance, especially in girls by professionals involved in the development process and selection of talent in young triathletes.

Key words:
Anthropometry. Triathlon. Talent. Growth. Maturation.

Perfil antropométrico de jóvenes triatletas y su asociación con variables de rendimiento

Resumen

La diferente naturaleza de cada disciplina en triatlón dificulta el consenso en relación a los factores antropométricos óptimos para un alto rendimiento global, especialmente en jóvenes. Por eso, el objetivo fue analizar la correlación de los factores cineantropométricos con el rendimiento observado en los diferentes test. Triatletas infantiles y cadetes (44 masculinos y 20 femeninos) fueron sometidos a una medición antropométrica completa, así como a la evaluación del rendimiento (100 m y 400 m en natación, potencia crítica en ciclismo y 1.000 m en carrera). Las variables fueron sometidas a una prueba de normalidad (Shapiro-Wilk) y un análisis correlacional (coeficiente de correlación de Spearman). Los resultados muestran que tanto en el test de 100 m como en el de 400 m, las medidas corporales básicas, los diámetros Biacromial y Biileocrestal, así como los perímetros del brazo, muslo y tórax (perímetros sólo en chicas) tienen las correlaciones más altas con el rendimiento. En el test de ciclismo se observa una correlación moderadamente significativa y negativa ($p = -0{,}556$) entre el pliegue de la pierna y la potencia crítica relativa sólo en chicas. Finalmente, el test de carrera a pie correlacionó negativamente con el porcentaje de masa grasa en ambos sexos (Chicos: $p = -0{,}323$; chicas: $p = -0{,}646$). Estos resultados indican que se deberían tener en cuenta, especialmente, la estatura y la envergadura en el rendimiento en natación, así como el tejido graso en el rendimiento de carrera, especialmente en chicas, por aquellos profesionales que intervienen en el proceso de desarrollo y selección de talento en jóvenes triatletas.

Palabras clave:
Antropometría. Triatlón. Talento. Crecimiento. Maduración.

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Introduction

Triathlon is a combined endurance sport involving back-to-back swimming, cycling and running events. Numerous studies have shown that not only physiological aspects such as economy of movement or VO_2max[1,2] but also anthropometric factors influence performance in the sport[3]. The differences between the three disciplines making up triathlon hinder consensus when it comes to drawing firm conclusions regarding the optimal anthropometric factors for high overall performance because such factors do not affect the three events in equal measure[4]. The specific somatotypes of swimmers, cyclists and runners reveal dissimilar values[5-7] which are hard to extrapolate to the optimum specific somatotype of the triathlete.

In general, performance in triathlon in adults has been linked to taller individuals, longer lower limbs contributing to running performance[8] and longer upper limbs facilitating swimming performance[9,10]. Triathletes would also appear to be smaller than swimmers and more akin to runners and road cyclists[3].

Body mass is another prominent factor to take into account in endurance sports, especially in those in which the athletes need to carry their own body weight[11].

Landers *et al.*[9] observed that senior triathletes performed significantly better than junior triathletes, showing that lower fat mass was the characteristic most related to overall success in the sport. Body segment length was also seen to be important to performance, especially in swimming.

Canda *et al.*[3] described the complete anthropometric profile of the triathlete and found that, in the men, juniors triathletes had less body mass and were shorter both in height and sitting height than senior triathletes. The junior triathletes, both male and female, also presented greater fat percentages and values related to endomorphy than the seniors. At the same time, in boys they only noticed differences in the anterior thigh skinfold, which was smaller for triathletes categorised as level 1, when comparing according to performance level. In contrast, they observed a lower percentage of fat, lower values of endomorphy and a greater muscle percentage in level 1 female triathletes.

Accordingly, after evaluating a sports orientation programme in Belgium, Pion *et al.*[7] noted that the factor which most differentiated triathletes from other athletes was the body fat percentage and performance in the endurance test.

Unlike a few years ago, more triathletes are now trained from an early age and, therefore, changes can be observed in their body morphology[4]. Consequently, the aim of this study was to analyse the extent to which kineanthropometric factors and performance in the tests for each of the disciplines making up the triathlon were correlated in young athletes.

Method

Participants

A total of 64 U14 and U16 triathletes (44 male and 20 female) took part in the research. The triathletes who took part in this research trained for a total of 6-10 hours a week, split, roughly, into 2-3 hours swimming, 1-2 hours running and 2-3 hours cycling. All the triathletes had to meet the following inclusion criteria: (one) to have between 2 and 4 years' experience in triathlon, (two) to belong to a club and have a coach responsible for their training and (three) to perform all the performance tests rating over 8.5 on the Borg scale. All the participants and/or their parents/guardians signed the informed consent (1978 Declaration of Helsinki, revised in 2008) and were informed of the benefits, risks and objective of the study, the protocol for which had been previously approved by the Ethics Committee at the University of Alicante (UA-2016-06-0).

Procedure and instruments

The anthropometric measurements were taken following the international standards set by ISAK[12]. The data were collected by an ISAK level II anthropometrist, taking into account the intraobserver variability associated with measurements indicated in 2019 (5% for skinfolds and 1% for other measurements). The approved, calibrated anthropometric equipment used consisted of: a wall-mountable height rod (precision: 1 mm); Tanita scales (precision: 100 g); a Rosscraf narrow, non-stretching metal measuring tape (precision: 1 mm), a Holtain small diameter bone pachymeter (precision: 1 mm); a Holtain skinfold calliper (precision: 0.2 mm). Basic measurements were taken: skinfolds, perimeters and bone diameters. The measurements of these variables were used to calculate fat mass[13], bone mass[14] and muscle mass[15], following the specifications for children and adolescents. To calculate the somatotype, the average somatotype was determined using the method devised by Heath-Carter and the classification of somatotype categories according to Duquet and Carter[16].

Several performance tests were then carried out for each discipline. The swimming and running tests were held in the same day; in the morning the anthropometric measurements were taken and the swimming test was conducted (9 a.m.), and the running test was conducted in the afternoon (6 p.m.). All the triathletes did the same warm-up for both swimming and running. The next day there was a session so the participants could familiarise themselves with the velodrome and then the cycling test was conducted. At the end of each test, the athletes were asked individually to rate their perceived exertion in conditions of confidentiality[17,18] in order to ensure the assessment of maximum capacity for each test.

Swimming test. The swimming tests consisted of a 100-metre and then a 400-metre freestyle test[19,20], starting from the water and touching the wall in a heated, in a 25-metre, indoor pool.

3-min all-out cycling test. The cycling test was conducted in a velodrome between 9 and 11 a.m. All the triathletes did the same warm-up (adapted from Burnley *et al.*) [21]. The power data were collected using a power meter (Powertap G3, precision: ± 1.5%) on the rear wheel (Zipp 404 carbon) and a bike computer (Garmin Edge 810). For inclusion in the analysis of the data for the cycling test, the data had to reflect a reproducible power profile and the maximum power peak had to be reached in the first 5 seconds[21,22]. The open-source software Golden Cheetah for MAC OS X (v. 3.4) was used to import the data to a spreadsheet (Microsoft Excel 2016).

Running test. The 1000-metre running test[23] was conducted on a 400-m synthetic race track.

Statistical analysis

The dependent variables were subjected to a test of normality (Shapiro-Wilk). Spearman's rank correlation coefficient was calculated. The significance level was set at 0.05 in all cases. Statistical analysis of the data was carried out using version 24 of IBM® SPSS® (Statistics Package for the Social Sciences) MAC and Microsoft Excel 2016® for MAC.

Results

Characteristics of the sample

Table 1 shows by sex all the variables of the sample which were analysed.

100-metre swimming test (Swm100)

The stroke rate -SR- showed no significant correlation with any of the variables in either sex. Stroke length -SL- and mean speed -MS- gave the highest positive correlations with the basic measurements (height, arm span, etc.) and with the biceps and leg skinfolds in the boys. In the girls, the greatest positive correlation was observed with wrist and thorax diameters. In both sexes, positive correlations were registered between both the biacromial and bicristal diameters, and swimming speed.

400-metre swimming test (Swm400)

The SR seen during the test did not give any notable correlations with any of the anthropometric variables of either sex. Meanwhile, as with the data collected in the 100-m test, both SL and MS showed moderately positive correlations with the basic measurements (height, sitting height, arm span and body mass), but only in boys. In the male triathletes, it was observed that those with smaller biceps, thigh and leg skinfolds, sum of the 8 skinfolds and fat mass percentage swam the 400-m test more quickly. Moderate positive correlations involving wrist diameter, bone mass and biacromial and bicristal diameters were only observed in the girls. As occurred with the girls in the 100-m test, the highest correlations were between arm, leg and thorax perimeter, and SL and MS.

3-min all-out cycling test (Cyc 3min all-out)

In female triathletes, a significant but moderate negative correlation (p = -0.556) was registered between the leg skinfold and the power to-weight ratio. In male triathletes, no such significant correlation was seen. Moderate correlations were observed between absolute critical power and body mass, as well as sitting height and leg length in the boys, and height, arm span and leg length in girls.

Table 1. Characteristics of the participants (Mean ± standard deviation).

	Male (N=44)	Fem (N=20)	Total (N=64)
Age (years)	14.5±1.5	14.7±1.3	14.6±1.4
Height (m)	167.4±10.5	162.0±6.4	165.0±9.2
Sitting height (m)	85.9±6.3	82.8±5.0	84.8±6.0
Arm span (m)	169.6±10.8	162.6±6.4	166.5±9.7
Body mass (kg)	56.8±9.4	51.6±6.8	54.5±8.7
Leg length (m)	81.6±6.3	78.4±3.9	80.5±5.7
Subscapular (mm)	6.9±2.6	8.6±2.8	7.6±2.8
Triceps (mm)	7.7±4.7	11.8±3.4	9.3±4.7
Biceps (mm)	4.1±3.6	6.6±2.1	5.1±3.3
Iliac crest (mm)	10.6±5.9	12.7±5.0	11.4±5.6
Supraspinal (mm)	7.2±4.4	8.8±4.1	7.8±4.3
Abdominal (mm)	10.8±6.8	14.1±6.0	12.1±6.6
Thigh (mm)	12.5±7.4	20.2±4.4	15.5±7.4
Leg (mm)	8.3±6.2	12.5±4.1	9.9±5.8
Σ 8 skinfolds (mm)	63.9±42.1	76.6±44.3	69.3±43.1
Relaxed arm (mm)	27.4±2.8	24.4±1.9	26.2±2.9
Contracted arm (mm)	29.2±2.8	24.9±1.7	27.5±3.2
Maximum thigh (mm)	49.0±3.6	46.6±2.8	48.3±3.5
Maximum leg (mm)	34.8±2.2	32.9±2.1	34.1±2.3
Thorax (mm)	85.5±6.7	77.8±6.5	83.0±7.5
Wrist (cm)	5.4±0.3	4.9±0.2	5.2±0.3
Humerus (cm)	6.8±0.3	6.0±0.2	6.5±0.4
Femur (cm)	9.3±0.5	8.6±0.3	9.0±0.6
Biacromial (cm)	36.4±2.8	34.7±2.0	35.7±2.6
Bicristal (cm)	25.9±2.0	25.0±1.6	25.5±1.9
Endomorphy	2.5±1.1	3.0±1.0	2.7±1.1
Mesomorphy	4.2±1.0	3.0±0.6	3.6±0.8
Ectomorphy	3.2±0.9	3.6±0.6	3.4±0.8
Fat mass (kg)	9.1±4.3	10.2±3.3	9.6±3.8
% fat mass	14.6±5.2	19.6±4.5	17.1±4.9
Skeletal muscle mass (kg)	32.9±4.1	19.7±6.4	26.3±5.3
% skeletal muscle mass	54.5±2.0	38.2±10.5	46.4±6.2
Bone mass (kg)	10.9±1.4	8.8±0.8	9.8±1.1
% bone mass	18.1±1.5	17.2±4.1	17.6±2.8
Swm100 SR (strokes per minute)	45.2±6.1	41.4±5.0	43.6±6.0
Swm100 SL (cm per stroke)	55.9±10.8	57.8±9.2	56.7±10.1
Swm100 MS ($m{\bullet}s^{-1}$)	1.3±0.2	1.2±0.1	1.3±0.2
Swm400 SR (strokes per minute)	37.3±4.4	33.7±4.3	35.7±4.7
Swmt400 SL (cm per stroke)	55.6±10.5	60.4±31.0	57.8±22.4
Swm400 MS ($m{\bullet}s^{-1}$)	1.1±0.2	1.0±0.2	1.0±0.2
Cyc 3min all-out CP(W)	275.5±56.4	198.0±39.1	247.6±62.8
Cyc 3min all-out PWr ($W{\bullet}kg^{-1}$)	4.5±0.5	3.8±0.5	4.3±0.5
Run 1.000m MS ($km{\bullet}h^{-1}$)	18.5±1.7	15.8±1.6	17.3±2.1

Male: male; Fem: female; SR: stroke rate; SL: stroke length; MS: mean speed; CP: critical power; PWr: power-to-weight ratio.

Running test (Run1000)

In the boys, a low correlation was recorded between sitting height and arm span, and performance in the running test. A low negative correlation was also observed with the thigh and calf skinfolds; that is to say, the greater the skinfold, the lower performance. In the girls, there was a moderate negative correlation between the calf, biceps, triceps and abdominal skinfolds, and performance. Finally, there was a correlation with the fat mass percentage in both sexes, more notable in the girls (Table 2, Figure 1, Figure 2 and Figure 3).

Discussion

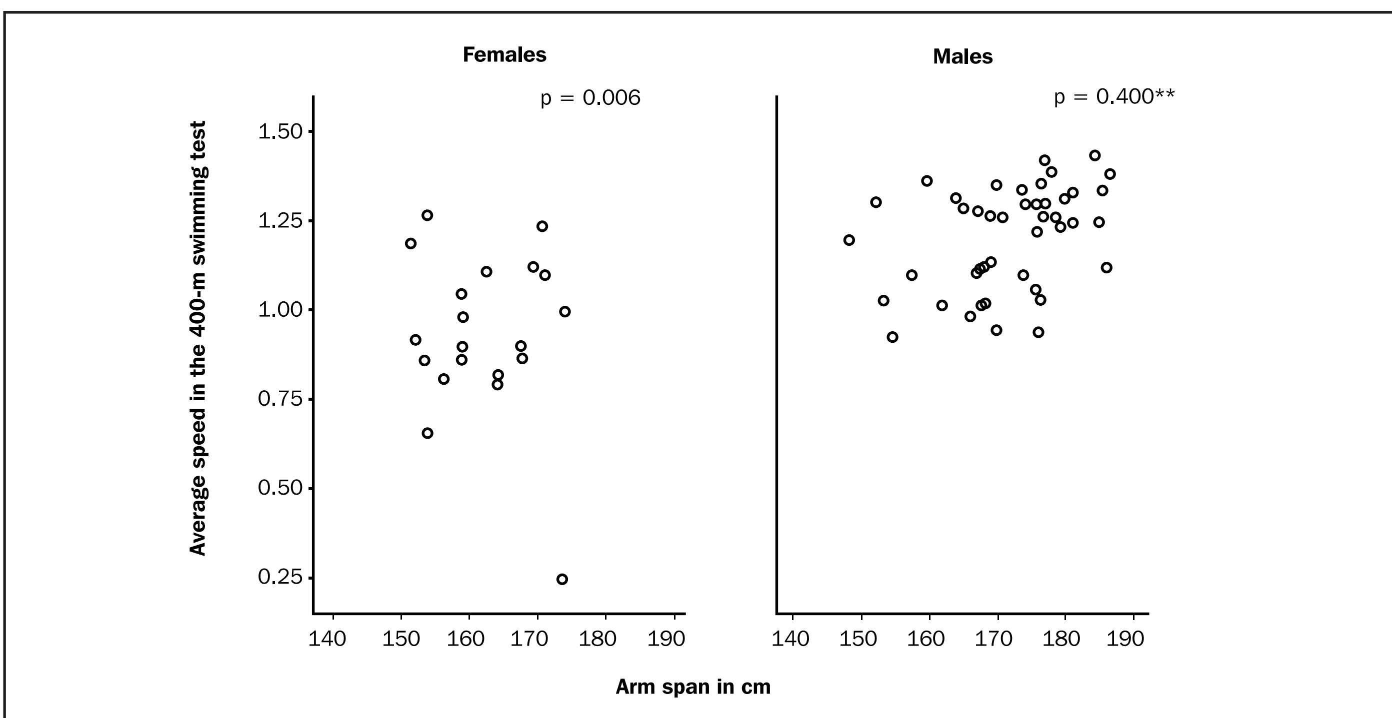
Firstly, of the basic measurements, the arm span variable correlated positively with performance in both swimming tests for young triathletes, a result consistent with other studies[9,10,24,25]. Height would also seem to be quite decisive for performance in the 400-m swimming test, and leg length would appear to be more closely related to performance over shorter distances, as suggested in other sources[26].

Height and sitting height are both very important measurements when it comes to assessing an individual's maturational status, as reflected in the equation for determining Peak Height Velocity[27]. Growth and development may be particularly relevant to performance at these ages[28]. However, the same behaviour is not observed in girls. Given that they usually mature two years earlier than boys, it is possible that the results in girls result from the fact that the vast majority were at or had already passed Peak Height Velocity[29]. In a similar vein, Moreira *et al*.,[10] highlighted differences in swimming speed over 25 m after 10 weeks of rest, attributing the difference especially to the effects of growth.

In the males, the fat mass percentage was negatively correlated with performance in the two swimming tests and in the running test, results consistent with other studies[7,30]. More specifically, the biceps and thigh skinfolds, and the sum of the 8 folds were the factors most correlated with performance in both the swimming tests, while the thigh and leg skinfolds both correlated negatively with performance in the 400-m swimming test and the 1,000-m running test.

In the cycling test, no correlation with the power-to-weight ratio was observed in the males, these results agreeing with those registered by Landers *et al*.[9]. These authors found no relationship in their factor analysis between the factor they called segmental length and cycling performance in elite junior and senior triathletes, even though this study was conducted at a time when drafting was not permitted. In the girls, the biceps and thigh skinfolds were negatively correlated with the power-to-weight ratio. Although some studies correlate a low fat percentage with cycling performance[31], it may be that this effect is not observed in adolescents because most triathlons are held on flat ground and with drafting, and the importance of fat tissue may not be so relevant in this form of the discipline. The greatest correlation values for absolute critical power in the cycling test were found to be

Figure 1. Relationship between the triathletes' arm span in cm and mean speed in the 400-m swimming test by sex.



ρ: Spearman's rank correlation coefficient: ** p <0.01.

Table 2. Spearman's rank correlation coefficient for the anthropometric measurements and the different performance tests.

	100-m swimming test				400-m swimming test				Cycling test				Running test	
	Male		Fem		Male		Fem		Male		Fem		Male	Fem
	SL	MS	SL	MS	SL	MS	SL	MS	CP	PWr	CP	PWr	MS	VMS
Height (m)	0.497**	0.369**	0.219	0.250	0.382**	0.341**	0.379**	0.322*	0.339	-0.076	0.636*	-0.454	0.318*	-0.146
Sitting height (m)	0.469**	0.541**	0.263	0.340	0.381**	0.498**	0.371*	0.418*	0.625**	0.276	0.357	-0.385	0.379**	0.199
Arm span (m)	0.463**	0.436**	0.361**	0.414**	0.438**	0.400**	0.561**	0.006	0.332	-0.085	0.789**	-0.393	0.368**	-0.215
Body mass (kg)	0.503**	0.400**	0.290*	0.393**	0.443**	0.366**	0.526**	0.452**	0.611**	0.168	0.807**	-0.429	0.209	-0.079
Leg length (m)	0.331*	0.265*	0.384*	0.403*	0.272	0.267	0.510**	0.439*	0.585**	0.286	0.846**	-0.257	0.218	-0.231
Subscapular (mm)	-0.161	-0.231	0.107	0.229	-0.072	-0.266	0.274	0.242	-0.002	-0.299	0.715**	-0.161	-0.251	-0.300
Triceps (mm)	-0.286	-0.150	0.035	0.015	-0.160	-0.203	0.122	0.038	0.434*	0.154	0.726**	-0.356	-0.168	-0.595**
Biceps (mm)	-0.447**	-0.481**	0.045	0.109	-0.274	-0.536**	0.197	0.164	0.266	0.088	0.448	-0.305	-0.357*	-0.486*
Iliac crest (mm)	-0.264	-0.161	0.243	0.373	-0.107	-0.185	0.520	0.376	0.053	0.024	0.549*	-0.542*	-0.059	-0.289
Supraspinal (mm)	-0.340*	-0.269	0.024	0.206	-0.204	-0.290	0.360	0.221	0.292	0.070	0.760**	-0.231	-0.137	-0.315
Abdominal (mm)	-0.298	-0.245	0.206	0.254	-0.160	-0.223	0.372	0.237	0.406*	0.235	0.782**	-0.270	-0.236	-0.469*
Thigh (mm)	-0.378*	-0.344*	0.077	0.069	-0.243	-0.373*	0.264	0.096	0.432*	0.181	0.768**	-0.265	-0.363*	-0.192
Leg (mm)	-0.453**	-0.465**	-0.206	-0.294	-0.306*	-0.505**	-0.135	-0.341	-0.010	0.096	0.499	-0.556*	-0.363*	-0.600**
Σ 8 skinfolds (mm)	-0.339*	-0.316*	0.132	0.196	-0.152	-0.359*	0.351	0.192	-0.210	-0.088	0.638*	-0.077	-0.300	-0.392
Relaxed arm (mm)	0.122	0.012	0.288	0.531**	0.168	0.064	0.578**	0.633**	0.215	0.114	0.761**	-0.361	<0.001	0.262
Contracted arm (mm)	0.153	0.111	0.360	0.615**	0.212	0.121	0.614**	0.704**	0.565**	0.217	0.777**	-0.386	-0.032	0.385
Maximum thigh (mm)	-0.118	-0.081	0.377	0.583*	-0.018	-0.018	0.618*	0.731**	0.424*	0.089	0.779**	-0.186	0.109	0.600
Maximum leg (mm)	0.103	0.088	0.190	0.268	0.079	0.004	0.413*	0.389	0.508*	0.076	0.393	-0.714	0.224	0.070
Thorax (mm)	0.281	0.271	0.532*	0.766**	0.257	0.335	0.907**	0.738**	0.435*	0.184	0.640*	-0.286	0.328	0.433
Wrist (cm)	0.287	0.303*	0.577**	0.587**	0.135	0.240	0.587**	0.547**	0.482	-0.024	0.107	-0.214	0.385*	0.055
Humerus (cm)	0.166	0.216	0.313	0.335	0.076	0.252	0.460*	0.351	0.508*	0.234	0.235	-0.237	0.353*	0.125
Femur (cm)	-0.271	-0.274	0.106	0.061	-0.467**	-0.283	0.260	0.184	0.508*	0.302	0.212	-0.152	0.178	-0.171
Biacromial (cm)	0.471**	0.486**	0.279	0.446*	0.410**	0.423**	0.504**	0.483**	-0.094	0.180	-0.757**	0.321	0.309	0.136
Bicristal (cm)	0.392**	0.509**	0.287	0.473**	0.360**	0.492**	0.455*	0.495**	0.550**	0.202	0.229	-0.472	0.227	-0.335
Endomorphy	-0.287	-0.267	0.035	0.145	-0.142	-0.310*	0.246	0.135	0.451*	0.297	0.442	-0.460	-0.064	0.350
Mesomorphy	-0.282	-0.243	0.101	0.254	-0.279	-0.191	0.149	0.287	0.297	0.151	0.682**	-0.307	-0.245	-0.515
Ectomorphy	0.322*	0.220	-0.256	-0.578**	0.235	0.218	-0.617**	-0.551**	0.299	0.323	0.018	-0.089	0.024	-0.209
Fat mass (kg)	-0.258	-0.197	0.148	0.221	-0.149	-0.276	0.395	0.252	-0.403	-0.281	-0.446	0.171	-0.154	-0.344
% fat mass	-0.384*	-0.348*	-0.131	-0.165	-0.228	-0.434**	-0.017	-0.462*	0.334	0.062	0.811**	-0.275	-0.443**	-0.684*
Skeletal muscle mass (kg)	0.309*	0.247	0.248	0.293	0.291	0.281	0.433*	0.381	0.041	0.001	0.611*	-0.214	0.276	-0.243
% skeletal muscle mass	0.029	-0.092	0.079	0.148	0.220	-0.112	0.146	0.250	0.582**	0.143	0.793**	-0.286	-0.110	-0.127
Bone mass (kg)	0.257	0.229	0.432*	0.472*	0.059	0.216	0.636**	0.557**	-0.428*	-0.210	0.504	-0.036	0.346	0.018
% bone mass	0.034	-0.009	-0.213	-0.496*	-0.217	-0.032	-0.580**	-0.530**	0.522**	0.170	0.725**	-0.482	0.084	-0.251

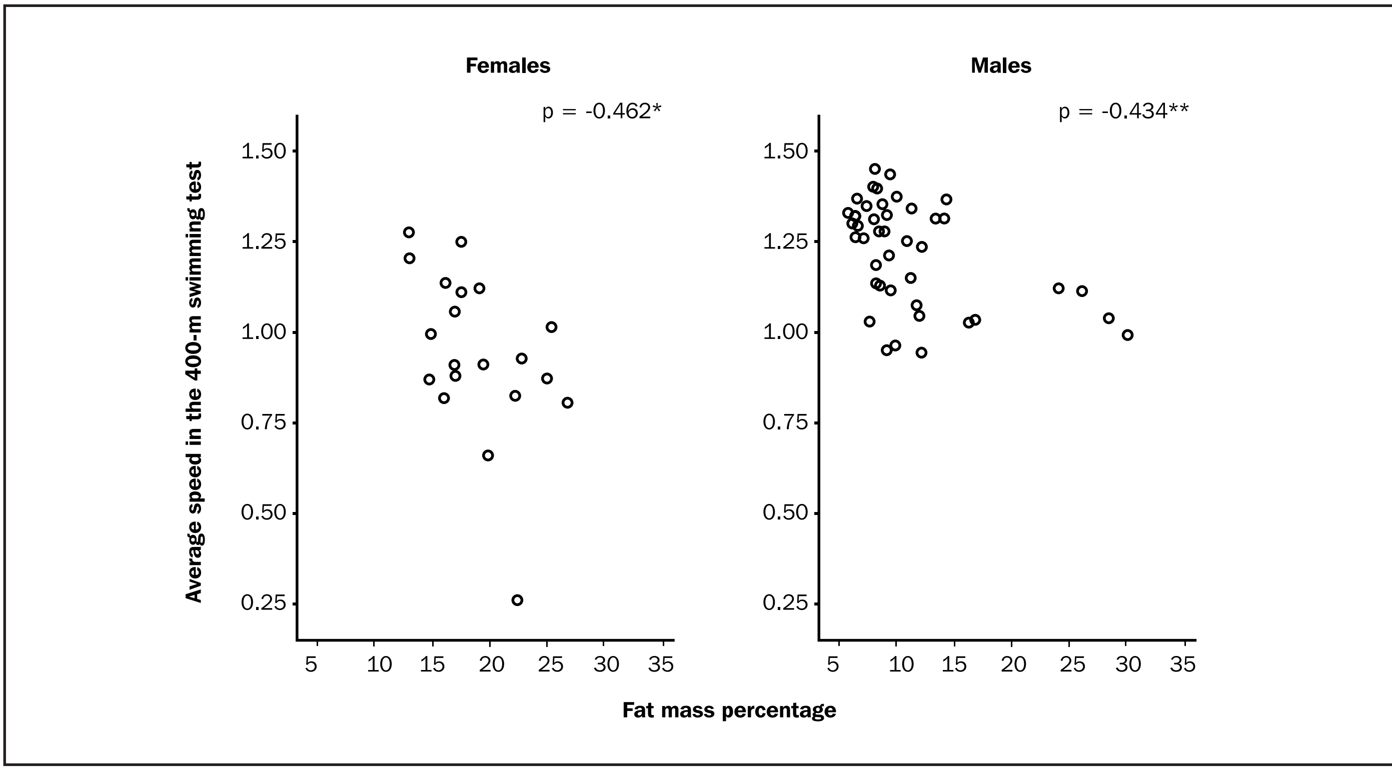
Male: male; Fem: female; SR: stroke rate; SL: stroke length; MS: mean speed; CP: critical power; PWr: power-to-weight ratio.
*p<0.05; **p<0.01.

with the basic measurements, particularly body mass in both sexes. It would seem reasonable to suppose that the heavier the triathlete, the easier a greater absolute critical power. However, it is unclear how this may affect overall competition performance. For this reason, the triathletes' power-to-weight ratio is discussed more fully, this being the most reliable and valid approach[32].

In the running test, the fat percentage was negatively correlated with performance, especially the triceps, biceps, abdominal and leg skinfolds. These folds, it should be noted, are the most sensitive to training and diet[33]. Although this study did not collect data on stride rate and length, the results of the running test with young triathletes showed no relationship with those observed with adults[8], where taller athletes perform better overall in triathlon thanks to their greater stride length.

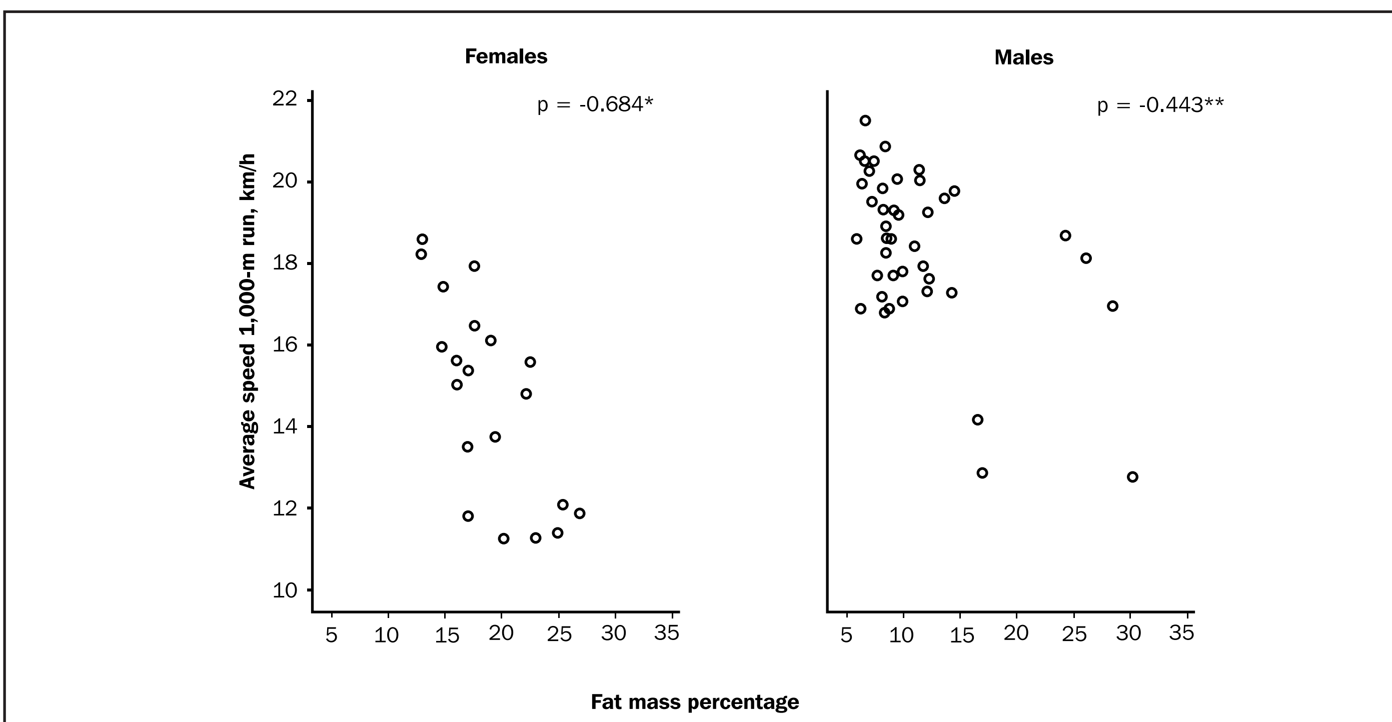
Finally and in view of the results of this study, its most noteworthy limitation is that the point of development of the triathletes was not taken into consideration, something which would be particularly impor-

Figure 2. Relationship between the triathletes' fat mass percentage and mean speed in the 400-m swimming test by sex.



ρ: Spearman's rank correlation coefficient: *p<0.05; **p<0.01.

Figure 3. Relationship between the triathletes' fat mass percentage and mean speed in the 1,000-m running test by sex.



ρ: Spearman's rank correlation coefficient: *p<0.05; **p<0.01.

tant in order to arrive at firmer conclusions. Nor did the design of the study take into account other factors which can affect the development of sporting talent, such as psychological factors, social factors, relative age and so on.

Conclusions

Sports coaches and managers should consider this study for their day-to-day work, taking into account the following for young triathletes who are still growing:

- Arm span favours swimming performance, meaning that comparing two individuals at different points of development could mean overlooking sporting talent.
- The fat mass percentage is a determining factor for performance in triathlon at all ages, thereby suggesting the convenience of a good grounding and education in balanced, healthy eating habits to control optimum individual weight.
- An individual's point of development is also key, peak height velocity representing a turning point involving significant charges in the athlete's proportions and somatotype. The coaches of young athletes, therefore, should know and apply the formula to calculate peak height velocity with a standard error of ±12 months.
- Cycling performance, particularly the power-to-weight ratio, would seem to be the least sensitive area to the effect of anthropometric characteristics, maybe due to the shorter distances or the drafting effect, but is nonetheless important for a good overall result.

Conflict of Interests

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

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Original article

Frontal lobe executive dysfunction in short-term attentional control following a header in women's soccer

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Summary

Introduction: Football is currently the most popular and fastest growing sport in the world. Women's football players does not stop growing and currently arouses great interest, but most of the scientific recommendations for the female game have been based so far on research conducted in men. The increasing increase in the practice of women's football makes it necessary to include these types of studies.
Objective: To assess the executive functions of the frontal lobe in the control of short-term attention after having performed 6 heading shots with an intelligent ball, in non-professional adult football players.
Methodology: The study design was experimental of an intervention group with pre and post evaluation. The study consisted of two phases, in the first phase the collection of personal data, sports history, anthropometric measures was performed, and the Stroop Test was performed to evaluate the executive functions of the frontal lobe. In the second phase, 6 consecutive head shots were made from 28 meters and the Stroop test was carried out again. The sample consisted of 12 players, with an average age of 25.3 (SD = 6.5 years) and a range between 18 and 40 years. The average number of years they had been playing football in federated teams was 6.5 (SD = 2.35 years), practicing between 7 and 10 hours per week in football.
Results and conclusions: The repeated impacts when football heading, when the speed is higher than 62 km / h, produce significant and specific cognitive changes in female football players, immediately after the auction; indicating a disruption in voluntary brain functions, causing negative alterations in executive functions.

Key words:
Brain injuries. Head injuries. Football. Executive function. Prefrontal cortex. Stroop test.

Disfunciones ejecutivas del lóbulo frontal en el control de la atención a corto plazo tras el remate de cabeza en el fútbol femeninos

Resumen

Introducción: El fútbol es actualmente el deporte más popular y de más rápido crecimiento en todo el mundo. El fútbol femenino no para de crecer y despierta en la actualidad un gran interés, pero la mayoría de las recomendaciones científicas para el juego femenino se han basado hasta ahora en investigaciones realizadas en hombres. El aumento creciente de la práctica del fútbol femenino hace necesario incluir estos tipos de estudios.
Objetivo: Fue valorar las funciones ejecutivas del lóbulo frontal en el control de la atención a corto plazo después de haber realizado 6 remates de cabeza con un balón inteligente, en jugadoras de futbol adultas no profesionales.
Metodología: El diseño de estudio fue experimental de un grupo intervención con evaluación pre y post. El estudio constó de dos fases, en la primera fase se realizó la recogida de datos personales, la historia deportiva, las medidas antropométricas y se realizó el Test Stroop para evaluar las funciones ejecutivas del lóbulo frontal. En la segunda fase, se realizaron 6 remates de cabeza consecutivos desde una distancia de 28 metros y se volvió a realizar el test de Stroop. La muestra estuvo formada por 12 jugadoras, con una media de edad de 25,3 (DE=6,5 años) y un rango entre los 18 y 40 años. La media de años que llevaban jugando al futbol en equipos federados fue de 6,5 (DE=2,35 años), practicando entre 7 y 10 horas semanales al futbol.
Resultados y conclusiones: Los impactos repetidos al realizar los remates de cabeza con un balón de fútbol, cuando la velocidad es superior a los 62 km/h, producen cambios cognitivos significativos y específicos en jugadoras de fútbol femenino, inmediatamente después del remate; indicando una disrupción en las funciones cerebrales voluntarias, provocando alteraciones negativas en las funciones ejecutivas.

Palabras clave:
Lesiones cerebrales. Lesiones cabeza. Fútbol. Función ejecutiva. Corteza prefrontal. Test Stroop.

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Introduction

Soccer is currently the most popular and fastest growing sport in the world. In recent times, women's soccer has experienced exponential growth at all levels and is currently awakening considerable interest. According to the FIFA 2014 Survey, 30 million women are currently playing soccer worldwide[1]. The rollout of the FIFA Women's Soccer Strategy is a road map that aims to get 60 million women playing soccer by 2026[2]. In Spain, the number of registered women players increased from 11,300 in 2003[3] to 60,329 in 2017[4]. As is the case with many sports, soccer carries an inherent risk of injury, including cerebral concussion and subconcussion. However, soccer is unique in the use of headers, a defensive or offensive movement used to deliberately hit the ball and direct it during play. In matches, players may head the ball an average of 6-12 times, with the ball reaching high speeds of up to 80 km/hour or more. During training sessions, headers, often at low speed, can occur 30 times or more[5].

Although not all football headers produce concussion, these subconcussive impacts may impart acceleration, deceleration and rotational forces on the brain, leaving structural and functional deficits[6]. Poor attention, memory performance, and verbal learning results may occur after subconcussive impacts, and have been attributed to damage to the white matter in the brain and possible chronic neurodegenerative consequences[7-9]. These forces imparted on the midbrain, corpus callosum and fornix could be responsible for the symptoms of concussion, such as loss of consciousness, amnesia and cognitive impairment. Even in the less serious, subconcussive impacts, significant forces are transmitted to the deep structures of the midbrain and brain stem, also implying injuries[9,10].

Although there is growing concern with regard to sports-related brain injuries and possible long term consequences, there has been less emphasis on the cumulative effects of repetitive subconcussive impacts. Subconcussive impacts are defined as similar events to concussion or mild traumatic brain injury, but apparently they imply insufficient impact or acceleration forces to produce symptoms associated with concussion[7].

The cumulative effect of repetitive subconcussive impacts on the structural and functional integrity of the brain still remains largely unknown. Athletes in impact sports, such as soccer, experience a large number of impacts in just one playing season[7]. On the other hand, most of these header impacts are not considered to be a factor associated with potential injuries. As a result, few studies have been made of the long term consequences.

Most soccer studies have been conducted on male players. Therefore, up to now, most of the scientific recommendations for women's soccer are based on investigations made on men, which may not be appropriate[11]. The growing increase in women's soccer makes it necessary to include studies of this nature.

The following working hypothesis is put forward: the repeated impacts from headers during non-professional soccer in the adult female population cause executive dysfunctions of the frontal lobe in short-term attentional control.

The study aimed to assess the executive functions of the frontal lobe in short-term attentional control after performing headers with the ball, in non-professional women soccer players.

Material and method

Subjects

The study population comprised non-professional women soccer players. The players taking part in the study were selected by intentional sampling from among the women's senior team of CF Arenys de Mar (Barcelona) according to the following inclusion and exclusion criteria. Those who voluntarily agreed to participate in the study were included, while any players with head injuries, prior concussion, or acute or chronic disorders were excluded.

Firstly, the authorisation of the soccer club was requested and then the players were informed of the purpose of the study. They were asked to give their signed informed consent to voluntarily take part and under the data protection law, ensuring the anonymity and confidentiality of the data at all times.

Design and procedure

The study design was experimental on an intervention group with pre- and post-assessment. The study comprised two phases. The first phase consisted in the collection of sociodemographic variables and variables related to the practice of sports (athletic history, number of years registered as a soccer player, predominant position on the playing field, total number of hours per week playing soccer and frequency of headers during a match) and anthropometric measurements. The Stroop test was subsequently conducted, without interference (Stroop effect off) recording the number of errors and the speed of processing, and then with interference (Stroop effect on) recording the number of errors and the speed of processing.

In the second phase, 6 consecutive headers were performed from a distance of 28 metres. It was decided to do 6 headers as this is the average number of headers performed during a training session[12]. Furthermore, consecutive headers facilitate the appearance of subconcussion. All the shots were performed by the same person, trying, as far as possible, to achieve shots of a similar speed. The variables collected with the smart ball were the ball speed in km/h, the RPM rotation at the time of the header and the total time of the header. This was immediately followed by another Stroop Test, without and with interference, recording the number of errors and the processing speed.

Stroop test

The test was developed by Ridley Stroop13 to assess the processing speed of the inhibition component of the executive functions, the ability of the subject to inhibit an automatic response and to select a response based on arbitrary criteria[14]. Using the Stroop test to produce response inhibitions, frequently committed errors and the opportunity for subsequent behavioural correction, the different cortical areas associated with each of these specific executive processes were identified[15].

To measure the inhibition capacity, interference based actions were used. Numerous versions of the Stroop Test have been developed. This study used the EncephalApp-Stroop smartphone application based on the adaptation of the classical stest. It consists in a colour and word test in which the subject reads the names of randomly placed colours and must always select the colour of the sign that appears (green, blue and red). It has 2 different conditions: 1. With no interference (Stroop off effect). The colour sign # is shown with no significance, there is no interference. 2. Interference (Stroop on effect). The words green, blue and red appear randomly written with the three possible colours (Figure 1). The colour in which they are written must be selected, not the meaning of the written word. This causes an interference, in which the inhibitory component of the executive functions appears.

When the Stroop effect does not appear, it is more a reflex reaction towards the achievement of the goal. However, when the Stroop effect is on, this implies the inhibition of the reflex action towards the initial response, which then generates a new response implying a voluntary act, the colour-word interference effect[14].

The test is performed from 7 consecutive measurements. Any errors in the first two were not counted, being used to get the player familiar with the test and to reduce the learning effect that could be reflected in the post-test.

At the end of the test, the actual application calculates the time of each phase, the total speed of each condition and records the number of errors.

Smart ball

The Adidas Smart Ball miCoach is fitted with inner sensors that provide data on each shot, sending these data to an iOS device using Bluetooth 4.0 technology. This ball has the same weight and size as a standard soccer ball, with a weight of 450 g and a diameter of 68.6 cm. The study recorded the ball speed in km/h, the rotation in RPM and the path of the shot up to the impact on the player's forehead.

Figure 1. Stroop effect off (without interference) and Stroop effect on (with interference).

Statistical analysis

A statistical analysis was made of the data obtained. Initially the descriptive analysis was made: for the quantitative variables, the study used the indicators of mean, standard deviation, range and the confidence intervals were presented at 95% provided that the variable had a normal distribution. For the comparison of two means, the Student-Fisher T test for independent groups was used, given the normality of distributions. The General Linear Model (GLM) analysis was used to study the mean differences with repeated measures and a multivariable analysis was made from the means of the number of errors taken from the post-test. An alpha risk of 5% was assumed.

An analysis was made of the mean velocity differences and the errors drawn from the pre- and post-tests, taking account of the off and on Stroop effect. The speeds recorded in each of the post-test phases were also detailed, as well as the phase in which the errors were made. Finally correlations were established between the variables for the players making up the sample with the amount of errors drawn, as well as the correlation between the speed of the ball, km/h, with the post-test errors.

Results

The sample comprised 12 players with an average age of 25.3 (SD=6.5 years) and a range between 18 to 40 years. The average number of years in which the women had been playing soccer in registered teams was 6.5 (ST=2.35 years), playing soccer between 7 to 10 hours per week.

Characteristics on heading the ball

The results obtained from the smart ball were as follows: the average speed reached by the ball at the time of impact was 62.5 km/h (CI 95%: 57.8 - 67.7 km/h), the average number of revolutions per minute was 373 RPM (CI 95%: 286 - 446 RPM). The average time employed to perform 6 headers was 2.55 min (CI 95%: 2.03 - 3.38 min).

Stroop Test response speed

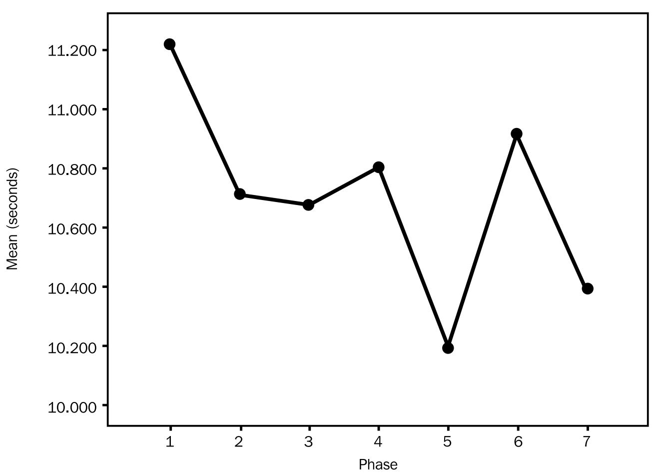
Comparing the speed in the average response time, expressed in seconds (s), of the test with the Stroop effect off (no interference) before the header was 10.8 s (CI 95%: 9.8 - 12.6 s) and after the header 10.7 s (CI 95%: 9.4 - 12.0 s), no statistically significant differences were observed (p = 0-737). Neither were any differences observed (p= 0.302) with the Stroop effect on (with interference), before the head it was 12.0 s (CI 95%: 9.5 - 13.3 s) and after the header 11.7 s (CI 95%: 9.9 - 13.2 s) (Table 1).

When analysing the response speed for each phase of the test after the header with the Stroop effect off (no interference), significant differences were observed between phases 1-2, 1-5, 1-7, 4-5 and 5-6 (F=7.39; gl=6.0; p=0.014) (Figure 2), which indicates that the Stroop effect response speed with no interference drops from one phase to another.

Table 1. Speed of response in the Stroop test with and without interference.

	Pre-test		Post-test		Difference
	Mean (s)	CI95%	Mean (s)	CI95%	T-test Student-Fischer
Stroop without interference	10.8	9.8 - 12.6	10.7	9.4 – 12.0	p= 0.737
Stroop with interference	12.0	9.5 – 13.3	11.7	9.9 – 13.2	p= 0.302

Figure 2. Response speed, in seconds, at each test phase after the header with the Stroop effect off.



The greatest drop in response time was between phase 1 (11.2 s) and phase 2 (10.7 s) (p=0.018).

With regard to the response speed with the Stroop effect on (interference) performance was extremely variable in each phase, with no statistically significant differences observed between phases (Figure 3). This indicates that the response speed during the Stroop effect with interference is independent of the time that has elapsed after the header.

Number of errors in the Stroop Test

With regard to the number of errors made before the header with the Stroop effect off (no interference) an average of 0.42 errors was obtained (CI 95%: 0-2 errors). After the header, the average number of errors was 0.75 (CI 95%: 0-2 errors). No significant differences were observed between both situations, before and after (p=0.220). With regard to the number of errors with the Stroop effect on (interference), the average before the header was 0.50 errors (CI 95%: 0-2 errors) and 1.5 errors (CI 95%: 0-3 errors) after the header, noting a statistically significant increase in the number of errors after the header (p=0.015) (Table 2).

Figure 3. Response speed, in seconds, at each test phase after the header with the Stroop effect on.

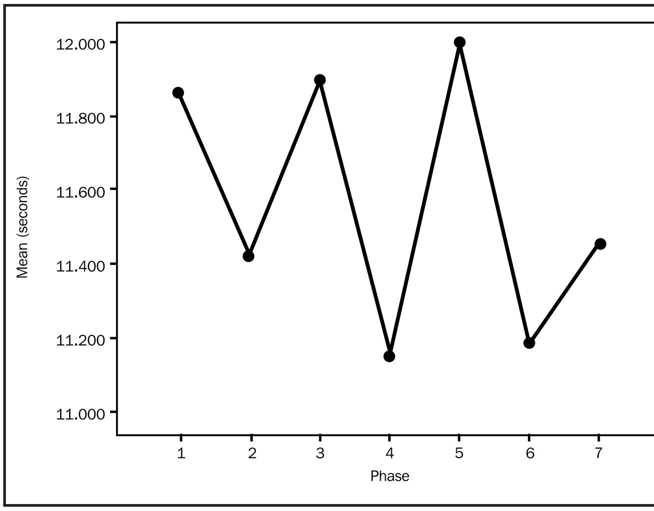


Table 2. Mean number of errors in the response in the Stroop test with and without interference.

	Pre-test		Post-test		Difference
	Mean errors	CI95%	Mean errors	CI95%	T-test Student-Fischer
Stroop without interference	0.42	0 - 2	0.75	0 - 2	p= 0.220
Stroop with interference	0.50	0 - 2	1.5	0 - 3	p= 0.015

When analysing the number of errors in the responses, based on the time or phases where such errors occurred with the Stroop effect with no interference, it was noted that phase 1 gave an average of 0.25 errors, phase 2 an average of 0.33 errors and phase 3 an average of 0.17 errors. From phase 4 to 7, no errors were made, noting statistically significant differences with regard to the number of errors in the phases (F=5.2; gl= 9.0; p=0.024). It is from phase 2 onwards where the greatest number of errors were located, significantly dropping (Figure 4).

When analysing the number of response errors based on the time or phase in which these occur with the Stroop effect with interference, significant differences are observed (F=8.75; gl= 7.0; p=0.007) between the following phases: in phase 1 the average was 0.36 errors, in phase 2 it was 0.27 errors, in phase 3 it was 0.45 errors, in phase 4 it was 0.27 errors and from phase 5 to 7 there were no errors. The most noteworthy differences were observed between phase 1 and phase 3, after which the number of errors dropped to reach 0 in phase 5 (Figure 5).

Figure 4. Average errors in each test phase after the header with the Stroop effect.

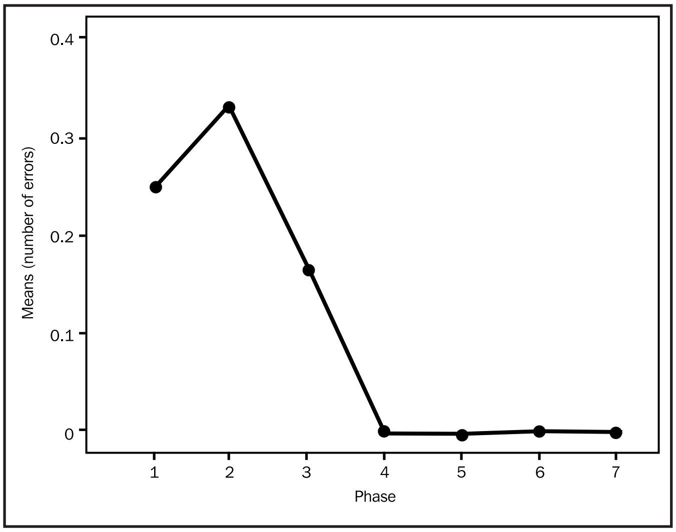


Figure 5. Average errors in each test phase after the header with the Stroop effect on.

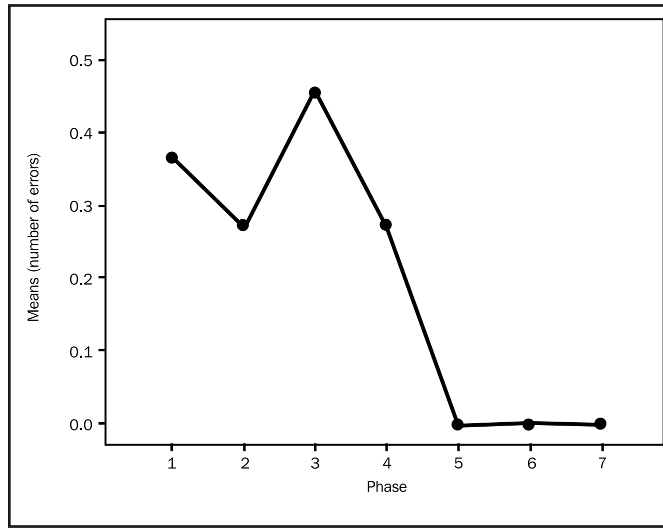


Table 3. Speed of response according to ball speed.

Speed ball	Test Stroop	Speed of response (s)	Difference (s)	CI 95% of the difference		T-test Student-Fisher
				Lower	Higher	
≤62 km/h	Without interference	10.58	-1.10	-1.69	-0.52	p=0.005
	With interference	11.68				
>62 km/h	Without interference	10.86	-0.78	-1.42	-0.15	p=0.025
	With interference	11.65				

Ball speed and number of errors

By correlating the ball speed during the header with the number of errors made with the Stroop effect on, a modest statistically significant association was observed (r=0.59; p=0.043). The greater the speed, the greater the number of errors made. On the other hand, with the Stroop effect off, no correlation was observed. By classifying the speed of the ball into two groups, over or under 62 km/h, it was observed that when the ball speed is more than 62 km/h this is significantly associated with a greater number of errors in the test (r=0.95; p=0.003). This relationship is not established for lower ball speeds.

Ball speed and response time

When relating the speed of the ball to the response speed in the Stroop test, off and on, no statistically significant association was observed.

When the analysis is made by classifying the ball speed into two group, over or under 2 km/h, then a comparison of the response speed in the on and off Stroop test shows statistically significant differences between the groups. The speed of response is faster with the Stroop effect off, with no interference, moreover it is independent of the ball speed (Table 3).

Number of revolutions per minute of the ball and response errors

The revolutions per minute (RPM) of the ball showed no correlation with the number of errors made (r=0.20; p=0.52), neither with the Stroop effect on (r=0.16; p = 0.62) nor with the effect off (r=0.06; p = 0.84).

Errors and speed of response

No statistical relationship was observed between the number of errors and the speed of response at each stage of the Stroop test, on and off. The number of errors was not associated with the speed of reaction. On analysing the relationship between the number of errors and the speed of response in the subsequent phase, with the Stroop test on and off, no statistical relationship was observed between both variables in any of the 7 phases. The reaction time for the execution of the following test was not related to previous errors made, with or without interference.

With regard to the time taken to execute all the headers, no correlation with the number of errors was observed (r=0.11; p = 0.74), either with the Stroop effect on (r=-0.07; p = 0.83) or with the effect off (r=-0.10; p = 0.76).

Finally, neither did age show any correlation with the number of errors (r=-0.26; p = 0.41), nor the number of years playing in a registered team (F=1.17; p = 0.35), nor the position on the field (F=0.04; p = 0.96) or the number of headers (F=0.304; p = 0.59).

Discussion

This study showed that the repetitive impacts of heading the soccer ball cause a disruption in the voluntary brain functions. Female soccer players experienced significant and specific changes in cognition immediately after the header, with ball speeds of more than 62 km/h. A negative alteration was observed in the processing of the inhibition component of the executive functions, the ability of the subject to inhibit the automatic tendency to select the habitual response and to generate behavioural correction in the response, implying a voluntary act (Stroop effect) and a response conflict.

Neuroimaging studies suggest that neurocognitive symptoms are due to the microstructural and metabolic alterations accumulated in the brain caused by repetitive head-impact exposure[16,17]. The force of the impact causes subconcussion in the cerebral cortex that may alter the neurometabolism and functional connectivity, as suggested by Svaldi DO[18], finding a decrease in the cerebrovascular reactivity in female soccer players, preceding the neurocognitive symptoms. Rodrigues AC[19] and Bigler ED[20] provided preliminary evidence of the relationship between head impact exposure and the structural and functional changes in the brain. Koerte IK[21] found differences in the white matter integrity in soccer players, suggesting a possible demyelination caused by neuroinflammation. The regions most affected are the right orbitofrontal white matter, the genu and anterior portions of the corpus callosum, the association fibres involving bilateral inferior fronto-occipital fasciculus, optic radiations, and right superior and bilateral anterior cingulum, as well as the corona radiata, the internal capsule and the superior frontal gyrus. The most persistent cerebral regions that present changes in cerebrovascular reactivity are the frontal dorsolateral[22] and frontotemporal18 regions. All these cerebral regions are responsible for processing the input signals and for the executive response functions. In a broad sample of young soccer players with a history of prior concussion, there was no evidence of negative effects on cognition and no evidence of differences between genders[23].

Male and female brains show anatomical, functional and biochemical differences in all stages of life[24,25]. In women's brains, the neurons are packed tightly together, so that certain layers of the cerebral cortex are more densely populated. Some women even have as many as 12 percent more neurons than men[26]. Although men have larger cerebral volumes than women, the ratio of grey to white matter is higher in the frontal, temporal, parietal, occipital lobes, cingulate gyrus and insula in women in relation to men.[25,27] These regional differences may be related to the distribution of the oestrogen and androgen receptors. Global cerebral blood flow is higher in women than in men, while global cerebral metabolism is equivalent[25]. The results suggest that the cortical functional unit has a different ratio of input and output components in men and women that could have implications for the gender differences in cognition and behaviour[26].

A noteworthy fact is the speed of the ball. Lewis ML *et al*[28] observed that players are exposed to a mean acceleration force of 49 G when heading the ball at a speed of 39.3 miles per hour (63 km/hour). Exposure to repetitive blows to the head entails the risk of microstructural and functional changes to the brain[17]. The study results suggest that ball impacts of more than 62 km/h cause subconcussion, altering the quality of the response and negatively affecting the test results.

These impacts may produce changes in the cerebral blood flow, neurometabolic changes and changes in the cortico-subcortical and subcortico-subcortical connectivity, causing a dissociation between the dorsolateral prefrontal cortex, involved in the response inhibition, and the anterior cingulate cortex that affects attention control, important role in regulative processing of perceptual conflict and in detecting response conflict.[29-31], hindering the response planning of the executive functions. Consequently, the errors of commission would be due to late activation instead of low activity in these same areas of response inhibition, as suggested by Garavan H, *et al*[15]. It was observed that the restoration of connectivity and the response reaction time improved from the second phase of the test onwards.

On the other hand, when there is no response conflict, it is more of a reflex action towards the achievement of the goal, not being affected by the speed of the ball. In the automation of the response, there is a learning process with regard to the appearance of the response conflict. For irrelevant tasks (Stroop effect off) when the involvement of inhibition is unnecessary, there is no interference with the execution of the task. This makes us suspect that there is no involvement of the dorsolateral prefrontal cortex.

With regard to the errors in the execution of the tests, no relationship was observed between the number of errors and the player's age, nor years of experience, position on the field or frequency of headers. However, the immediate acute negative effect on the executive functions is evident. The headers do not appear to cause any cumulative effects of subconcussions on the executive functions among the players taking part in the study. A history of cerebral concussion is associated with a greater risk of clinically diagnosed depression and depressive symptoms, however it is not clear whether these findings can be generalised beyond former professional male soccer players[32]. Soccer players have been reported to have a greater cortical thinning with age and early cognitive impairment as a result of the repetitive impact of the ball.[33]. To avoid the possibility of a cumulative chronic negative effect when heading the ball, a series of recommendations were proposed and the correct playing technique[34].

The results of our study suggest that the heavy impacts of heading the ball and successive headers should be avoided. There is a need to limit the accumulated load during the season, both in training sessions and matches alike. A period of rest after the competition season is also necessary in order to maintain a good brain health. Evidence of a negative effect on brain functionality must be taken into account when making recommendations for practising sports at school.

The conclusions obtained in this present investigation must be adopted with the necessary caution, given that the results come from a small sample of 12 subjects, which is a limitation to the study. Despite this, the results point in the same direction as other investigations and, in turn, suggest that there is a need to continue to investigate. For this reason, the number of subjects will be increased for subsequent investigations. There is also another limitation inherent in the study design, which is the non-randomisation in the selection of participants and the lack of a control group. Although both aspects were considered, it was not possible to implement them. Prospective studies are required, in order to assess the relationship of accumulated subconcussive impacts with the cognitive functions and mental health of soccer players, registered and amateurs alike. The lack of studies on players in the medium and long term means that it is not possible to identify the future consequences of headers and the neurocognitive symptoms caused by metabolic and microstructural damage accumulated in the brain.

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Conflict of interests

The authors have no conflict of interest at all.

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Original article

Compressive cryotherapy as a non-pharmacological muscle recovery strategy and with no adverse effects on basketball

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Summary

Introduction: Both cold water immersion and compression garments have been routinely used to speed recovery after exercise, however, there is a lack of knowledge of applying both techniques simultaneously. Pressurice Compressport, which is a simple tool, non-pharmacological and free of side effects that allows the application of compressive cryotherapy (CC).
Objective: To investigate the chronic effect of Pressurice Compressport, after each match and training session, on the markers of muscle damage, muscle strength and fatigue.
Methods: A prospective cohort design. In 24 male basketball players divided into two groups, recovery (RP) (n=12) and control (GC) (n=12). Serum markers of muscle metabolism, quadriceps strength (FC) and perceived effort values (RPE) by Borg CR10 scale were measured at 3 times in the study: a) day 1, (T1); b) day 28 (T2) and c) day 56 (T3). The CC was applied immediately after each match and training.
Results: A progressive decrease in all markers of muscle damage was observed at the end of the pre-season in the RP group. On the contrary, in the GC they increased significantly for creatine kinase (CK) (T1 vs. T3 $p<0.05$). The time course of myoglobin (Mb) in the RP group ($p>0.05$) followed a pattern different from that of GC ($p<0.05$). In RP, the RPE significantly decreased ($p<0.05$) in all points of the study. The HR was higher in the RPE than in the GC, in addition gains were obtained throughout the pre-season in RPE and a decrease in GC.
Conclusion: CC is potentially capable of promoting recovery from muscle damage associated with competition and training, with reductions in markers of muscle damage, improvements in muscle strength and significant decrease in RPE.

Key words:
Recovery. Muscle damage. Basketball. Cryotherapy. Compression garments. Sports medicine.

Crioterapia compresiva como estrategia de recuperación muscular no farmacológica y sin efectos adversos en baloncesto

Resumen

Introducción: Tanto la inmersión en agua fría como las prendas de compresión han sido usadas rutinariamente para acelerar la recuperación después del ejercicio, sin embargo, hay una falta de conocimiento del uso de ambas técnicas de forma simultánea. *Pressurice Compressport,* es una herramienta simple, no farmacológica y carente de efectos secundarios que permite aplicar la crioterapia compresiva (CC).
Objetivo: Investigar el efecto crónico del *Pressurice Compressport,* tras cada partido, y sesión de entrenamiento, sobre los marcadores de daño muscular, la fuerza muscular y la fatiga.
Métodos: Un diseño de cohorte prospectivo. En 24 jugadores de baloncesto masculinos divididos en dos grupos, recuperación (RP) (n=12) y control (GC) (n=12). Los marcadores séricos del metabolismo muscular, la fuerza de cuádriceps (FC) y los valores de esfuerzo percibido (RPE) por escala de Borg CR10, se midieron en 3 momentos del estudio: a) día 1, (T1); b) día 28 (T2) y c) día 56 (T3). La CC se aplicó inmediatamente después de cada partido y entrenamiento.
Resultados: Se observó una disminución progresiva de todos los marcadores de daño muscular al final de la pre-temporada en el grupo RP. Por el contrario, en el GC aumentaron y fueron significativas para la creatina quinasa (CK) (T1 *vs.* T3 $p<0,05$). El curso temporal de la mioglobina (Mb) en el grupo RP ($p>0,05$), siguió un patrón diferente al GC ($p<0,05$). En RP los RPE disminuyeron significativamente ($p<0,05$) en todos los puntos del estudio. La FC fue mayor en el RP que en el GC, además se obtuvieron ganancias a lo largo de la pre-temporada en RP y una disminución en GC.
Conclusión: La CC es potencialmente capaz de promover la recuperación del daño muscular asociada con la competición y el entrenamiento, con reducciones en los marcadores del daño muscular, mejoras de la fuerza muscular y disminución significativa RPE.

Palabras clave:
Recuperación. Daño muscular. Baloncesto. Crioterapia. Prendas de compresión. Medicina deportiva.

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Introduction

Basketball players are constantly exposed to high physical demands due to repeated accelerations/decelerations and explosive jumps. This generates muscle pain, caused mainly by eccentric loads and due to trauma through contact[1]. In addition to these factors, short recovery times between training sessions and competitions lead to an excessive level of fatigue accumulated throughout the weekly cycle, all driving towards low performance in competition[2].

The capacity to recover after intense training sessions and matches, constitutes one of the most determining factors in the performance improvement process of the athletes. When correct physical and therapeutic recovery is applied after training sessions or competition, athletes can return more quickly to their sporting routines compared to when they do not receive any[3].

To reduce the magnitude of fatigue and to speed up recovery time, sports teams have a wide range of regenerative strategies: active recovery (continuous low-intensity running and stretches), ergo-nutritional methods (replacing substrates and electrolytes), passive recovery (sleep and rest), and physiotherapy methods[4,5]. Various recovery methods are used in physiotherapy after exercise, with the aim of relieving secondary muscle-skeletal alterations cause by training and competition. Among these interventions are "contrast therapy", which alternates between hot and cold treatment; full-body "cryotherapy"; "cold water immersion" (CWI); and hydro-massage". These physiotherapy modalities can alleviate fatigue and increase performance during training and competition[6].

Today, compression garments are commonly used by athletes during and/or after a training session or competition. The most used compression garments are compression stockings, which have numerous applications in the sporting world (Table 1). The physiological grounding is based on decreasing pressure that is generated in the leg, with the maximum pressure on the ankles (15-30 mmHg), reducing gradually to the top of the leg (10 mmHg)[7]. Compressions are used frequently in high performance sport as a recovery practice following physical exercise, with the aim of reducing delayed onset muscle soreness (DOMS), diminishing associated symptoms and the perception of pain. They can also reduce inflammation and the volume of the lower limbs, as well as the diameter of gastrocnemius veins[8]. Using them may also generate ergogenic benefits, such as a reduction in lactate levels associated with an acceleration of venous return by reducing venous distension, restoring valvular insufficiency and the reduction of venous blood[9]. Therefore, as a recovery strategy, compression stockings are cheap, easily accessible and non-invasive, as well as easy to implement during exercise and 15-24 hours after training and competition[10].

A recent study[6] has indicated the use of CWI as a technique to improve muscle damage recovery and to prevent over-training symptoms in basketball players. The effects of CWI are reflected in reduced pain, inflammation, blood flow, cell metabolism and muscle pain[11-13]. The efficiency of CWI appears to depend on the application length, the treatment area, the time it is applied, level of physical activity and the modality used[6,14]. Whatever the protocol used, the main beneficial effect of cold during recovery is vasoconstriction, which limits the permeability of the vessels and therefore inflammatory processes, reducing muscle pain[15].

Table 1. Applications of support stockings in sport.

Applications	Basis
They enhance venous return	They improve the circulation, stimulating the distribution of blood flow, achieving better tissue oxygenation.
They improve metabolic efficiency	They demonstrate the effectiveness of low intensity running, but not that of intensities over 14-16 km/hr.
They cool, driving out heat	These garments comprise two layers, one used to cool / wick away sweat, and another to absorb part of the heat produced.
They avoid heat loss	If it is cold, the stockings have a heat-preserving function
They avoid vibrations	The compression holds the muscles in the zone and prevents the lateral movement of the calf muscles.
They encourage recovery	The increase venous return and toxin drainage. They reduce inflammation and muscle pains.

In view of the above, the study of the effects of recovery practices for performance has become a priority issue for players, coaches and sports researchers alike, as improved recovery has the potential to increase sporting performance. Both CWI and compression stockings have been used routinely to speed up recovery after exercise on an individual level[6,8]. Therefore, applying compressive cryotherapy (CC) allows two recovery practices to be applied together, which could potentially yield better results in the athletes' recovery and performance.

There is currently a specific instrument for applying CC - Pressurice Compressport - which is a simple, non-pharmaceutical resource with no side effects.

Therefore, the aim of this study was to research the chronic effect of Pressurice Compressport, after each match and after each training session, on muscle pain indicators, by assessing the serum levels of enzymes and/or proteins. This work is a new study, as some basketball studies have researched the effect of diverse recovery procedures on recovery and fatigue indicators, yet these studies do not usually include the analysis of muscle metabolism markers[1,16].

Material and methods

A prospective cohort study was carried out. Twenty-four voluntary male basketball players participated in this study, which adhered to the

Helsinki Declaration recommendations and that was approved by the local university ethics committee.

Physical examination

All the subjects signed an informed consent form and underwent a medical examination. None of the participants smoked, drank alcohol or took medication or illegal substances. No injuries were obtained before or during the study.

Subjects

Participants were recruited using a non-random consecutive sample method of the two groups. The intervention group, with recovery practices (RP), 12 professional male basketball players (EBA League) (23.3 ± 5.4 years; 194 ± 9.8 cm, 95.8 ± 12.7 kg; 56.5 ± 7.7 mL-kg^{-1} -min^{-1}). The control group (CG) 12 university league students (22.1 ± 3.8 years; 178 ± 8.6 cm; 78.3 ± 8.6 kg; 47.2 ± 6.3 mL-kg^{-1} -min^{-1}).

Training

All the professional players followed the same training plan (2 daily sessions, held 5 days in a row with 1 day of rest, staggered with 6 friendly matches. After each session, the RP group received the corresponding recovery practices via CC.

All the university players followed the same training plan, 1 daily session, with 4 days in a row of training and 2 days of rest, staggered with 3 friendly matches. After each session, the CG did not receive the CC because this group did not have the *Pressurice Compressport*.

Dietary assessment

A professional dietician registered the strict daily intake of food and liquids of the athletes throughout the study (Table 2) using the EasyDiet©[17] package. All participants also received multivitamin complexes that included folic acid (5 mg/day), vitamin C (1 g/day), vitamin B12 (1.000 µg/day), ramified amino acids and glutamine.

Protocol

All the participants had to attend the laboratory at three specific times during the pre-season (8 weeks). We performed the analytical control at 3 points during the study: a) on day 1, just before starting the study (T1); b) in week 4, halfway through this period (T2); and in week 8, corresponding with the end of this period (T3).

Determining perceived effort

Before extracting blood, the participants were asked to grade their perceived muscle discomfort at each point in time (T1, T2, T3), using the Borg CR-10 scale validated to rate perceived effort (RPE)[18,19].

Determining quadriceps strength

For the strength test, we measured the quadriceps strength (QS) at each point in time (T1, T2, T3) with a dynamometer (Leg Jamar, USA). Two attempts were made with the predominant leg and the best score was noted[20].

Blood extraction and analysis

Regulations from the World Anti-Doping Agency (WADA) were followed for the collection and transport of samples (www.wada-ama.org). Antecubital venous blood samples were taken from the basketball players All the samples were collected under basal conditions and in fasting, with at least 12 hours fasting prior to the intervention, either

Table 2. Average daily energy and micro-nutrient intake in each group of basketball players from the recovery group (RP) and the control group (CG) during the 8-week long study.

Group	Control (CG)	Recovery (RP)	p	RDA*
Energy (kcal/kg)	42.3±5.8	42.7±5.2	0.293	
Ca (mg)	1,196±222	1,251±123	0.361	1,000
Mg (mg)	572±109	581±85	0.863	320
P (mg)	2,184±84	2,276±94	0.583	700
Fe (mg)	24.0±5.6	24.5±4.7	0.880	10
Zn (mg)	14.7±0.8	14.7±0.8	0.763	8
Vitamin A (µg)	1,951±1,270	2,002±875	0.679	700
Vitamin E (mg)	18.0±3.5	17.5±2.6	0.466	15
Thiamine (mg)	2.70±0.20	2.68±0.32	0.537	1.1
Riboflavin (mg)	2.87±0.22	2.95±0.28	0.693	1.1
Niacin (mg)	39.0±6.8	38.2±4.8	0.850	14
Vitamin B6 (mg)	3.99±0.62	4.01±0.86	0.831	1.3
Folic Acid (mg)	654±176	656±169	0.985	400
Vitamin B12 (µg)	9.79±3.89	9.55±3.55	0.768	2.4
Vitamin C (µg)	361±148	401±179	0.683	700

**RDA: Recommended Dietary Allowances*

Data is expressed as Average ± Standard Deviation. p: Differences between groups determined by independent *t* tests (CG vs. RP).

sitting or lying. The Vacutainer system was used (10 ml for tubes of serum, 5 ml and 3 ml tubes with EDTA). Immediately after extraction, the tubes were inverted 10 times and stored in a sealed box to be later kept at 4ºC. During the 30-minute journey to the laboratory, temperature was controlled using a specific label (Libero Ti1, ELPRO-BUCHS, Switzerland). The EDTA samples (anti-coagulant) were homogenised for 15 minutes before being analysed. The tubes that contained blood plus EDTA were centrifuged at 2,000 rpm for 15 minutes. The plasma was extracted using a Pasteur pipette and was transferred to a sterile storage tube where it was kept at -20ºC until it was analysed.

Leukocytes (LEU), monocytes (MON), lymphocytes (LIN), red blood cells (RBC), haemoglobin (Hb) and haematocrit (Hct) were determined using a haematological counter System Coulter MAX-M model. The serum levels of creatine kinase (CK), lactate dehydrogenase (LDH), aspartate transaminase (AST), alanine transaminase (ALT) and total proteins (TP) were measured at each point of the study (T1, T2 and T3) using coupled enzymatic reactions in an automatic self-analyser (Hitachi 917, Japan). The myoglobin (Mb) was measured using a "sandwich" immunochemiluminescent trial technique of two points.

Percentage changes in the plasmatic volume (% ΔPV), were calculated using the Van Beaumont[21] equation, and all the values of the parameters analysed were adjusted[22].

Use of compressive cryotherapy: *Pressurice Compressport*

After each training session (48 sessions) and after each match played (6 matches), the RP group received CC. The Pressurice Compressport (Compressport® Veno-Muscular Compression Technology, Switzerland) was fitted to the lower extremity, from the ankle to the iliac crest. The special gel formulation in the silicon compartment enabled it to remain flexible after cooling, allowing it to mould optimally to the shape of the leg. The gel was cooled at a controlled temperature of 8ºC. It comprised 2 applications of 15 minutes each, separated by 5 minutes, in which the athletes rested at room temperature. The compression wrapping was applied along with the cold gel and later the cold gel was removed (after the two 15-minute positions), and the compression garment was left on for a total of 90 minutes at complete rest in a sitting position. The garment was personal and provided a constant pressure of between 20 and 25 mmHg.

Statistical analysis

This was performed using the IBM Statistical Package (SPSS Version 22) and Graphpad Prism (Graphpad Software Version 6.01 San Diego, CA). The data was expressed as average ± standard deviation (SD). The differences in the parameters were assessed using a Scheffé test to identify significant differences between T1, T2 and T3 independently. Next, the normality of the data was confirmed using the Wilks lambda test to decide to use the parametric analysis. Significant differences are $p<0.05$.

Results

Dietary intake

Table 2 displays the energy and micro-nutrient intake of the basketball players. There were no significant differences between the study groups (CG and RP) in total calorie intake, vitamins and minerals ($p> 0.05$).

Haematology

Analysing the different haematological markers (Table 3), significant differences were only observed in the behaviour of the Hb in the CG throughout the study ($p<0.05$). Furthermore, in the CG Hb, significant differences were established ($p<0.05$) between T1 (15.33 ± 0.72) vs. T2 (16.15 ± 0.85) and significant differences ($p<0.05$) were also found between T2 (16.15 ± 0.85) vs. T3 (14.97 ± 0.92).

Biochemistry

Muscle markers

Table 4 displays the behaviour of the hormonal biochemical serum indicators and total proteins during the pre-season (T1, T2 and T3) in the CG and RP. Compared to the CG, the RP group had a better pattern of change over the pre-season period, demonstrating a descending trend between T1 and T3 in all muscle markers. CK, AST, ALT, LDH and Mb.

Individually, the most relevant results demonstrated: CK activity increased significantly ($p < 0.05$) in the CG in T3 (304.56±123.16) compared to T1 (201.43±88.73); in terms of the transaminases for the AST there was a significant decrease

($p < 0.05$) in the RP in T3 (18.09±2.18) compared to T1 (22.09±4.18) and for the ALT there was a significant increase ($p < 0.05$) in the CG in T2 (33.08±2.99) compared to T1 (30.25±1.32). Furthermore, significant changes ($p< 0.05$) can be seen (Figure 1, Table 4) in the behaviour of Mb in both groups (CG and RP) throughout the study. Also, for the Mb we observed a significant increase in the CG ($p < 0.05$) between the start (T1) (19.77±0.74) and the end of the study (T3) (25.68±3.68), however, in the RP there was a significant reduction ($p < 0.05$) between the study points T2 (27.88±3.67) and T1 (24.60±1.98).

Total proteins

The total proteins (Table 4) did not reveal significant changes in behaviour throughout the study, nor between the points analysed (T1, T2, T3).

Determining perceived effort

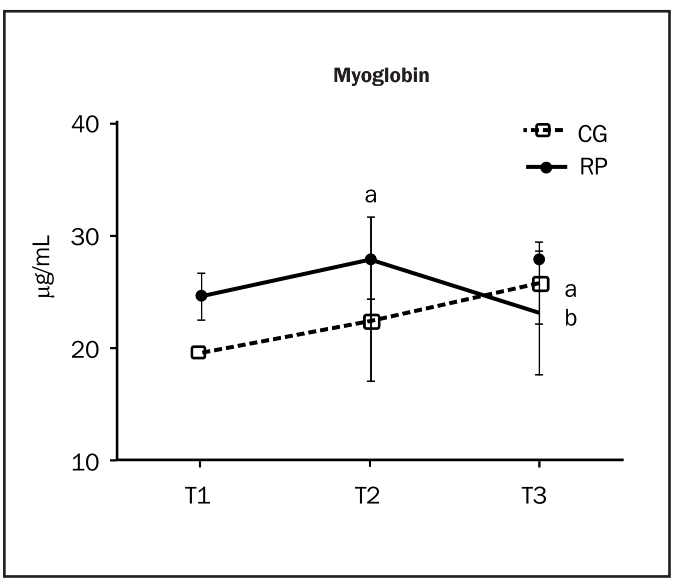
Table 5 displays the RPE in the CG, the Borg CR10 scale indicates a significant increase ($p<0.05$) of the perceived fatigue in T2 (8.64±1.26) and T3 (8.96±1.16) compared to T1 (7.03±1.79); conversely, for the RP there was a significant reduction in perceived fatigue ($p<0.05$) in T2

Table 3. Haematological markers in the basketball players from the recovery group (RP) and the control group (CG).

Test	Group	Time			Sign.
		T1	T2	T3	p
LEU (x10³ mL⁻¹)	RP	4.79±0.94	4.53±0.87	4.07±1.14	NS
	GC	5.97±1.54	6.16±1.41	5.89±1.39	NS
Monocytes (%)	RP	7.81±1.12	7.41±1.26	7.58±1.14	NS
	GC	6.97±1.47	6.69±1.43	7.67±2.09	NS
Lymphocytes (%)	RP	39.16±9.54	37.31±9.31	36.01±8.36	NS
	GC	37.51±8.50	37.35±7.45	37.98±7.73	NS
HEM (x10⁶ mL⁻¹)	RP	5.23±0.33	5.30±0.34	5.13±0.20	NS
	GC	5.25±0.40	5.52±0.49	5.27±0.33	NS
Hb (g.dL⁻¹)	RP	15.39±1.11	15.53±0.97	14.99±0.65	NS
	GC	15.33±0.72	16.15 ± 0.85[a]	14.97 ± 0.92[b]	S
Htc (%)	RP	45.77±2.79	46.00±2.53	45.74±2.22	NS
	GC	46.10±2.46	47.67±2.25	47.07±2.51	NS

Data is expressed as Average ± Standard Deviation. The Wilks lambda test was carried out to check for variations throughout the different study phases. Statistical significance was indicated with $p<0.05$.
Significant differences during the study period calculated using the Scheffé test.
a: Significant difference vs. T1, $p < 0.05$.
b: Significant difference vs. T2, $p < 0.05$

Figure 1. Representation of the myoglobin values (Mb) in the control group (CG) and recovery group (RP) throughout the study period.



(5.14±1.98) and T3 (4.12±2.06) compared to T1 (7.62±2.13). Moreover, the RP group displayed significant changes ($p<0.05$) in the behaviour of the RPE throughout the study.

Determining quadriceps strength with dynamometer

Table 6 displays the determination of QS. Compared to the CG, the RP group displayed a better pattern of change over the pre-season period, demonstrating an ascending trend (non-significant) in strength gain from the start of the study (T1 77.42±8.34) and the two points assessed (T2 78.41±6.82; T3 80.10±7.31). However, the in CG the opposite was observed, i.e. a non-significant reduction. None of the groups (CG and RP) revealed significant changes in QS behaviour throughout the study.

Discussion

As far as we are aware, this study may be the first to examine the application of CC with the Pressurice Compressport tool as a muscle recovery strategy in basketball players, using biochemical responses as indicators. The main finding in this research was that the use of CC with the usage protocol described in our study, could be associated with reductions in muscle pain markers and inflammation that entail improvements in muscle recovery in line with descriptions in other studies that use cryotherapy [6,11,13] or the use of compression garments[9,23,24]. Moreover, the significant improvement in perceived exertion (RPE) and an increasing trend in quadriceps strength (QS) observed at the end of the pre-season in the RP, could point towards the effective intervention of the CC programme as an applicable recovery model.

It is already recognised that repeated high-intensity training sessions or matches induce fatigue, muscle pain and a poorer performance, with reduced competitive capacity[1,5]. Faced with this situation, different recovery mechanisms have been proposed using cold therapies[8,9,13,15] and compressive mechanisms[8,9,25].

Sustained intense exercise increases levels of circulating muscle pain markers, of LDH, CK and Mb[26] and ALT/AST[27]. All these parameters are indicators of increased muscle pain and oxidative stress, which negatively affect athletes as not only can it reduce their performance, but it can also put their health at risk[28,29].

Table 4. Muscle metabolism markers and total proteins in the basketball players from the recovery group (RP) and the control group (CG).

Test	Group	Time			Sign.
		T1	T2	T3	p
Creatine Kinase (CK) (U/l) (0-190 U/L)	RP GC	236.72±98.13 201.43±88.73	239.14±95.18 254.16±118.26	232.29±96.76 304.56±123.16[a]	NS NS
Aspartate transaminase (AST) (U/l) (80-40 U/L)	RP GC	201.43±88.73 23.64±2.11	19.52±7.83 22.55±2.55	18.09±2.18[a] 24.97±1.93	NS NS
Alanine transaminase (ALT) (U/l) (10-50 U/L)	RP GC	31.53±8.79 30.25±1.32	31.25±5.29 33.08±2.99[a]	26.96 ± 7.88 31.66±2.26	NS NS
Lactate dehydrogenase (LDH) (105-333 UI/L)	RP GC	409.77±73.90 322.43±110.15	391.19±72.49 334.27±108.90	360.34±64.07 357.68±113.59	NS NS
Myoglobin (Mb) (ng/mL) (25-72 ng/mL)	RP GC	24.60±1.98 19.77±0.74	27.88±3.67[a] 22.43±5.40	23.17±5.53[b] 25.68±3.68[a]	NS S
Total proteins (TP) (g/dL) (6.6-8.7 g/dL)	RP GC	7.70±0.44 7.73±0.32	7.73±0.51 7.77±0.38	7.80 ± 0.55 7.78±1.11	NS NS

Data is expressed as Average ± Standard Deviation. The Wilks lambda test was carried out to check for variations throughout the different study phases. Statistical significance was indicated with $p<0.05$.
Significant differences during the study period calculated using the Scheffé test.
a: Significant difference vs. T1, $p < 0.05$.
b: Significant difference vs. T2, $p < 0.05$.

Table 5. BORG CR-10 Determining perceived effort in the basketball players from the recovery group (RP) and the control group (CG).

Test	Group	Time			Sign.
		T1	T2	T3	p
BORG CR-10	RP GC	7.62±2.13 7.03±1.79	5.14±1.98[a] 8.64±1.26[a]	4.12±2.06[a] 8.96±1.16[a]	S NS

Data is expressed as Average ± Standard Deviation. The Wilks lambda test was carried out to check for variations throughout the different study phases. Statistical significance was indicated with $p<0.05$.
Significant differences during the study period calculated using the Scheffé test.
a: Significant difference vs. T1, $p < 0.05$.

Table 6. Determining quadriceps strength by dynamometer in the basketball players from the recovery group (RP) and the control group (CG).

Test	Group	Time			Sign.
		T1	T2	T3	p
Quadriceps dynamometer	RP GC	77.42±8.34 71.06±7.91	78.41±6.82 68.97±7.26[a]	80.10±7.31 68.66±8.27	NS NS

Data is expressed as Average ± Standard Deviation. The Wilks lambda test was carried out to check for variations throughout the different study phases. Statistical significance was indicated with $p<0.05$.
Significant differences during the study period calculated using the Scheffé test.
a: Significant difference vs. T1, $p < 0.05$.

Depending on the intensity of the exercise performed, physiological recovery times vary, from hours right up to a week, meaning the different recovery systems develop a different muscle-skeletal evolution[27,30]. As a result of muscle pain and muscle fatigue in athletes, muscle strength drops, as well as work capacity and sporting performance. Deterioration occurs in the muscle's capacity to store glycogen, the ultra-structural alteration of the sarcomere associated with the increase of decomposition of contractile muscle proteins, and exacerbated inflammatory responses[1,31,32].

Until this study was performed, the effects of CC as a muscle recovery therapy had not been researched in real, long-term situations (8 weeks), during a pre-season of high physical requirement training sessions. In turn, some studies indicate that a single episode of cold therapy[26] or compression stockings[9,25] after exercise do not significant modify muscle recovery. Therefore, the optimum duration and the combination of recovery interventions, of cold and compression, are not well defined collectively in athletes.

In our study, recovery intervention with CC was performed daily after each training session and matches. In both study groups (RP and CG), CK and LDH activity displayed levels above the physiological range at the start of the study (T1), revealing a progressive decrease in the muscle pain markers at the end of the pre-season in the RP group (T3). However, the CG increased the markers of the muscle metabolism levels LDH and CK (T1 vs. T3 $p<0.05$). In terms of the Mb of the RP group, it followed a different pattern during the season to that of the CG, with no significant changes observed in the duration of the season ($p>0.05$), but with increases in the CG ($p<0.05$). More specifically, after a significant increase between T1 and T2 ($p<0.05$), the Mb then dropped considerably between the following sample points (T2 vs. T3 $p>0.05$), despite the RP group following a greater training and match load, suggesting the high efficiency of the CC programme over long application periods (8 weeks). Conversely, in the CG, in which players did not follow the CC recovery programme, there were increases in Mb, especially in T3, where it increased significantly ($p>0.05$) compared to the start T1, suggesting worse muscle recovery to that observed in the test group.

In this respect, the diverse forms of cryotherapy, including CWI, are effective treatments in reducing the metabolism, inflammation, blood flow, pain, and cutaneous, muscular and intra-articular temperatures[33]. Some studies have used immersions of <10 °C with different treatment durations (3-10 minutes), contracting capillaries, reducing capillary permeability and blood flow, thus reducing swelling and the inflammatory response, which could reduce the negative effects associated with exercise[12,15,33,34]. Furthermore, theories have been made regarding the application of CWI on local inflamed areas, allowing for a reduction in the permeability of the membranes, thus reducing the intracellular-intravascular flow of CK and Mb[33,35], which could explain the results observed in the RP group. In this respect, Seco *et al*[6], report that in the intervention group of basketball players that were treated with CWI, the Mb was significantly lower than in the control group, between the start and finish of the study, and that between both groups the Mb displayed a significantly different behavioural pattern, yielding extremely similar results to those described in this study. Also in the CG throughout the pre-season, evident with the significant increase of ALT (T1 vs. T2 $p<0.05$) and AST, indicative of muscle fatigue[27], in contrast to the levels of the RP group (significant reduction of ALT and AST; T1 vs. T3 $p<0.05$).

After analysing our results, it is relevant that the strength studied in the QS test was greater in the RP than in the control group after recovery at the end of the pre-season. Gains were observed throughout the pre-season in the RP and there was a decrease in the CG. We believe that both the biochemical and strength responses suggest the high effectiveness of the CC muscle recovery strategy used with the test group. These results were supported by reductions in RPE ($p<0.05$), at the mid-point (T2) and at the end of the season (T3), according to the Borg CR-10 rating measurements.

In turn, the use of compression garments applied to local-regional zones, have proven to be effective at reducing some muscle metabolism markers, observing a significant positive effect of compression in CK[24] as well as the Mb[36] and a moderate effect on the attenuation of AST[10]. Nevertheless, previously the positive (yet non-significant) influence was described of compression garments on reducing muscle pain markers, with the significant increase of CK, LDH, AST and ALT on the CG associated to the non-significant increase in the group using compression garments (with no differences between groups)[37]. These results are similar to those we have reported, in which there is a progressive reduction of the muscle pain markers at the end of the pre-season in the RP, which suggests that the compressive therapy we applied stimulates faster recovery.

Our data suggests a positive impact of CC in the long term, and we believe that applying CC via Pressurice Compressport could also potentially be used for short-term muscle recovery due to its synergistic effect based on the collective actions of both recovery tools. A reduction in cutaneous blood flow occurs, as well as changes in the intracellular-intravascular fluid, a reduction of muscle inflammation and an increase in the cardiac output, which could increase blood flow and the possible transportation of nutrients and waste through the body[6,25]. However, previous specific studies are needed to compare and guide the selection of the sample interval.

For the data provided in this study, this work supports the theory that sports medicine techniques such as CC contribute to a better and faster recovery from fatigue, thus improving performance over an extended period of high physical demand. The study also suggested that future research is required to exploit the benefits of therapeutic methods even further, to promote recovery from muscle fatigue, including cheaper methods that require less infrastructure.

We acknowledge that this study faced various limitations. Firstly, the consecutive sample method and the prospective design of the cohort should be considered for future studies with the aim of designing random controlled clinical trials. Moreover, as CC is a recovery practice that encompasses two techniques (CWI and the use of compression garments), the inclusion of the two groups receiving a single therapy would provide a foundation for examining if there is greater muscle recovery, variations in strength and in perceived exertion in CC than in CWI or in the use of compression garments.

To conclude, we believe that applying CC during the pre-season is a potential method of promoting the recovery of muscle damage associated with competition and training. In particular, it has been demonstrated that CC improved muscle recovery in basketball players during an 8-week long pre-season, associated with reductions in muscle pain markers. Furthermore, improvements in muscle strength and the significant reduction of perceived fatigue at the end of the study, suggest a reduction of muscle fatigue in the group of athletes that received CC.

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Conflict of interests

The authors claim to have no conflict of interest whatsoever.

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Effect of strength training on physical and mental health and quality of life of people with spinal cord injury: a literature review

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Summary

Life expectancy of individuals with spinal cord injury (SCI) has increased over the years; although not proportional or equal to that of the general population, there is a slight approximation in life expectancy between the groups. However, the mortality rate in individuals with SCI remains high. SCI is a serious medical condition that causes functional, psychological and socioeconomic disorders. Therefore, people with SCI experience significant disabilities in various aspects of their lives. Strength training has been used as an instrument to improve functional, cardiorespiratory, psychological and quality of life (QoL) parameters. However, studies that discuss the effect of strength training on health-related aspects of people with SCI are still rare. The aim of this study is to review the literature on the effects of strength training on physical and mental health and QOL of people with SCI. A bibliographic research was conducted with subjects related to the SCI, strength training, functionality, health and mental state and QOL. SCI is a complex disability that causes many changes, which can be physical, psychological and social. It is accompanied by comorbidities, which directly affect the health status and, consequently, the QOL of the affected individual. In general, exercise has been postulated as an alternative for health promotion and QOL in people with SCI. In particular, strength training is used to promote physical and mental health and QOL as it produces positive results for different aspects of health and QOL, especially muscle strength and functional capacity, reducing symptoms of anxiety and depression and increasing indicators. of QOL in people with SCI.

Key words:
Spinal cord injury.
Strength training. Mental health.
Quality of life.

Efecto del entrenamiento de fuerza en la salud física y mental y la calidad de vida de personas con lesión medular espinal: una revisión de la literatura

Resumen

La esperanza de vida de las personas con lesión de la médula espinal (LME) ha aumentado con los años; aunque no es proporcional o igual al de la población general, existe una ligera aproximación en la esperanza de vida entre los grupos. Sin embargo, la tasa de mortalidad en individuos con LME sigue siendo alta. ML es una condición médica grave que causa trastornos funcionales, psicológicos y socioeconómicos. Por lo tanto, las personas con LME experimentan discapacidades significativas en varios aspectos de sus vidas. El entrenamiento de fuerza se ha utilizado como un instrumento para mejorar los parámetros funcionales, cardiorrespiratorios, psicológicos y de calidad de vida (CV). El objetivo de este estudio es revisar la literatura sobre los efectos del entrenamiento de fuerza sobre la salud física y mental y la CV de las personas con LME. Se realizó una investigación bibliográfica con temas relacionados con ML, entrenamiento de fuerza, funcionalidad, salud y estado mental y CV. La LME es una discapacidad compleja que causa muchos cambios, que pueden ser físicos, psicológicos y sociales. Se acompaña de comorbilidades, que afectan directamente el estado de salud y, en consecuencia, la CV del individuo afectado. En general, el ejercicio se ha postulado como una alternativa para la promoción de la salud y la CV en personas con LME. En particular, el entrenamiento de fuerza se utiliza para promover la salud física y mental y la calidad de vida, ya que produce resultados positivos para diferentes aspectos de la salud y la CV, especialmente la fuerza muscular y la capacidad funcional, reduciendo los síntomas de ansiedad y depresión y aumentando los indicadores. de CV en personas con LME.

Palabras clave:
Lesión medular espinal.
Entrenamiento de fuerza.
Salud mental. Calidad de vida.

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Introduction

The life expectancy of individuals with spinal cord injury (SCI) has increased over the years. Nevertheless, the mortality rate in individuals with SCI remains high[1,2]. It's possible that rehabilitation and treatment methods for health have evolved, and the increase in life expectancy is directly related to this evolution[3]. The evolution of rehabilitation has occurred as a change in its final goal over time: previously, the purpose was to increase life expectancy, and at present, the focus is on functional independence and quality of life (QoL)[4].

Physical training has been used as a implement to improve functional, cardiorespiratory, psychological, and QoL parameters[5]. One type of physical training is strength training (ST), which is widely used for its beneficial effects on health-related risk factors such as insulin resistance, resting metabolic rate, blood pressure, and body composition, as well as strengthening of the musculoskeletal system, contributing to the maintenance of functionality, and preventing osteoporosis, sarcopenia, heart disease, and various cancers[6].

However, studies that discuss the effect of ST on health-related aspects of people with SCI are still rare. Given the awareness of the increased life expectancy of individuals with SCI, the ease and low cost of performing ST, and the benefits of this type of training for the health of the general population, understanding the possible effects of ST on the health of individuals with SCI may constitute to a non-drug intervention strategy to promote improvements in health, functional independence, and QoL of these individuals.

Thus, the aim of the present study is to perform a literature review about the effects of ST on the physical and mental health and QoL of people with SCI.

Spinal cord injury: definition and classifications

SCI is mainly caused by external trauma and has the potential to unexpectedly modify the life of the injured individual and interfere with professional, recreational, and social activities[7]. It is caused by any trauma that damages the structures contained in the medullary canal, causing temporary or permanent motor, sensory, autonomic, and psychoactive changes or losses[8].

SCI can be classified on the basis of its severity (complete or incomplete) and the level of injury occurrence, and the symptoms presented by individuals with SCI will depend on these two factors. According to the American Spinal Cord Injury Association (ASIA)[9], when there is total loss of voluntary and sensory motor activity in S4–S5, the lesion is classified as complete. When there is any maintenance of motor activity or sensitivity to the sacral segment S4–S5 the lesion is classified as incomplete. As to the level of occurrence of the injury, the loss of trunk, upper, and lower limb function is defined as quadriplegia, and the loss of trunk and lower limb function, as paraplegia[10].

A systematic review analyzing studies published between 2000 and 2016 showed that the worldwide incidence of SCI is 10.5 cases per 100,000 people, resulting in an estimated 768,473 new cases annually[11]. The highest incidence of SCI was found in low- and middle-income countries, affecting more males aged 20–24 years (80% of cases)[8,12].

Regardless of the cause and classification, an SCI can affect the person's physical and mental health, as well as their QoL. Understanding how SCI can affect these aspects of a person's life can aid in the design of intervention strategies to improve their overall health and QoL.

Aspects related to physical and mental health and quality of life of people with spinal cord injury

After SCI, several changes may occur in physiological, physical, psychological, and social aspects of life[13]. These may alter the individual's health condition, leading to reduced life satisfaction and emotional well-being, decreased life expectancy, and consequently, increased mortality[14].

The impact of SCI on the individual's health condition is directly or indirectly related to their physical and psychological diagnosis, and the activity limitations and participation restrictions it imposes on the person in their socio-cultural environment[7]. These impacts may cause several impairments, such as reduced functionality, impairment of body systems, QoL, and psychological aspects such as depression and anxiety.

The health status of an individual with SCI is also compromised by secondary comorbidities such as complications of the urinary, respiratory, and intestinal systems, as well as changes in skin sensitivity and muscle tone[14–19].

SCI can cause long-term complications in the urinary system, leading to bladder dysfunction, often called neurogenic bladder[20]. The most important factor in controlling dysfunction is maintaining continence and preventing the development of upper urinary tract dysfunction.

Respiratory complications in SCI can lead to respiratory muscle failure, reduced vital capacity, ineffective cough, and reduced lung and chest compliance. These respiratory complications will depend on the level of SCI and the degree of impairment[15]. Bowel problems may also occur as a consequence of SCI, common in between 27% and 62% of individuals. The most common complications are constipation, distension, abdominal pain, rectal bleeding, hemorrhoids, and autonomic hyperreflexia. These complications are related to the sacral region. Anterior sacral root stimulation between S2 and S4 may reduce some of the damage[21].

Below the level of the lesion, some or all of the skin's sensitivity will be compromised by failure to send information through the afferent nerves, and this damage can cause heat, cold, impact, and prolonged pressure injury such as pressure ulcer, which is a leading cause of SCI hospitalization[14,22]. Muscle tone dysfunction may also occur, with spasticity being the most common type. Muscle spasticity is characterized by involuntary and continuous muscle contractions caused by changes in and increased excitability of motoneurons and interneurons[16].

Another dimension of health affected by SCI is mental health, especially due to the onset of symptoms related to depression and anxiety. Individuals with SCI have a high incidence of anxiety or post-discharge depression, especially among younger patients (<50 years)[23]. The causes of depression and anxiety are unclear, but some factors assumed to be involved are the abrupt and unexpected nature of the injury itself; the person is unprepared to cope with their new reality and may have difficulties coping[24]. In addition, deterioration of function (for example: respiratory disorder, sexual functioning, balance)[20], pain associated with changes in cognition, anger, or psychosocial impairment[25], and the need for retrofitting of the body in space and the fact that this process is dependent on the help of others, may be factors that help explain the high incidence and prevalence rate of depression and anxiety in individuals with SCI.

All these comorbidities affect the general health status of individuals with SCI and can directly impact their QoL, since health is understood as an element of QoL. However, QoL and health can be understood as two distinct concepts, and correlating the two can be a mistake, as a totally healthy life may not result in high QoL[26].

In addition, the concept of QoL is characterized as aspects of an individual's subjective experience that are directly and indirectly related to health, illness, disability, and treatment effectiveness[27]. It has objective and subjective dimensions. The subjective dimension assumes that QoL may be partially independent of health status and is a reflection of the way individuals perceive and react to their health status and other non-medical aspects of their lives, i.e., the subjective dimension refers to one's own perceptions. On the other hand, the objective dimension is composed of observable conditions or physical functioning and can be assessed by external persons (researcher, physician, evaluator) and/or physical tests[28]. Thus, QoL should be evaluated on the basis of the individual's own concept and not associated with the quantification of objective dimensions related to health.

Accordingly, the theory of the disability paradox, in which people with disabilities who are supposed to have depressed QoL levels report good QoL[29], allows us to understand why, when observing an individual with MSD, their situation may seem adverse; however, they may be able to perform desired activities, and their self-perception of QoL may be positive. Thus, health-related QoL cannot be used exclusively by researchers and physicians as a reference to patients' perceived health[30].

QoL is generally lower in individuals with SCI than in those without SCI, being justified by the severity of the injury and difficulties with adaptation after injury[31]. When assessed by the World Health Organization (WHOQOL) Brief Self-completed questionnaire, the QoL of individuals with SCI was significantly lower than in the general population in the physical, social relationship, and psychological domains. However, the authors suggest that despite the difference, subjective assessment is necessary to better understand the results[32].

A recent cohort study looked at 1-, 2-, and 5-year-olds with SCI, and researchers found that QoL increased over time[33]. The authors' argument to justify this result was that individuals with SCI learn over time to adapt to their situation, and this adaptation seems to reflect a progressive disconnect between symptoms and physical or mental health, leading to a real improvement in physical functioning over time.

Death can be considered to have the greatest negative impact on people with SCI. A higher percentage of individuals with severe injury die in the first year after injury; the most common causes of death are pulmonary alterations, cardiovascular diseases, and infectious diseases[34,35].

One of the causes of mortality in people with SCI is a reduced ability to produce autonomic actions from the central nervous system, thus causing dysfunction in the control of the heart rate and blood pressure and rendering communication between the nervous system and other body systems inefficient[36].

Another important cause of mortality is cardiovascular disease, which is generally associated with sedentary behavior. The low level of physical activity in people with SCI induces a decrease in energy expenditure, which may cause changes in the health condition of these people, such as fat accumulation and overweight and obesity[37]. The combination of SCI and insufficient levels of physical activity can lead to metabolic changes such as hyperinsulinemia, insulin resistance, type 2 diabetes, dyslipidemia, and cardiovascular disease[38]. Thus, a sedentary lifestyle, glucose intolerance, insulin resistance, and a reduced metabolic rate result in a general deconditioning of the individual, with a consequent increased risk of mortality[39].

For all these changes presented by people with SCI, in physical and mental health, as well as in QoL and increased mortality, it is up to professionals involved with the health care of these people to seek strategies to reduce these negative changes caused by SCI. Along these lines, physical exercise has been postulated as a possible non-pharmacological treatment strategy to combat some of these negative changes in the health and QoL of people with SCI.

Benefits of regular exercise for people with spinal cord injury

In an attempt to “cure” and/or rehabilitate an injured/mutilated body, sometimes the process of insertion of physical exercise for people with SCI is palliative, without consideration of its value for leisure, as well as social, psychological, and physiological well-being.

In general, the regular practice of physical exercise has several beneficial effects for individuals with SCI; the most prominent and researched of these are the benefits that it brings to the functional state and QoL[40]. The effects of exercise on psychological health, especially on the symptoms of depression and anxiety, are still not well studied.

Recently, new guidelines on the prescription of exercise to promote physical and cardiometabolic health in people with SCI[41] stipulate that, in order to improve cardiorespiratory fitness and muscle strength, individuals with SCI should practice at least 20 minutes of moderate to vigorous exercise twice a week and three sets of strength exercises for muscle groups with moderate–vigorous intensity, also twice a week. For cardiometabolic health benefits, the guidelines state that at least 30 minutes of moderate to vigorous aerobic exercise should be performed three times a week.

The lower values of volume and intensity are due to the fact that people with SCI are less active, thus adopting a sedentary behavior and, consequently, lower their level of physical conditioning[42,43] argue that the dose response for physical exercise will depend on several factors and that health benefits can be achieved with lower volumes and intensities in apparently healthy individuals and those with chronic clinical conditions. Thus, individuals with SCI may experience improvements in fitness and health indices from lower doses of exercise[41].

ST has been evidenced in the exercise prescription guidelines for people with SCI, as it is a type of exercise that provides improvements in neuromuscular, cardiometabolic, and functional components[41]. In addition, this type of exercise also seems to induce improvements in overall physical health, mental health, and QoL, and is therefore a possible strategy to use when promoting health and QoL of people with SCI.

Effects of strength training on functional aspects of people with spinal cord injury

One of the main goals of ST for individuals with SCI is to increase strength to improve functionality in activities of daily living[44]. However, for the promotion of benefits in functional capacity and strength of people with SCI, there is no well-defined standardization regarding intensity and volume. The average of intervention is 2x to 3x per week lasting 40 minutes, with intensity that can vary from 50% to 100% of the maximum dynamic strength (1RM), and the main focuses are the superior functional muscles[41,45].

Serra-Añó[46] conducted a study to evaluate the effect of a resistance shoulder training program on isokinetic and isometric strength, body composition, pain, and functionality in paraplegic individuals. The program lasted 8 weeks with a frequency of 3 times a week, with 8 exercises performed at 70% of 1RM. The results showed increased isometric and isokinetic shoulder strength, increased fat-free mass, reduced arm fat mass, reduced shoulder pain, and increased functionality.

Bye[47] in studied the effect of ST on partially paralyzed muscles of newly injured individuals who underwent 12 weeks of training, with a weekly frequency of 3 times, using isometric exercises and concentric actions. Subjects were stimulated into a target muscle on one side of the body, and the control was the unstimulated opposite side. Training increased isometric strength in trained and unstimulated muscles, suggesting improvement in strength of partially paralyzed muscles, although it is not clear whether the training effect was clinically significant.

ST for individuals with SCI has also shown positive effects, such as increased muscle strength, anaerobic power, and increased peak oxygen uptake (VO_2peak) in response to a 12-week training program with an intensity of 60% to 70%. of 1RM and the use of a hand cycle ergometer, with an intensity between 70% an 85% of the heart rate[48].

Thus, ST programs with different configurations and different volumes and intensities induce an increase in muscle strength in individuals with SCI, which can directly or indirectly impact the improvement of these individuals' functional capacity. However, few studies use only ST as an intervention strategy, since ST is often associated with a rehabilitation program.

Effect of strength training on mental health and quality of life of people with spinal cord injury

In addition to the intrinsic relationship of QoL with general health, mental health is also inserted in this context, since psychological problems such as depression and anxiety can negatively affect QoL. Along these lines, regular exercise has beneficial results and has been shown to reduce symptoms of depression and anxiety[49,50].

The benefits of regular exercise for relieving symptoms of depression and anxiety can be proposed as distraction, self-efficacy, and social interaction. Distraction is related to the deviation of unfavorable stimuli that can lead to mood improvement after exercise. Self-efficacy proposes that the challenging view of exercise can stimulate self-confidence. Finally, the social interaction inherent in the practice of supportive physical exercise among those involved can lead to positive effects on psychological health[51].

The discussion about QoL is directly involved with the discussion about the most diverse aspects of the health of people with SCI. Along these lines, different exercise programs can be used to promote health and QoL in these people.

Kemp *et al*[52] evaluated the effect of a 12-week ST program, 3 times per week, with an average of 11 repetitions using low-intensity exercises, by supporting the body itself, on the relationship between pain and shoulder movement in individuals with SCI. The results showed a two-thirds reduction in basal shoulder pain levels, and this pain reduction allowed individuals to successfully participate in their social and daily life activities, with consequent improvement in QoL and physical and social functions. However, there was no increase in physical activity level (assessed by wheelchair propulsion speed and physical activity scale score for individuals with physical disabilities). The authors admit that the questionnaire may not have been sufficient to evaluate, since it only analyzes quantity and not quality of physical activity.

Another study showed that both the traditional rehabilitation method (5 days a week, 60-minute daily sessions for 6 weeks, including sitting, balancing, wheelchair transfer, mobilization, and functional exercise) and addition of circuit training performed for 6 weeks, 5 days a week, and lasting 60 minutes with progressive loads of 50% to 100% of 10RM were able to increase QoL due to increased functionality[53].

Thus, ST programs also seem to be an efficient alternative intervention in people with SCI when aiming at improving mental health and QoL. Future studies on this topic will define the mechanisms by which exercise would act on the symptoms of anxiety and depression, as well as determine the magnitude of the impact of participation in ST programs on the improvement of QoL in people with SCI.

Conclusion

SCI is a complex disability that causes many changes, which can be physical, psychological, and social. It is accompanied by comorbidities, and these directly affect the health status and, consequently, the QoL of the affected individual.

In general, physical exercise has been postulated as an alternative for health promotion and QoL in people with SCI. ST especially is a strategy to promote physical health, mental health, and QoL, as it presents positive results in different aspects, especially in terms of improving muscle strength and functional capacity, reducing symptoms of anxiety and depression, and increasing the general indicators of QoL in people with SCI.

Conflict of interest

The authors do not declare a conflict of interest.

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Methods for measuring physical activity in children and their relationship with nutritional status: a narrative review

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Summary

In recent decades, overweight and obesity have become a global epidemic that affects not only the adult population but also children and adolescents. In Spain the prevalence reaches 46%, with a greater presence in men. On the other hand, in some countries of Latin America the rates are close to 50% of overweight and obesity in children between 5 and 9 years old. Excess weight negatively affects the motor function of a child, causing a low ability to develop basic motor skills such as balance, gait and jumping. Also, overweight and obesity in children have been associated with a low motor repertoire, which translates into a delay in psychomotor development. These alterations influence the low motivation and interest in physical activity (PA) and less integration in games and sports practices. PA can be measured in different methods in children, the most commonly used instruments being pedometers, accelerometers and self-report questionnaires. The relationship between the level of PA and the nutritional status behaves in an inverse manner, that is, those with a higher BMI have low levels of PA. This occurs mainly in children older than 7 years old, since in children of lower ages this relationship is inconsistent. On the other hand, it has been possible to demonstrate the negative effects of low PA on motor skills and physical fitness in children, which is exacerbated by overweight and obesity in children. The regular performance of PA favours the development of motor skills in children with excess weight, favouring a more active participation in sports activities. Consequently, the development of effective intervention programs specifically targeting motor skills and physical fitness could help break the vicious circle of obesity and reduce the prevalence of comorbidities.

Key words:
Overweight. Obesity. Physical activity. Children.

Métodos de medición de la actividad física en niños y su relación con el estado nutricional: una revisión narrativa

Resumen

En las últimas décadas, el sobrepeso y obesidad se han convertido en una epidemia mundial que afecta no solo a la población adulta sino también a niños y adolescentes. En España la prevalencia alcanza el 46%, con mayor presencia en hombres. Por otro lado, en algunos países de América Latina, las tasas se acercan al 50% del sobrepeso y obesidad en niños de 5 a 9 años. El exceso de peso afecta negativamente la funcionalidad del niño, causando una baja capacidad para desarrollar habilidades motoras básicas como el equilibrio, marcha y salto. Además, el sobrepeso y obesidad en niños se han asociado con un bajo repertorio motor, que se traduce en un retraso del desarrollo psicomotor. Estas alteraciones influyen en la poca motivación e interés en la actividad física (AF) y en una menor integración en juegos y prácticas deportivas. La AF puede medirse con diferentes métodos en niños, siendo los instrumentos más utilizados los podómetros, acelerómetros y cuestionarios de autoreporte. La relación entre el nivel de AF y el estado nutricional se comporta de manera inversa, es decir, aquellos con un IMC más alto tienen niveles bajos de AF. Esto ocurre principalmente en niños mayores de 7 años, ya que en niños de edades más bajas esta relación es inconsistente. Por otro lado, ha sido posible demostrar los efectos negativos de bajo nivel de AF en las habilidades motoras y condición física en niños, que se ve agravada por el sobrepeso y obesidad. La práctica regular de AF favorece el desarrollo de habilidades motoras en niños con exceso de peso, favoreciendo una participación más activa en actividades deportivas. En consecuencia, el desarrollo de programas de intervención eficaces dirigidos específicamente a las habilidades motoras y condición física podría ayudar a romper el círculo vicioso de la obesidad y reducir la prevalencia de comorbilidades.

Palabras clave:
Sobrepeso. Obesidad. Actividad física. Niños.

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Introduction

In recent decades, overweight and obesity have become a global epidemic that affects not only the adult population but also children and adolescents. In 2010, the prevalence of overweight and obesity among pre-school children increased by 60% since 1990, affecting some 43 million children worldwide[1]. In the United States of America, 29% of children and adolescents have excess weight[2], while in Spain the prevalence reaches 46%, with a greater presence in men[3]. On the other hand, in some countries of Latin America the rates are close to 50% of overweight and obesity in children between 5 and 9 years old[4].

Excess weight has a negative effect on a child's motor function. Studies have described that children who are overweight and obese have a low ability to develop basic motor skills such as balance, gait and jumping[5-8]. Also, overweight and obesity in children have been associated with a low motor repertoire, which translates into a delay in psychomotor development[6,9]. These changes influence the low motivation and interest in physical activity (PA) and less integration in games and sports practices[6,10]. It has been described that the motor capacity improves with the regular practice of PA, where the motor performance is related to the quantity and diversity of motor proposals that are offered to children[10].

For its part, PA plays an important role in the prevention of overweight and obesity in childhood and adolescence, and in reducing the risk of obesity in adulthood[11]. Although the levels of PA in adolescents have been studied more frequently, those of children have not received as much attention[12]. Currently, the most important official reports on PA levels in children have been based on data obtained through pedometers, accelerometers and self-report questionnaires. Many countries and organisations have developed PA recommendations for children and young people of school age[13]. With few exceptions, these countries and organisations recommend that children and adolescents should participate in at least 60 minutes of moderate to vigorous daily PA[14,15]. It has been seen that children who have higher levels of PA have a better physical fitness and greater development of motor skills[15]. Therefore, studying the levels of regular PA and its consequences in children has become a major challenge in both health and research.

Methodology

Search strategy

In the period between October 2018 and February 2019, an exhaustive search was performed of the scientific literature concerning the existing links between the PA level and the nutritional status in children. To discover and obtain the academic articles, PubMed, Scopus, Sciencedirect, SciELO and Ovid databases were used.

Combinations of the following key terms were used to search the above databases: PA level terms ("physical activity", "exercise"); Children terms ("children", "child", "schoolchildren" and "creschool child"); general measurement terms ("measures", "measurement", "instruments", "tools", "tests", "assessment", "testing"); nutritional status terms ("obesity", "pediatric obesity", "overweight", "body mass index"); and functional terms: ("fitness", "motor development", "motor skills").

Study selection

The articles compiled are in Spanish, English and Portuguese. The selection was performed using three filters: 1) The articles taken from the database were initially selected for their titles, ruling out publications that were clearly not related to the study objective; 2) Next, the abstracts were read, selecting the studies that were directly related to the central interest of this work, identifying the publications that appeared in more than one database. Then the complete texts of the potential articles were recovered to be put through the final filter; 3) In this phase a critical reading, analysis and assessment was performed on each study, to check the methodological truthfulness and quality. Each study was assessed independently by at least 3 of the authors. Finally, to develop each component of this study, publications with the highest relevance and importance were included.

Results

Next the exhaustive review of the literature obtained during the search of the consulted databases uncovered a total of 115 potentially eligible articles, of which a sample of 39 articles was taken of those in which the authors backed up their findings with the best theoretical bases, as well as using effective methodology and having greater scientific relevance.

Instruments to quantify the level of PA in children

Pedometry

Consists of counting the number of steps a subject gives through an internal sensor that detects accelerations and decelerations in a single direction of movement when taking a step[16]. In general, it provides a measure of the total PA in a given period of time, however it is unable to measure intensity, record activities such as cycling and detect increases in energy expenditure due to transport of objects or walking and running on a slope[16]. Recent studies have summarised the considerations for evaluating PA using pedometers in children[17-19]. These reviews have provided recommendations regarding the monitoring periods and the time of use of the pedometer. It has been suggested that it takes between 4 and 9 days to capture the usual activity in children and adolescents[19,20]. However, compliance decreases with increases in the monitoring period; therefore, it is more feasible to opt for 4 full days with at least 1 day of the weekend[17]. A problem related to the monitoring of the frame is the time of use of the pedometer. In monitoring studies, participants are usually asked to record in a diary the time of the morning the pedometer was placed, along with any time during the day they left. It has been recommended that in the monitoring studies the data of a particular day be excluded if a participant reports on the elimination of his pedometer for more than 1 hour on that day[17,21]. It is recommended to use from 3 years onwards regardless of their nutritional status[19,22], however most studies have evaluated children older than 5 years[19]. The recommendations establish that children of both genders should walk at least 12,000 steps/day to be classified as physically active[23]. In addition, Tudor-Locke *et al.*[24] have proposed different values for boys (15,000 steps/day) and girls (12,000 steps/day) in order to prevent childhood overweight and obesity, measured by body mass index (BMI).

Accelerometery

Accelerometers are the most used method to objectively quantify PA and have been used in different populations[25-27]. Accelerometers quantify movement over a period of time by measuring the frequency, duration, and intensity of the PA, as well as the PA patterns[26,27]. During the last few years there has been a great increase in the number and variety of PA monitors commercially available in the market. Accelerometers are reasonably reliable and valid measures of PA. Its small size makes it a practical and comfortable instrument to wear. Accelerometers can provide a comprehensive profile of the behaviour of the PA, describing the total amount and intensity of the PA, the when and how the PA accumulates, and when periods of inactivity occur[28]. However, they do not provide information on the type of activity and cannot estimate whether people are walking with or without a load[28]. Most appropriate, is that the accelerometer is worn for seven consecutive days, since the subjects do not follow the same pattern of PA every day. Other authors, however, indicate that 5 days is enough, including the weekend. In order to analyse the PA record and follow up, most authors agree that subjects must fill out a "record sheet" to supplement the data acquired by the accelerometers[28]. The use of accelerometery is a widely accepted form of objective monitoring of free-living PA in children with any nutritional status and it is recommended to use from 3 years onwards due to its simplicity in use, a relatively cheap economic cost and low physical load for participants[29-32].

Among the most commonly used models of accelerometers as PA measurement instruments, are ActiGraph and ActivPal. During the last 10 years, ActiGraph accelerometers (AM7164 or CSA, GT1M, GT3X and GT3X +) have been used to evaluate PA levels and sedentary behaviours at all ages. They are practical and widely used devices that measure accelerations (counts) and are generally worn at the waist with an adjustable strap. Although these devices are used in many studies, they still have some limitations. First, ActiGraph accelerometers do not measure posture, but measure PA and time without movement. Because these accelerometers use traditional vertical accelerations to define sedentary behaviour, the device can reliably detect dynamic events, but cannot distinguish between standing and sitting[33]. As a consequence, the periods of sitting and some standing are classified as sedentary behaviour[33]. Some studies classify standing still as a light PA because standing is related to the large muscles of the lower part of the body and, therefore, a distinction must be made with sedentary behaviour. A second limitation of these accelerometers is that several calibration studies have defined different cut-off points of the accelerometer to estimate time in sedentary behaviour in young children from 3 to 8 years old[34], therefore, there is no clear consensus in this regard. On the other hand, ActivPAL devices are also relatively new accelerometers that are used to measure the activity of daily living and sedentary behaviour in different age groups. It is a small, single-unit, lightweight PA monitor and used at the thigh level. With this accelerometer the position and activity of the limbs can be detected, which gives rise to different postures that will be determined in three different categories depending on the inclination of the thigh (sitting/lying down, standing and walking). Because accelerometery is not able to discriminate between activities when there is no movement (for example, between sitting and standing), the inclination and/or rotation of the thigh could indicate the difference between sitting and standing[35].

Regarding cut-off points to classify PA levels in children, Riddoch *et al.*[36] revealed that 3 METs were equivalent to roughly 1000 counts per minute (cpm) among 9-year-old children, establishing it as the cut-off score to discriminate active and inactive children. However, Puyau *et al.*[37] defined physically active children as activity counts above 3200 cpm. The lack of standardization regarding how accelerometers are used, which outcome measures are used and how the output is interpreted[38]. This limits comparability between studies and the accumulation of knowledge relating to children's activity[38].

Self-report questionnaires

PA can be measured objectively by different methods, requiring special devices that can be very expensive and impractical for population studies in children[39]. Therefore, subjective methods using questionnaires represent a viable tool for studies based on large populations[40,41]. The self-report questionnaire used internationally to estimate the level of PA is the *Physical Activity Questionnaire for older Children* (PAQ-C). This is a self-administered questionnaire designed to measure moderate to vigorous PA performed in the last 7 days in children and adolescents[42,43]. It consists of ten items, nine of which are used to calculate the level of activity and the other item assesses if any illness or other event prevented the child from doing their regular activities in the last week[42]. The administration time of the instrument is around 20 minutes[44]. The overall result of the questionnaire is a score of 1 to 5, so that higher scores indicate a higher level of activity. The PAQ-C in its original version has shown a good internal consistency, test retest reliability, and has been shown to correlate with other instruments that measure PA as the accelerometer[45]. The recommended ages for the administration of PAQ-C range between 8 to 12 years and any nutritional status[46]. After 12 years there are other questionnaires such as Physical Activity Questionnaire for adolescents (PAQ-A)[44]. Due to the nature of children's activity and children's limited ability for recall, objective techniques are recommended for the assessment of their PA in children under 8 years[38]. For the PAQ-C the cut-off point near 2.75 has been suggested to discriminate between children with low and high PA levels[47].

Table 1 shows a comparative of the most used instruments to measure the level of PA in children.

Relationship between the level of PA and nutritional status in children

Among the main factors that influence the nutritional status of children, the level of PA is considered as one of the most determining[48,49], however, the information available is inconsistent and controversial regarding the relationship between the level of PA and nutritional status in children. There are studies that indicate that children who are overweight and obese have a low level of PA compared to their similar normal weight[48-54]. More active children present lower body fat percentage, as well as lower values of the BMI[55]. Muros *et al*. (2016), reported negative associations between the BMI and the percentage of

Table 1. Comparison of the instruments of measurement of physical activity in children.

	Pedometry	Accelerometery	Self-report questionnaires
Type of measurement	Direct	Direct	Indirect
Economic cost	Medium	High	Low
Evaluation time	4-9 days[19,20]	5-7 days[28]	20 minutes[44]
Recommended ages	From 3 years old onwards[19,22]	From 3 years old onwards[31,32]	8-12 years of age[46]
Advantage	Portable and objective method that allows to evaluate any type of population. In children, you do not need to be able to understand instructions or remember their activities[16].	Portable and objective method that allows to evaluate any type of population. In children, you do not need to be able to understand instructions or remember their activities[28].	Recommended for large populations for simplicity of application and time required for evaluation[38,44].
Disadvantage	Inability to measure intensity, record counts during cycling and record increases in energy expenditure due to carrying objects or walking/running uphill[42]. The display of the step counter in children can alter the measurement (it is recommended to 'blind' children to their scores by sealing the pedometers)[16,38].	Lack of standardization regarding how accelerometers are used, which outcome measures are used and how the output is interpreted[44]. This limits comparability between studies and the accumulation of knowledge relating to children's activity[38].	Its use depends on the ability of children and parents to remember their activities in the last 7 days[38].

fat with the level of PA measured through the PAQ-C in schoolchildren between 9 and 11 years old, that is, children who performed lower PA had a tendency to be overweight and obese[48]. In this same context, the systematic review carried out by Jimenez-Pavon *et al*. concluded that the high levels of PA measured with pedometry and accelerometery showed a protective factor in the development of corporal adiposity and childhood obesity[49]. Compared to non-obese children, obese children are less active and participate less in moderate and/or intense activities, with predominance of low intensity activities[56,57]. However, when it is considered that the chance for an obese child to be less active is twice higher than a normal weight children[55], this reinforces the hypothesis that the nutritional status can determine the level of the PA in obese children[49], and to make difficult to control the excessive body fat. This means that those children are less active than the obese ones, rather than being obese simply because they are less active. But it is worthy to mention the importance to practice physical activities, once active children from early ages are more likely to remain active in the adult age[55].

On the other hand, there are investigations that indicate that the level of PA does not influence the nutritional status in children[58-61]. Nava *et al*. (2011), evaluated children between 4 and 7 years old through a self-report questionnaire and found a significant relationship between the level of PA with eating habits, but not with nutritional status, which coincides with what was described by other authors[62,63]. The results in this age range are interesting because apparently the influence of PA does not manage to impact as strongly as it does in later stages of childhood. It has been reported that the first parameter that is modified with the change of eating habits is PA, and that the affectation of anthropometric parameters, such as BMI, manifests itself in prolonged periods of behavioural changes[62].

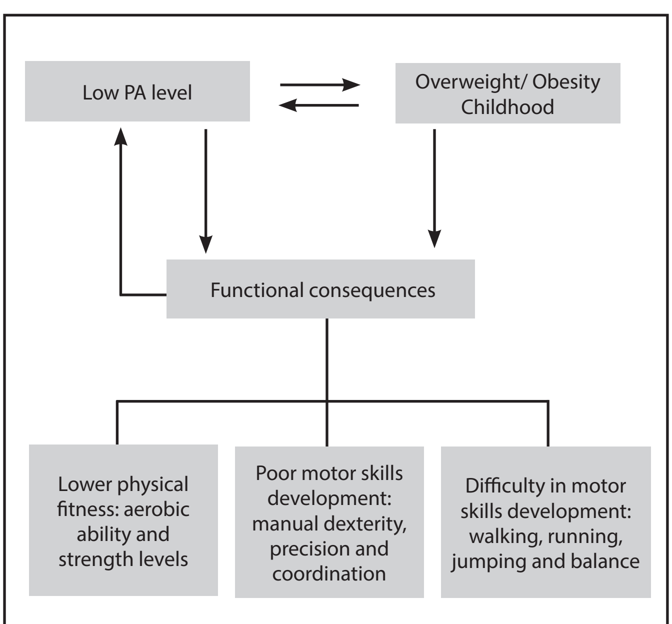
Impact of the low level of PA on motor function of children with overweight and obese

PA is often assumed to be causally related to motor function, suggesting that the most active individuals usually have a better physical fitness and motor ability. However, there are few studies that describe the functional consequences of low levels of PA in children. It has been seen that children under 12 years are overweight and obese, and also with a low level of PA have a lower cardiorespiratory fitness and lower levels of force upper and lower body compared to children with high levels of PA[48]. In this sense, the studies indicate that males have better physical fitness than girls in the variables of cardiovascular endurance, muscular strength, muscular endurance, speed and power[48,64]. With respect to motor development, it has been reported that children with low levels of PA have a poor development of motor skills such as control of objects, precision, coordination and postural balance[65,66]. Also, it has been described that children with low levels of PA have less ability in the development of motor skills such as walking, running and jumping[67-71]. Burgui *et al.* (2011), observed weak to moderate associations between PA and motor skills (that is, agility and balance) in pre-schoolers[72]. They found that higher baseline PA was associated with beneficial changes in motor skills at follow-up. This data suggest that the relationship between PA and motor skills is dominated by the impact of PA on motor skills[72]. This would be in accordance with the model of Stodden *et al*. (2008) that assumes that young children's PA might drive their development of motor skill competence[73]. This model suggests that in early childhood the relationship between PA and motor skills is still weak, but strengthens over time[73]. It appears plausible to argue that in young children, initial high motor skills performance levels per se do not guarantee a more active lifestyle, but that there is a need to continuously promote PA throughout childhood[72].

Fang *et al*. (2017), indicated that PA was positively associated with agility, balance, and aerobic fitness[74]. Physical fitness among normal-weight preschool children was significantly better obese and overweight children were less physically active and had lower physical fitness than normal-weight children in comparison to their overweight counterparts[74]. Similar results were reported that obese and overweight children were less physically active and had lower physical fitness than normal-weight children[75]. Research has noted a gender difference in the relationship between fitness and PA level. In boys, it has been proposed that a high level of PA has a relationship with body fat, upper limb muscular strength, explosive strength, agility and aerobic fitness[74]. For girls, a high level of PA showed associations with balance, agility and aerobic fitness[74].

A hierarchical order of development of motor skills has been proposed that includes four levels: reflexes, fundamental motor skills, transitional motor skills and specific skills of the sport[76]. The progression through each level occurs over time as a result of growth, maturation and experience. However, failure to achieve optimal competencies in basic and transitional motor skills limits the development of PA and, consequently, promotes the development of overweight and obesity in children[69,70,76]. Therefore, low levels of PA during childhood combined with excess weight contribute to poor physical fitness, and reduce confidence in the motor skills of these children to participate in sports and PA[77]. In contrast, the improvement of motor skills has the potential to improve children's motivation to participate in PA due to better self-esteem and greater fun, which could help break the vicious circle of obesity (Figure 1)[77,78].

Figure 1. Functional consequences of the low level of PA and its relationship with childhood overweight and obesity.



Although several investigations have shown that an PA program improves motor skills and physical fitness in children[79-84], there are few studies that have analysed the effects of PA on motor function, specifically in groups with excess weight. Among the interventions through PA in obese children, it has been seen that in 13 weeks, with sessions of 3 times per week, the motor skills improved, specifically, precision skills, manual dexterity, coordination and balance[85]. While other authors have proposed that intervention programs between 8 and 9 months (2-3 times per week) improve motor skills such as walking, running and jumping in children with overweight and obesity[86-88]. Consequently, PA can positively impact the motor function of overweight and obese children, helping to reduce the presence of comorbidities[89].

Conclusions

PA can be measured in different methods in children, the most commonly used instruments being pedometers, accelerometers and self-report questionnaires. Due to their portability, objectivity in measurement and consensus on cut-off scores to classify PA levels, pedometers seem to be the most recommended measurement method in children of all ages. Although acceleremotres are an alternative that delivers a greater number of variables, in children there is little consensus regarding cut-off scores to determine the PA level. For its part, the self-report questionnaires are the most economical and simple alternative, in children under 8 years of age their use is not recommended.

The relationship between the level of PA and the nutritional status behaves in an inverse manner, that is, those with a higher BMI have low PA levels. This occurs mainly in children older than 7 years, since in children of lower ages this relationship is inconsistent. On the other hand, it has been possible to demonstrate the negative effects of low PA on motor skills and physical fitness in children, which is exacerbated by overweight and obesity in children. The regular performance of PA favours the development of motor skills in children with excess weight, favouring a more active participation in sports activities. Consequently, the development of effective intervention programs specifically targeting motor skills and physical fitness could help break the vicious circle of obesity and reduce the prevalence of comorbidities.

Conflict of interest

The authors do not declare a conflict of interest.

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- Sistemas complejos y deportes de equipo.
- Respuestas fisiológicas y patológicas de la frecuencia cardiaca y de la tensión arterial en la ergometría.
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