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Quantification and Description of Physical Exercise

Cuantificación y descripción del ejercicio físico

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Physical exercise is a core therapeutic modality in the practice of sports medicine, physical medicine, and rehabilitation that can be described as muscular activity that is planned, structured, repetitive, and purposeful for the improvement of functional movement capability. It has been shown to benefit patients with a wide variety of conditions such as neurologic injuries, musculoskeletal conditions, cardiorespiratory diseases, cancer, and many others. Further, it is practiced by persons with a wide variety of disabilities and Paralympic athletes. It encompasses combinations of concentric, eccentric, and isometric skeletal muscle actions[1]. In keeping with the standardization of procedures in the reporting of various types of research and the increased requirements for scientific manuscript preparation, it is vitally important that investigators conform to standard terminology. Failure to use appropriate terminology and the use of inappropriate measurements can adversely affect meaningful communication. The need for standard terminology is also evident in clinical settings where different health professionals must communicate and discuss rehabilitation interventions.

The International System of Units

First presented in 1960, an international system (SI)[2] has been universally accepted as the system of quantification for exercise performance. The units employed for quantifying exercise are mass (grams, kilograms), force (Newtons), energy (Joules), work (Joules), heat (Joules), distance (meters), torque (newton-meters) volume (liters), time (hours, minutes, seconds) and power (Watts) (Table 1). The Newton is the basic unit of force, but it is rarely presented in the research literature because "free weights" and weight stack machine plates are manufactured and labeled in terms of their kilograms of mass. The force for lifting 1 kg of mass against gravity is equal to 9.81 N on most of the earth's surface.

Energy, work, and heat are interrelated and, therefore, have the same unit of quantification, the Joule. As related to exercise, they conform to the equation:

Energy (J) = Work (J) + Heat (J). The energy released in the active skeletal muscle cells to produce body movement may result in mechanical work being performed. If no work is performed as a result of the muscular activity, all of the energy will evidence as heat. For dynamic human performance, the typical mechanical efficiency of 20% would result in 5 J of energy producing 1 J of work and 4 J of body heat.

Table 1. Certain base and derived units of the SI.

Quantities	Units	Symbols
Length	centimeter, meter, kilometer	cm, m, km
Time	second, minute, hour	s, min, h
Mass	gram, kilogram	g, kg
Volume	liter	l
Force	Newton	N
Torque	Newton-meter	N-m
Work	Joule	J
Energy	Joule	J
Heat	Joule	J
Power	Watt	W

Human Performance

Strength (maximal force or torque) can be measured for every movement of the human body and is, in part, dependent on the speed of movement. A system of strength assessment and exercise program design was presented in 1945 as the Repetition Maximum system by DeLorme[3]. Assessing a person's ability to exert force or torque via free weights or an exercise machine is determined as the resistive force or torque that can barely be performed for a given number of repetitions (R) and is termed a "repetition maximum" (RM). The highest resistance that can be performed for only one movement thru the full range of motion of a joint is identified as the 1RM for the particular movement and is defined as an individual's strength for the movement. Muscular endurance for a movement is often quantified as the weight with which an individual can barely perform a given number of repetitions (e.g. 10RM).

Aerobic exercise involving large muscle activity, such as in walking, running, bicycling, cross country skiing, exercise on treadmills, elliptical machines, rowing machines, exercise cycles, and other endurance exercise machines depends in great part on the delivery of oxygen from the lungs to the active muscles.

Utilizing a special ergometer for the performance of leg "cycling" exercise[4], it was possible to evaluate subjects through the entire range of power production from long term (e.g., 20 minutes or longer) to the

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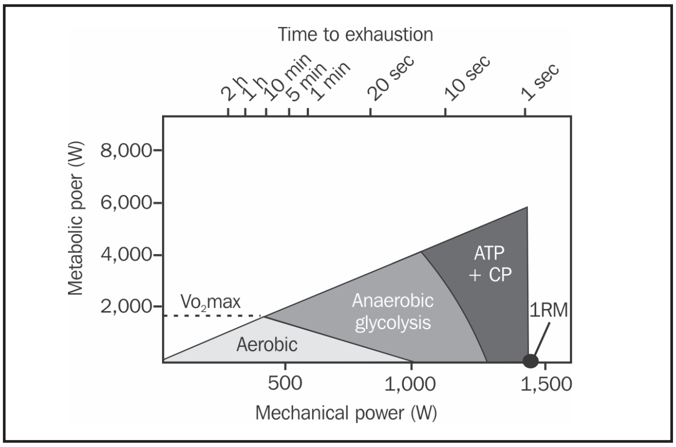
Figure 1. Relationship of sources of metabolic power vs. mechanical power for the leg exercise of a 80 kg male subject on a cycle ergometer at an rpm of 60/min. The upper horizontal coordinate presents the time to exhaustion at the various levels of mechanical power.



highest force and torque development (as in the RM system). In Figure 1, metabolic power is plotted *vs.* the mechanical power that the subject transfers to the exercise ergometer. The metabolic power is provided in the muscle cells via aerobic metabolism of carbohydrate and fat, via anaerobic metabolism (with production of lactic acid), or directly from the high-energy phosphates (ATP and CP) as dependent on the intensity of the exercise.

At the lower intensities of exercise, the muscles provide energy exclusively through the aerobic metabolism of carbohydrates and fats (e.g., in this example, for as high as 450 W of mechanical power). The aerobic metabolism is measured via spirometry and identified as the rate of oxygen uptake in the lungs and referred to VO_2 (l/min). As the subject approaches maximal oxygen uptake (VO_2max), the muscles turn increasingly to the anaerobic metabolism of carbohydrate with the production and appearance of lactic acid in the muscles and into the circulating blood. Between 450 W and 1,300 W, power for the exercise relies predominantly on anaerobic glycolysis and, above 1,000 W and exercise to exhaustion in less than 20 s, increasingly on the energy from the high-energy phosphates, ATP and CP, that are stored in the muscle cells.

Exercise prescription

Most exercise programs for conditioning and rehabilitation are oriented either to strength development, to aerobic (cardiovascular) fitness, or to a combination of the two[5]. Because strength performance and aerobic performance are located at the opposite extremes of the muscular power continuum (Figure 1), the design of a program must be highly specific as regards the exercise to be undertaken. This includes the intensity, duration, frequency (daily and weekly), and type of exercise in order to attain optimal results. Strength exercise programs involve free weight training or the use of high-resistance machines, in both cases with exercise that is limited to a few repetitions in a set (generally less than 20) before exhaustion. Aerobic exercise involves exercise performed for extended periods (e.g., 10-40 minutes) with large muscle activity involving hundreds to thousands of consecutive repetitions that challenge the delivery of oxygen to the active muscles. The chronic physiological adaptations and the variables in program design are highly specific to the type of exercise performed.

Strength exercise performance is mainly related to the recruitment of Type 2 (fast-twitch) skeletal muscle cells that will respond to systematic training by increasing in cross-sectional area, anaerobic metabolic capacity, and force development. Aerobic exercise relies on Type 1 (slow-twitch) muscle cells and appropriate training programs can be expected to improve both the oxidative processes in the cells and the ability of the cardiorespiratory system to deliver oxygen.

Utilizing the performance of the subject in Figure 1, exercise for the improvement of aerobic performance and cardiovascular capacity would involve the range of power output from 300 to 450 W which this subject could sustain resulting for many hours to a few minutes. Strength exercise prescription would involve performance exercise in the range of 1,000 – 1,400 W (e.g., 20RM – 1RM). Testing of various other movements and the related muscles would yield a wide variety of power values and must be determined by methodical testing.

The term, "work", should never be employed as an alternative to "exercise" because it is specifically defined in the SI as the product of force and a displacement and not of continuing muscle activity. The term, "workload", should not be employed when the unit of measurement presented is for "power" (W). Strict adherence to the definitions of the SI will insure standardization of terminology and make scientific communication more readily understandable to the worldwide scientific community.

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Characteristics of physical activity during recess: an analysis with Galician Elementary and Secondary Education students

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Summary

Introduction: The analysis of the characteristics of physical activity during recess is highly important in the fight against childhood obesity rates and the sedentary lifestyle at an early age. There is a need to broaden the knowledge on this topic, delving into the types of activities, their intensity, the geographical area in which they are carried out, etc. Thus, the purpose of this study was to examine the characteristics of physical activity during recess in the last two years of Elementary Education and Compulsory Secondary Education in schools of the Atlantic axis.
Material and method: The study involved 707 students from Galicia (Spain). 49.08% were male students with an average age of 13.25 ± 1.76 years and 50.91% were female students, with an average age of 13.22 ± 1.77 years. The independent variables were sex, educational level and grade. The dependent variables included the activities performed during recess and their intensity. Data collected used the Recess Physical Activity Recall (Martínez-Gómez *et al.,* 2010) instrument.
Results: It was found that recess time was basically spent eating, resting, going down or up the stairs. Girls played mostly sports for the fun of it and walked more. Boys practiced more competitive sports. The intensity of physical activity was low, with male students and elementary school students being significantly more active.
Conclusions: The time that students spend practicing sports is very limited. The choice of sports is different depending on the sex. The highest activity rates occur after the first ten minutes and are maintained until the end of recess. Greater efforts are needed to change the culture of recreation, optimize time and redesign spaces, placing the focus especially on women and Secondary Education students.

Key words:
Playground. Physical activity levels. Promoting exercise.

Características de la actividad física en el recreo: un análisis con alumnado gallego de educación primaria y secundaria

Resumen

Introducción: El análisis de las características de la actividad física durante el recreo es de gran importancia en la lucha contra las tasas de obesidad infantil y el estilo de vida sedentario en edades tempranas. Se necesita ampliar el conocimiento sobre este tema, profundizando en la tipología de actividades, su intensidad, la zona geográfica, etc. Por ello, el objetivo de este estudio fue examinar las características de la actividad física durante el recreo en los dos últimos cursos de Educación Primaria y en Educación Secundaria Obligatoria en centros del eje atlántico.
Material y método: El estudio incluyó a 707 estudiantes de Galicia (España). El 49,08% son varones con una edad media de 13,25 ± 1,76 años y el 50.91% son mujeres, con una edad media de 13,22 ± 1,77 años. Las variables independientes fueron sexo, etapa educativa y curso. Las variables dependientes incluyeron las actividades realizadas durante el recreo y su intensidad. El instrumento utilizado para la recogida de datos fue el *Recess Physical Activity Recall* (Martínez-Gómez *et al*., 2010).
Resultados: El tiempo de recreo se pasaba básicamente comiendo, descansando, bajando o subiendo las escaleras. Las niñas practicaban fundamentalmente deportes con un objetivo no competitivo (para divertirse) y caminaban más. Los niños practicaron más deportes competitivos. La intensidad de la actividad física fue baja, siendo los varones y el alumnado de primaria significativamente más activos.
Conclusiones: El tiempo que el alumnado dedica a ejercitarse en deportes es muy bajo. La elección de deportes es diferente en función del sexo. Los mayores índices de actividad se producen pasados los diez primeros minutos y se mantienen hasta el final. Son necesarios mayores esfuerzos para cambiar la cultura del recreo, optimizar el tiempo y rediseñar los espacios, poniendo el foco de atención especialmente en las mujeres y el alumnado de Educación Secundaria.

Palabras clave:
Recreos. Niveles de actividad física. Promoción del ejercicio.

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Introduction

The importance of physical activity for health is thoroughly proven. It reduces the incidence of cardiovascular diseases, diabetes, hypertension, obesity, depression, osteoporosis and some forms of cancer[1]. Obesity is currently a high-prevalence health problem, which affects the body in multiple ways[2]. For this reason, in recent years, there has been an urgent need to implement educational interventions to reduce excess weight in children and youth[3-5].

For years, the European institutions have warned that many children only engage in physical activity (PA) during school hours[6]. At school, in addition to the amount of hours dedicated to Physical Education, students have recess multiple times throughout the day as a resource for the promotion of a healthy lifestyle. Recess can be defined as a non-curricular break period between classes, where students engage in leisure activities[7]. It often includes lunchtime[8]. Therefore, it refers to a resting time frame, while the playground is the recreational area.

Over the past decade, many researchers have emphasized the importance of recess as an opportunity to increase physical and sport activities[9-12].

It is well known that the World Health Organization[13] advises Elementary and Secondary Education students to perform daily PA in the form of games, sports, travel, recreational activities, etc. in the context of family, school and community. It particularly recommends at least 60 minutes of moderate-to vigorous-intensity PA (MVPA) each day; it also recommends aerobic exercises and movements that reinforce muscles and bones at least three times a week. Pate *et al.*[14] have suggested that at least half of the recommended MVPA for health reasons could be carried out in the school context. Lopes *et al.*[10] have also drawn the same conclusion, pointing out that this is an achievable goal.

The inclusion of PA during recess may have significant implications for health and physical, social and cognitive development, as shown by Serra[15] in a review of different studies. So that playtime could contribute to the daily PA, it should be of moderate intensity for at least 40% of the time[7].

Therefore, the analysis of the characteristics of PA during recess is highly important in the fight against childhood obesity rates[16,17] and the sedentary lifestyle at an early age[18] since during this period everyone has the opportunity of being physically active[8]. Actually, the study carried out by Martínez *et al.*[19] has shown that recess highly contributes to the weekly amount of PA that students perform. In the same vein, although only related to male subjects, the work conducted by Aznar *et al.*[20] has indicated the existence of high peaks of MVPA, which corresponds to school playtime.

Despite this, as shown by Frömel *et al.*[21] the information on the type of physical activity and its intensity during recess is insufficient. Hence, the need to expand the knowledge on this subject, taking into account different variables of influence. One of them is related to the study of these issues in different geographical areas; for example, in Spain, in different autonomous communities or provinces, since the climatological and cultural characteristics are different.

Therefore, the research problem focuses on characterizing the type of activities and their intensity, depending on variables such as gender or the educational stage in a Galician area; in particular, the Atlantic axis (Pontevedra and A Coruña). Therefore, and as an objective, this study focuses on analyzing the characteristics of physical activity during recess in the last two years of Elementary Education and Compulsory Secondary Education in schools of the Atlantic axis.

Material and method

A quasi-experimental cross-sectional study was performed by means of a non-probability convenient sampling technique, where the independent variables were sex, educational level and grade. The dependent variables included the activities performed during recess and their subjective intensity of PA.

Participants

The study involved 707 students from Elementary and Secondary schools in the Atlantic axis of the Autonomous Community of Galicia (Spain). The Atlantic axis covers the provinces of Pontevedra and A Coruña, which have about 944.346, and 1.122,799 inhabitants, respectively. Its coast, where most of the Galician productive sector is located, is bathed by the Atlantic Ocean.

The schools were selected randomly and the sampling was intentional. There were six participating schools, all of them located in an urban area, with the classrooms on the second floor. Out of these, three belonged to the province of Pontevedra, and three to the province of A Coruña. Likewise, in each province, two were Early Childhood and Elementary Education schools, and one Secondary Education school.

49.08% of the participants were male students with an average age of 13.25 ± 1.76 years and 50.91% were female students, with an average age of 13.22 ± 1.77 years. 229 were enrolled in 5th and 6th grade of Elementary Education, 248 were enrolled in 1st and 2nd grade of Compulsory Secondary Education and, finally, 230 were enrolled in 3rd and 4th grade of Compulsory Secondary Education.

Instrument

For the collection of data, the Recess PA Recall (RPAR) elaborated by Martínez-Gómez *et al.*[22] was employed. This questionnaire divides recess into 5-minute fractions, and for each fraction participants had to indicate the type of activity that had been performed and with what intensity: very mild, mild, moderate and vigorous. The activities were codified and grouped into five categories (eating, active transportation, rest, hobbies, and physical activities). In addition, participants were provided with the option of adding new activities.

The used test (Martínez-Gómez *et al.*)[22] has a limited impact, although there is the advantage that it is a study of validity on the Spanish population.

Procedure

The study was conducted according to the ethical standards established by the Declaration of Helsinki (revised by the Declaration of Hong Kong, September 1989) and in agreement with the recommendations of EEC - Good Clinical Practice (Document 111/3976/88, July 1990) and with the Spanish legislation in force governing research.

The questionnaire was collectively administered during regular school hours, during the academic year 2016-2017. It is administered only once, during the winter season; given the Galician climate, we assumed that we could start from that point, considering that less physical activity is performed at this time. In the future, the same study should be performed in spring or summer, to observe whether there are any differences. After communicating the appropriate instructions and once the informed consent form was signed (by school and families), all students voluntarily completed the requested information.

Data analysis

First, a descriptive analysis was carried out for the items, showing the mean, standard deviation, as well as the asymmetry and kurtosis indices used to assess the normal behavior of variables.

Pearson's χ^2 tests were performed to determine the association between the nominal variables, Student's *t*-tests to compare independent means for continuous dichotomous variables, and ANOVA for polytomic variables with a significance level of $p < .05$. Subsequently, the relationship between the different levels of PA intensity during successive recesses were analyzed using Pearson's correlation coefficients.

Data analysis was performed using the SPSS 23.0 statistical package.

Results

Considering that in Elementary Education there is only one 30-minute recess and in Secondary Education two 20-minute recesses, the analysis focused on the activity during the first 20 minutes in both stages in order to compare them.

In the first five minutes the activity consists of going down the stairs and having a sandwich. After 10 or 15 minutes, the fundamental activity consists of walking, but also of playing games for fun and competitive sports. Finally, at minute 20, these games continue, students rest and go up the stairs. It is important to note that resting was always codified as a very light activity.

Since the temporal characteristics of the recess in Elementary and Secondary schools are not the same, the differences between them were analyzed within five and twenty minutes (Table 1).

The differences between educational levels are significant. Students usually spend the recess time eating, resting, going down or up the stairs. The number of students who engage in competitive and fun sports is very low. The performance of physical and sport activities is substantially higher within 20 minutes than within 5, both in Elementary and Secondary Education. In Elementary Education, a greater number of students practice competitive sports, regardless of the time frame (Table 1).

The proportion of students participating in activities differs according to gender ($\chi^2 = 77.45$, gl = 2, $p < .001$). Girls play more sports for the fun of it and walk more. Boys practice more competitive sports (Table 2).

The intensity of the PA performed is relatively low, since its trend is 2 (mild). It is obviously higher as recess progresses, becoming lower over the final minutes. In terms of asymmetry values, it was observed that the bias was positive in all cases except at minute 15. Hence, one can state that this distribution has an asymmetric tail extending toward negative values; that is, it tends to be skewed to the right side of the mean, where there are high values, but only at minute 15. On the con-

Table 1. Frequency and percentage of activities performed within 5 and 20 minutes, compared by educational level.

	Frequency and percentage of activities within 5 minutes				χ^2	Frequency and percentage of activities within 20 minutes				χ^2
	Secondary Education		Elementary Education			Secondary Education		Elementary Education		
	Freq.	%	Freq.	%		Freq.	%	Freq.	%	
Eating	151	78.2	42	21.8		42	85.74	7	14.3	
Walking	78	60.9	50	39.1		55	80.9	13	19.1	
Going up the stairs	13	54.2	11	45.8		85	94.4	5	5.6	
Going down the stairs	137	67.1	67	32.9		20	80	5	20	
Resting	18	81.8	4	18.2		71	82.6	15	17.4	
Listening to music	2	100	0	0		3	75	1	25	
Playing video-games	0	0	0	0		4	80	1	20	
Talking on the cell phone	4	100	0	0		16	100	0	0	
Reading	3	50	3	50		7	46.7	8	53.3	
Studying or doing homework	5	71.4	2	28.6		12	70.6	5	29.4	
Walking to exercise	4	80	1	20	.0001	11	64.7	6	35.3	.0001
Running	11	50	11	50		18	53	16	47	
Skating	1	100	0	0		5	50	1	50	
Dancing	0	0	0	0		4	83.3	4	16.7	
Games and sports (for fun)	16	64	9	36		63	52.1	58	47.9	
Competitive games and sports	14	35.9	25	64.1		32	32.7	66	67.3	
Others	21	84	4	16		30	62.5	18	37.5	

Note. $p < .01$.

Table 2. Activities carried out up to Minute 20 according to sex.

		Sex		
		Male	Female	Total
Eating	Freq.	20	29	49
	%	5.8%	8.1%	6.9%
Walking	Freq.	26	42	68
	%	7.5%	11.7%	9.6%
Going up the stairs	Freq.	45	45	90
	%	13.0%	12.5%	12.7%
Going down the stairs	Freq.	6	19	25
	%	1.7%	5.3%	3.5%
Resting	Freq.	39	47	86
	%	11.2%	13.1%	12.2%
Listening to music	Freq.	3	1	4
	%	.9%	.3%	.6%
Playing video-games	Freq.	5	-	5
	%	1.4%	.0%	.7%
Talking on the cell phone	Freq.	8	8	16
	%	2.3%	2.2%	2.3%
Reading	Freq.	6	9	15
	%	1.7%	2.5%	2.1%
Studying or doing homework	Freq.	4	13	17
	%	1.2%	3.6%	2.4%
Walking (to exercise)	Freq.	10	7	17
	%	2.9%	1.9%	2.4%
Running	Freq.	11	23	34
	%	3.2%	6.4%	4.8%
Dancing	Freq.	3	5	8
	%	.9%	1.4%	1.1%
Skating	Freq.	1	5	6
	%	.3%	1.4%	.8%
Games/sports (for fun)	Freq.	56	65	121
	%	16.1%	18.1%	17.1%
Competitive games/sports	Freq.	82	16	98
	%	23.6%	4.4%	13.9%
Others	Freq.	22	26	48
	%	6.3%	7.2%	6.8%
Freq.		347	360	707
% of students' gender		100%	100%	100%
% of the total		49.1%	50.9%	100%

trary, the distribution of the other variables has a positive bias, thus their values tend to be skewed to the right side of the mean, where there are low values. In the case of kurtosis, it was found that all distributions were negative, thus the distribution of the sample is platykurtic, which means that the concentration of the values in the central region of the distribution is low (Table 3).

Table 4 shows the subjects of the sample, classified according to gender. Our study sample was made up of 360 girls and 347 boys, that is why one could say that gender representation was equitable.

In the Levene's test for equality of variances, the value of the Levene's f contrast statistic is f = .221 and its associated statistical significance is p = 0.638. Therefore, the equality of variances is fulfilled. In the Student's t-test, the value of the contrast statistic is t = 4.392 and its statistical

Table 3. Intensity of PA during the first 20 minutes.

	Intensity				
	Minute 5	Minute 10	Minute 15	Minute 20	Mean 20 M
Mean	2.05	2.28	2.44	2.43	2.2988
Median	2.00	2.00	3.00	2.00	2.2500
Trend	1	1	3	3	2.50
Standard deviation	.999	1.045	1.081	1.090	.81652
Asymmetry	.545	.203	-.020	.042	.070
Standard error of the asymmetry	.092	.092	.092	.092	.092
Kurtosis	-.827	-1.180	-1.286	-1.299	-.856
Standard error of the kurtosis	.184	.184	.184	.184	.184
Minimum	1	1	1	1	1.00
Maximum	4	4	4	4	4.00

Table 4. Difference of intensity means in the first 20 minutes of recess according to sex.

	Sample		Levene's test		Student's t-test	
	Boys (n = 347)	Girls (n = 360)	F	Sig.	t	Sig. (bilateral)
Intensity Mean 20 M.	2.434±.83	2.16±.78	.221	.63	4.39	.0001

Note. Values are presented as mean ± standard deviation.

Table 5. Difference of intensity means in the first 20 minutes according to grade.

	N	Mean	F	Sig.	Groups	Bonferroni Sig*
1st G-CSE	101	2.2822			5th G-PE	.003
					6th G-PE	.0001
2nd G-CSE	147	2.0969			5th G-PE	.0001
					6th G-PE	.0001
3rd G-CSE	121	1.9793			5th G-PE	.0001
					6th G-PE	.0001
4th G-CSE	109	2.0734			5th G-PE	.0001
					6th G-PE	.0001
			21.776	.0001		
5th G-PE	111	2.6734			1st G-CSE	.003
					2nd G-CSE	.0001
					3rd G-CSE	.0001
					4th G-CSE	.0001
6th G-PE	118	2.7479			1st G-CSE	.0001
					2nd G-CSE	.0001
					3rd G-CSE	.0001
					4th G-CSE	.0001

Note. * The mean difference is significant at the level of .05; Note. G-PE: Grade of Elementary Education; G-CSE: Grade of Compulsory Secondary Education.

Table 6. Difference of intensity means in the first recess according to students' educational level.

	Sample (n = 707)		Levene's test		Student's t-test	
	Elementary Education (n=229)	Secondary Education (n=478)	F	Sig.	t	Sig. (bilateral)
Activity intensity	2.73±.705	2.100±.774	7.146	.838	-10.49	.0001

significance is lower than .001. It is concluded, in this case, that there are significant differences in the average intensity of PA performed during recess, higher in boys than in girls.

Table 5 shows there are differences between grades with respect to the PA intensity (f = 21.776, sig. < .0001). This suggests that Elementary students perform higher-intensity PA for the first 20 minutes of recess than Secondary students.

If we take into account the total number of recess minutes in Elementary (30 minutes) and Secondary Education (20 minutes), it is observed that intensity is still higher in the former (Table 6).

Discussion

This study is a novel approach to determine the typology and intensity of PA during recess in the last two years of Elementary Education and Compulsory Secondary Education in schools of the Atlantic axis (Galicia, Spain). This applies despite the fact that its climatological and cultural characteristics are different from other communities, in which other studies were carried out on PA during recess in Spain[20,23-26] and at international level[27-29].

The interest of this study lies in the fact that, generally, the levels of activity at these ages are considerably lower than the recommended guidelines. This is important because in Elementary Education, 30 minutes of daily recess mean two and a half hours of possible PA each week, which is a very important percentage[19]. This amount of time is even longer in Secondary Education, as it exceeds three hours. In other words, recess can make a valuable contribution to the recommended 60 minutes of daily PA[30]. It should be borne in mind that children are usually more active during school playtime compared to activities performed outside the school or on weekends[31].

Our research proves that students usually spend the recess time eating, resting, going down or up the stairs and as recess progresses, they perform fun and competitive sports. However, these sports account for a rather small percentage. The intensity of this physical activity is low. The highest activity rates occur after the first ten minutes and are maintained until the end of recess. There is also an increase of the number of students who play games and sports, or dance starting from that time frame.

There are differences according to the educational level, Elementary students being more active. This difference in intensity between educational levels was confirmed by other studies[20,23]. There were differences also between the first two grades of Secondary Education and the last two, as students of the first grades performed higher levels of PA[15]. The work conducted by Martínez-Gómez *et al.*[26] also revealed that the group of younger adolescents was more active than the older group, but this difference occurs only in boys. On the other hand, Wollersheim and DiPerna[32] compared sixth- and first-grade students and detected that sixth-grade males engaged in significantly more PA during recess.

On the other hand, as is often the case, it was observed that male students exhibit more sporting activity than female students. Recent studies, conducted in different countries, which focused on PA during recess according to gender, have reached the same conclusions. It has been stated that boys are physically more active than girls[24,26, 33,34]. In any case, certain exceptions have been reported. As an exception, in a study conducted by Mota *et al.*[35], among students aged 8 to 10, girls were significantly more active than boys during recess. According to Martínez-Gómez *et al.*[22] there were no differences according to gender in a group of adolescents aged between 12 and 14 years old.

It should be noted that girls play more sports for the fun of it and walk more. Boys practice more competitive sports. These data are in agreement with other literature contributions. There have always been differences in the type of activity in which boys and girls engage[27,36]. In fact, boys often participate in moderate to vigorous team sports activities, which usually have a competitive element. Girls tend to be more involved in lower-intensity activities, such as talking, walking, or jumping rope[28].

Certain studies showed that boys saw recess as an opportunity to participate in competitive games, while girls saw it as an opportunity to socialize with friends[37]. Therefore, it may seem logical to think that, given the intensity of PA during school recess, boys have a higher energy expenditure than girls[25,19,15].

The observed data suggest the need to increase the levels of physical activity, mainly in women and in Secondary Education. For this reason, and as preventive lines of action, the following recommendations are provided to redesign and boost recess time:

Regarding the agents involved:

- The educational community should be aware of its potential to be an active part of the change process of recess. Families can collaborate in the creation of new spaces, and reconditioning or re-adaptation of others. Family can also encourage students to make the most of recess times, by performing physical exercise.
- The teaching staff is a key element in the intervention programs that could be carried out. They are able to analyze the benefits of sports practice based on different variables, such as gender or grade, and implement strategies that favor the participation of all. In any case, it is worth mentioning that sometimes the intensity of physical activity during recess is higher without teachers' guidance[9].

– Students are the focal point of the intervention processes. The figure of playground mediators or recess mediators will help to understand what factors limit the physical activity practice and to settle conflicts.
– Moreover, in our opinion, setting up the figure of recess time sports facilitator is of great interest. It would be a similar figure to that of game coordinator from the study conducted by Chin and Ludwig[38]. This person's role would be to promote playgrounds as attractive environments for the performance of physical activity. In addition to an organization and supervision function, they could advise the school staff so that they could continue the work later in their absence. The *sports facilitator* can be employed by the municipal government or by health centers, and performs community health tasks.

Regarding time:

– Given the impact that recess may have on students' overall physical activity, an interesting alternative may be to lengthen the time spent performing it, and even increase the number of recesses. In addition, particular attention must be paid to the real time of practice, which should be as long as possible, and participation should take place from the very beginning.

Regarding space:

– The need to optimize the space during recess is very important. Molins-Pueyo[39] pointed out the poor and limited use of the playground as an educational space, falling short when it comes to deepening the possibilities offered. Students must have different possibilities in terms of space for the practice of physical activity. The existence of recreational areas should also be ensured when the weather conditions do not allow practicing outdoors.
– The space could be redesigned considering simple alternatives, such as painting floors or walls. Stratton and Mullan[34] concluded in their study that painting playgrounds with multicolored marks was a low-cost method to increases the percentage of time spent on MVPA.
– In terms of gender, Lamoneda and Huertas[25] have pointed out measures beneficial for girls, such as: facilitating a play area to avoid the tendency of boys to take up spaces, offering tasks of separate space use, or performing activities indoors.

Regarding materials:

– Facilitating the use of Physical Education material is a strategy that can be very motivating. These materials offer a possibility to carry out more physical and sport activities, educate students in values, and favor the interpersonal relations among peers[40]. This was verified by Lopes *et al*.[10] or Verstraete *et al*.[41], providing sports equipment during recess. This resulted in a significant increase in the percentage of time spent on PA.
– In addition, using disposable materials is another formula to create a playground that encourages motor learning. Reusing materials such as tires or cylindrical containers, making them part of the playground furniture can be a practical and cheap option, as well as of a high pedagogical value.

Regarding contents:

– When it comes to programming recess improvement interventions, contents should be diversified, based on students' interests. Preference for sports practice varies depending on gender, age or ability. The existing possibilities of participation, organized according to resources available in the environment, should be equitable. Certain positive action measures may also be interesting, for encouraging secondary education girls to practice physical activity.

As a limitation of the present study, and also as a future line of work, the use of accelerometers should be considered, as they would provide more objective data for the group under study. In addition, it would be interesting to check in further research the characteristics of practice in other seasons.

Conclusions

School recesses could be relied on to increase PA levels and, consequently, as a disease prevention factor. The time that students spend practicing sports is very limited. The choice of sports is different depending on the sex. The highest activity rates occur after the first ten minutes and are maintained until the end of recess. The culture of recess should be changed and redesigned so that it could become more attractive for activity practice placing the focus especially on women and Secondary Education students. Recommendations are made regarding the agents involved, spaces, time, materials and contents used.

Conflict of interest

The authors do not declare a conflict of interest.

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Original article

The effects of neuromuscular training on the postural control of university volleyball players with functional ankle instability: a pilot study

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Summary

Introduction: In volleyball about 90% of players ever suffer an ankle sprain, being repetitive episodes of main complications. It is suggested that neuromuscular training could improve the functionality of the ankle and decrease the risk of a sprain.
Objective: To determine the effects of a neuromuscular training on postural control in college volleyball players with functional ankle instability (FAI).
Method: Quasi-experimental research. The sample was composed of 12 college volleyball male players between 18 and 23 years old. A neuromuscular training of four weeks was carried out and it was distributed in three weekly sessions from 15 to 25 min, on non-consecutive days, totaling 12 sessions. The volume of training was regulated using a progressive periodization and focused mainly on the lower limb, performing it prior to the regular training of the volleyball players. Pre and post intervention postural control were evaluated on a force platform in conditions of open eyes (OE) and closed eyes (CE). From this evaluation, the following variables of the center of pressure (CP) were calculated: Area, mean velocity, medio-latera (ML) velocity and anteroposterior (AP) velocity. T-student test was applied for comparisons with an alpha level of 0.05.
Results: In OE there was a significant decrease in the ML velocity (p = 0.036). In CE significant differences between pre and post intervention were observed in mean velocity (p = 0.043), AP velocity (p = 0.019) and ML velocity (p = 0.027).
Conclusion: A four-week training neuromuscular improved postural control on college volleyball players with IFT included in this study.

Key words:
Ankle. Sprain. Joint instability. Postural balance. Volleyball.

Efectos de un entrenamiento neuromuscular sobre el control postural de voleibolistas universitarios con inestabilidad funcional de tobillo: estudio piloto

Resumen

Introducción: Alrededor de un 90% de los jugadores de voleibol sufren alguna vez un esguince de tobillo, siendo los episodios repetitivos una de las principales complicaciones. Se plantea que el entrenamiento neuromuscular podría mejorar la funcionalidad del tobillo y disminuir el riesgo de volver a sufrir un esguince.
Objetivo: Determinar los efectos de un entrenamiento neuromuscular sobre el control postural en voleibolistas universitarios con inestabilidad funcional de tobillo (IFT).
Método: Estudio cuasi experimental. La muestra fue compuesta por 12 voleibolistas universitarios de sexo masculino, entre 18 y 23 años. Se realizó un entrenamiento neuromuscular de cuatro semanas de duración y se distribuyó en tres sesiones semanales de 15 a 25 min, en días no consecutivos, totalizando 12 sesiones. El volumen de entrenamiento fue regulado usando una periodización progresiva y centrada principalmente en la extremidad inferior, realizándola previo al entrenamiento regular de los voleibolistas. Pre y post intervención se evaluó el control postural sobre una plataforma de fuerza en condiciones de ojos abiertos (OA) y ojos cerrados (OC). A partir de esta evaluación se calcularon las siguientes variables del centro de presión (CP): Área, velocidad media, velocidad medio lateral (ML) y velocidad anteroposterior (AP). Se aplicó la prueba t-student para realizar las comparaciones con un nivel alfa de 0,05.
Resultados: En OA solo hubo una disminución significativa en la velocidad ML (p = 0,036) posterior a la intervención. En OC se observaron diferencias significativas entre la evaluación pre y post intervención para las variables del CP velocidad media (p = 0,043), velocidad AP (p = 0,019) y velocidad ML (p = 0,027).
Conclusión: Un entrenamiento neuromuscular de cuatro semanas mejoró el control postural en los voleibolistas universitarios con IFT incluidos es este estudio.

Palabras clave:
Tobillo. Esguince. Inestabilidad articular. Balance postural. Voleibol.

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Introduction

An ankle sprain is one of the most common musculoskeletal injuries, with a prevalence of 16%[1]. With regard to the types of sprain, the lateral ankle sprain (LAS) accounts for between 77% and 85% of cases[2]. Around 90% of volleyball players have suffered this injury on at least one occasion, with repeated episodes being one of the main complications[3]. Moreover, almost 40% of sprains progress to functional ankle instability (FAI)[4], a concept used to described repeated sprains and/or the feeling of instability[5].

A neuromuscular deficit caused by a ligament injury has been associated with the development of FAI[6]. As the cause of instability, initial theories pointed to a loss of sensory information of the ankle joint, based on an essentially feedback model, caused by a proprioceptive deficit and a motor response deficit[5]. At present, the most widely accepted sensorimotor model is that proposed by Hertel (2008), arguing that not only is there a feedback mechanism caused by the ligament injury, but a feedforward mechanism is also generated associated with the motor control deficit. The initial ligament injury results in immediate ankle proprioceptive deficits, sensorimotor integration and efferent muscle activity. A number of studies have shown that individuals with FAI have a delayed muscle response[7,8]. This alteration of the reflex motor responses would indicate that the spinal motor control mechanisms are clearly affected. Given that proprioception requires the conscious awareness of the joints and muscles, it is reasonable to assume that, in some way, supraspinal aspects of motor control are also altered with FAI[6].

Postural control is considered to be a complex motor skill derived from the interaction of multiple sensorimotor processes directed at controlling the body in space[9]. This includes interaction between the sensory system, the central nervous system (CNS) and the motor system9. In relation to the quantification of postural control, the most common method is the centre of pressure (CP) displacement through a force plate that measures the postural sway experienced by a person in a bipedal stance[10]. Based on the PC, it is possible to obtain variables such as area, velocity and the medial-lateral (ML) and anterior-posterior (AP) components of its displacement[10]. The greater the value of these variables, the lower the postural control. It has been established that individuals with ankle instability show a deterioration in postural control in both the injured and uninjured lower limbs[8,11-13]. Furthermore, it has been shown that, for university athletes, the postural control deficit is a risk factor for FAI[14]. The presence of bilateral deficits in postural control in individuals with FAI provides clear evidence of the central changes in neuromuscular control[6].

FAI rehabilitation over the last decade has been directed at establishing exercise programmes intended to prevent the recurrence of ankle sprains. Different types of training have been recommended for the conservative treatment of this injury, based on exercises: proprioceptive, strengthening, and postural control[15,16]. However, in order to improve neuromuscular control in athletes, there is a need to train all these aspects as a whole and not separately[15,16]. This has led to the term neuromuscular training, used to describe the combination of proprioceptive, strength and postural control exercises as part of a comprehensive rehabilitation program[17]. Studies show that neuromuscular training improves the functionality and reduces the risk of a further ankle sprain[17]. However, few works have reported evidence of the effectiveness of neuromuscular training on FAI in athletes[15].

In this regard, the purpose of this study was to determine the effects of neuromuscular training on the postural control of university volleyball players with FAI.

Material and method

This is a quasi-experimental study. The sample was selected non-probabilistically and for convenience. All participants read and voluntarily signed an informed consent form based on the ethical principles set out in the declaration of Helsinki.

Participants

The sample comprised 12 young male adults, aged between 18 and 23 years, forming part of the men's volleyball team of the Santo Tomás University, Talca, Chile. The following inclusion criteria were considered: 1) History of at least one lateral ankle sprain in the last 12 months that had required immobilization and/or taking the weight off the ankle for at least three days[8]; 2) last episode of a lateral ankle sprain between three to 12 months prior to the study[8] 3) feeling pain, instability and/or weakness in the ankle[8]; 4) score of ≤ 22 points in the questionnaire *Ankle Joint Functional Assessment Tool* (AJFAT)[18]. The study excluded volleyball players who had shown the following characteristics over the last 24 months: 1) vestibular disorders; 2) history of a fractured ankle; 3) acute lower limb injury; 4) history of lower limb surgery; 5) pain in any joint at the time of assessment; 6) those who did not attend at least 70% of the intervention sessions considered in the study.

AJFAT Questionnaire

The AJFAT questionnaire was used as an assessment tool to discriminate between stable ankles and those with functional instability. The AJFAT contains 12 questions, divided into 3 sub-items: 1) limitations relating to pain, stability, stiffness, strength and false steps; 2) activities such as walking on uneven surfaces, changing direction when running, jogging and walking on stairs; 3) ability of the ankle to respond to a rollover[18]. Each question has five response options, with scores ranging from zero to four points. A high score indicates greater stability, with the maximum test score being 48. It has been reported that individuals with FAI have a score of under 23 points in the AJFAT questionnaire[18].

Assessment of postural control

The assessment was carried out at the biomechanical laboratory of the Santo Tomás University, Talca, Chile. In order to determine postural control, the CP displacement was assessed using an ArtOficio (Artoficio Ltda., Santiago, Chile) force plate, size 40x40 cm. The data were acquired with a 40 Hz sampling rate. For the calculation of the CP variables, the Igor Pro version 5.01 software was used (WaveMetrics Inc., Oregon, USA). Postural control measurement was made under eye-open (EO) and eye-closed (EC) conditions. Each visual condition had a duration of 30 seconds. Participants were instructed to maintain the bipedal stance as still as possible with their arms relaxed by their sides, and with their feet shoulder-width apart. Three attempts were made for each stance and these were averaged to give the CP variables. Based on the displacement of the CP in the ML and AP directions, the following variables were obtained: area of the CP (m^2), mean CP velocity (m/s), CP velocity in the ML direction (m/s) and CP velocity in the AP direction (m/s).

Neuromuscular training

The neuromuscular intervention had a duration of four weeks and was structured into three weekly sessions of 15 to 25 minutes, on non-consecutive days, totalling 12 sessions. The training volume was regulated using progressive periodisation and primarily centred on the lower limb, performed prior to the normal training of the volleyball players. All the sessions contemplated circuits with 30 second work stations consisting of coordination exercises on agility ladders, hurdles, step, going up and down stairs, squat exercises, mini-tramp jumping, and Bosu ball squats. Each participant had to perform three sets of the complete circuit per session, considering both limbs in the case of unipedal exercises. During the first week, all exercises were performed bipedally. During the second and third weeks, the physical exercises were performed unipedally, adding active movements of the upper limbs. During the last week, in addition to performing unipedal exercises, the motor tasks on unstable surfaces were performed with eyes closed.

Statistical analysis

The SPSS 20.0 (SPSS 20.0 for Windows, SPSS Inc., IL, USA) statistical software was used and the mean and standard deviation were calculated for all variables. Furthermore, the data distribution was determined with the Shapiro-Wilk test. The student's paired sample t test was used to compare the assessments before and after the intervention. An alpha level of 0.05 was considered for the entire analysis.

Results

All the study participants completed the intervention (n=12). The baseline characteristics of the study participants were on average 21.5 years, 82.3 kilogram of body weight, and a bipedal height of 1.81 metres.

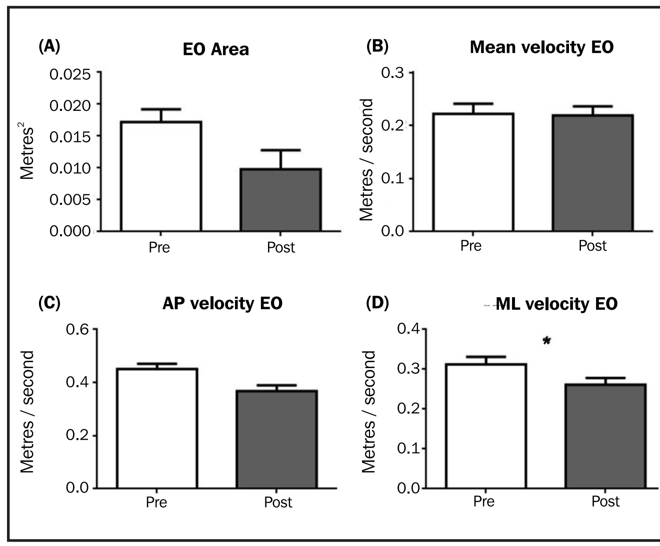
For EO there was a significant reduction in the ML velocity ($p = 0.036$) subsequent to the intervention. With regard to the area, mean velocity and AP velocity, a reduction in the values was observed, which were not statistically significant (Figure 1).

For EC, a significant improvement was observed in the postural control of the volleyball players in the variables for mean velocity ($p = 0.043$), AP velocity ($P = 0.019$) and ML velocity ($p = 0.027$) of the CP after being subject to neuromuscular training. The area was reduced following intervention, however this was not statistically significant (Figure 2).

Discussion

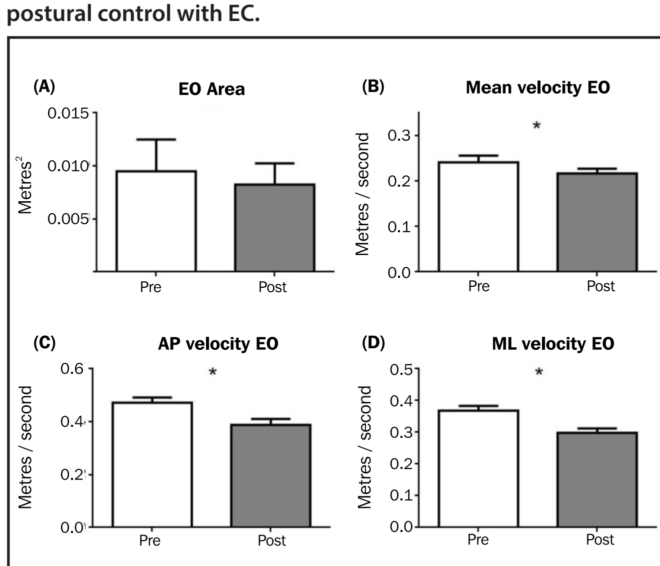
The main study outcome meets the proposed goal and indicates that four weeks of neuromuscular training improves the postural control of university volleyball players with FAI.

Figure 1. Pre- and post intervention results of the assessment of postural control with EO.



*Statistically significant differences ($p < 0.05$). EO: Eyes-open; AP: anterior-posterior; ML: medial-lateral.

Figure 2. Pre- and post intervention results of the assessment of postural control with EC.



Statistically significant differences ($p < 0.05$). EC: Eyes-closed; AP: anterior-posterior; ML: medial-lateral.

Over the last few years, studies have been made on the deterioration of postural control in subjects with ankle sprains and FAI, as well as the different types of training required for their rehabilitation[17]. The literature indicates that neuromuscular exercises improve postural control, muscle strength, proprioception, muscle latency and functionality[15]. Furthermore, these exercises reduce the risk of a further sprain for individuals with FAI[15-17]. However, it has been pointed out that the evidence of the effectiveness of neuromuscular training on FAI is limited[15].

The results of this study show that four weeks of neuromuscular training improves the postural control of university volleyball players with FAI, evidenced in a reduction of the CP variables. Similar findings have been reported in other investigations[5,17,19]. However, with regard to athletes, evidence is scarce. The neuromuscular training programs implemented in persons with FAI indicate that the time spent at the sessions is between 20 to 30 minutes with a duration of four to six weeks[17]. A similar prescription was used in our intervention.

Lateral ankle sprains are among the most common sports injuries and their recurrence is a factor associated with the development of FAI[3]. Postural control deficit in persons with FAI has been attributed to sensory receptor damage caused by the ligament injury[5]. Current literature includes studies on healthy subjects, with no findings of sensorimotor control deficits when simulating an ankle ligament injury[20,21]. This would indicate that the sensory information is not solely due to damage to the ligament, but that other receptors are also involved (i.e. capsular, muscle-tendon and cutaneous receptors) that are there to permit good sensorimotor control[20,21]. The postural control deficit detected in both the injured and uninjured ankles of the volleyball players would explain why not only do local sensorimotor deficits exist, but also centrally mediated deficiencies[6,8]. For this reason, the neuromuscular training applied in our study considered the performance of exercises with both limbs for unipedal tests.

Despite the various studies conducted in this area, it is still not clear which type of rehabilitation training is the most effective in the prevention of recurrent ankle sprains[16]. It could be considered that the restoration of proprioception would be the principal treatment to improve ankle stability[16,22]. However, adequate proprioception does not ensure that the muscle strength and activation are sufficient to respond to rapid and unexpected disturbances such as landing on an uneven surface[16]. With regard to muscle strength, some controversy exists with regard to its relationship with ankle instability. While some studies report that individuals with FAI exhibit weakness of the peroneus muscles and dorsal flexors of the ankle[23], other studies found no link between muscle weakness and instability[24]. For its part, the role of muscle activation on ankle instability appears to be slightly clearer, given that a number of studies have demonstrated that athletes with FAI exhibit an increased reaction time of the peroneus muscles[7,8]. For this reason, during rehabilitation it is suggested to include physical exercises on unstable surfaces and/or changes of direction that are demanding on the motor system, in order to provoke short-latency muscle responses, promoting adequate postural control[8].

Neuromuscular training focussed on balance or postural control is the most common rehabilitation treatment for individuals with FAI. The majority of the literature has reported positive therapeutic effects on this type of intervention[25,26]. However, it has been pointed out that the evidence is weak for the application of functional physical body weight-bearing exercises and balance activities on unstable surfaces[27]. In view of the above, over the last few years a combination of proprioceptive, strength and postural control exercises has been proposed for the treatment of individuals with FAI[17]. The neuromuscular training bases not only seek to stimulate the sensory system but also the centrally mediated mechanisms which interact in different kinetic chains of movement.

Our results show that postural control primarily improved in the EC position. Vision is an extremely important sense for postural control. It is believed that, even when the somatosensory input is interrupted due to injury, the visual information can provide an adequate amount of feedback to compensate the deficits in the central pathways[9]. When the eyes are closed, there is greater postural sway due to the inhibition of one of the sensory systems contributing to postural control[9]. Therefore, the possibilities of maintaining stability are decreased and, in compensation, the involvement of the somatosensory and vestibular systems increases. This means that the EC test is more demanding that the EO test and the differences are more evident. For this reason, rehabilitation exercises are performed with eyes open and eyes closed alike. It has been reported that the effects are greater when the training sessions are made in the absence of visual input[28].

The significant changes in the postural control of the university volleyball players following neuromuscular training were observed in the CP velocity variables. Although the CP area and velocity are the most representative measurements of postural sway, it has been established that velocity is the most reliable variable to represent postural control[29]. Wikstrom, Fournier and McKeon (2010) reported that one of the most sensitive variables to identify the deterioration of postural control in individuals with FAI is the CP velocity in the ML direction[30]. In our study, the intervention significantly reduced the ML velocity for EO and EC and the AP velocity for EC. This could be attributed to the fact that neuromuscular training would optimise the responses of the fibular and tibialis anterior muscles responsible for the ML[31] and AP stability[8] of the ankle, respectively. It has been demonstrated that athletes with FAI exhibit a greater reaction time for these muscles8. The postural control deficit is closely related to the increased reaction time of the muscles involved in joint stability[12].

The limitations of this study include the small sample size, the convenience sampling of participants and the lack of a control group. This will probably limit the external validity of the study. Despite this, the statistical significance observed in each comparison reflects the effectiveness of the intervention.

In conclusion, our study indicates that four weeks of neuromuscular training improved the postural control of the university volleyball players with FAI included in this study. We would suggest that this type of training should be applied to both the injured and uninjured limb, considering the central alterations caused by the injury. Furthermore, in order to enhance the effects of the training, we would recommend including physical exercises in EC conditions.

Conflict of interest

The authors have no conflict of interest at all.

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Original article

Short-term tapering prior to the match: external and internal load quantification in top-level basketball

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Summary

The purpose of this study was to compare accelerometry-derived external load and internal load calculated as a session rate of perceived exertion (sRPE) in elite male basketball over 3-days prior to the match and assessing players' recovery status on the match-day. Thirteen professional basketball players participated in this study (age: 25.7±3.3 years; height: 199.2±10.7 cm; weight: 96.6±9.4 kg). All players belonged to a team competing in LigaEndesa (Spanish 1st Division) and Euroleague in the 2016/2017 season. Variables used in external motion analysis were: PlayerLoad (PL), accelerations and decelerations (ACC and DEC), jumps (JUMP) and changes of direction (CoD), in total (t) and high intensity (h) thresholds, while internal demands were registered using sRPE method. All variables were expressed in absolute (accumulated in the session) and relative values (per min of practice). For the evaluation of readiness, Total Quality of Recovery (TQR) questionnaire was used, measured in Arbitary Units (AU). The results showed differences in load and intensity (p<0.01) for almost all external (PL, hACC, tACC, hDEC, tDEC, hCoD and tCoD; in both absolute and relative values) and internal (sRPE) variables as training sessions were closer to the match day or MD (MD-3>MD-2>MD-1). Only hJUMP, tJUMP and RPE variables showed no difference between MD-3 and MD-2, while both days significantly differed from MD-1. The average TQR score for all of the match days was 7.9±1.31 AU. This study showed differences in the amount of external and internal load between three days of training, where a team can be efficiently prepared for competitions by progressively decreasing the load over the 3-days prior to the match.

Key words:
Training monitoring. Micro-technology. Accelerometry. Team sports.

Tapering a corto-plazo antes del partido: cuantificación de carga externa e interna en baloncesto de élite

Resumen

El propósito de este estudio fue comparar la carga externa derivada de la acelerometría y la carga interna calculada a partir del esfuerzo percibido declarado en la sesión (sRPE) en el baloncesto masculino de élite durante los tres días previos al partido, evaluando el estado de recuperación en el día del partido. 13 jugadores de baloncesto profesionales participaron en este estudio (edad: 25,7±3,3 años, altura: 199,2±10,7 cm, peso: 96,6±9,4 kg). Todos los jugadores pertenecían al mismo equipo que compite en Liga Endesa (1ª división española) y Euroliga en la temporada 2016/2017. Las variables utilizadas para registrar la demanda externa fueron: *PlayerLoad* (PL), aceleraciones y desaceleraciones (ACC y DEC), saltos (JUMP) y cambios de dirección (CoD), tanto en el total (t) acumulado como en en rango de alta intensidad (h), mientras que las demanda interna fue registrada usando el método sRPE. Todas las variables se expresaron en valores absoluto (acumulado en la sesión) y relativos (por minuto de práctica). Para el resgistro del estado de recuperación, se utilizó el cuestionario *Total Quality Recovery* (TQR) medida en unidades arbitrarias (UA). Los resultados mostraron diferencias en la carga e intensidad (p<0.01) para casi todas las variables externas (PL, hACC, tACC, hDEC, tDEC, hCoD y tCoD, tanto en valores absolutos como relativos) e internas (sRPE), entre las sesiones de entrenamiento con respecto a su distancia al día de partido o MD (MD-3> MD-2> MD-1). Solo las variables hJUMP, tJUMP y RPE no mostraron diferencias entre MD-3 y MD-2, mientras que los dos días difirieron significativamente de MD-1. La puntuación promedio de TQR para todos los días de partido fue de 7,9 ±1,31 UA. Este estudio mostró diferencias en la carga total externa e interna entre los tres días de entrenamiento, donde un equipo puede prepararse eficientemente para la competición disminuyendo progresivamente la carga durante los tres días previos al partido.

Palabras clave:
Monitorización del entrenamiento. Micro-tecnología. Acelerometría. Deportes de equipo.

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Introduction

Training periodization and tapering are well-known principles commonly used in professional team-sports training during the season. According to literature[1,2], "long-term" tapering in team-sports is implemented two to three weeks before important events, such as cups and play-offs, with the intention of peaking individual and team's physical and tactical performance. A recent study focusing on basketball revealed a relationship between internal training load, recovery-stress status, immune-endocrine responses, and physical performance in elite female basketball players[3] over a 12-week period, including two overloading and tapering phases. This study covered the period preceding an international championship (characterized by a short duration), providing an insight into long-term training stimulus and adaptations in elite sports. Regarding training activities, taper was applied by decrease of training volume for the resistance training, especially with parameters such as repetitions per set, goal intensity and number of sessions per week. Moreover, in the first seven weeks endurance training consisted of moderate to high intensity interval runs while in the weeks 8 to 12 endurance training was substituted with less metabolic speed-agility training. Finally, authors concluded that the application of session rate of perceived exertion (sRPE) method, as well as the recovery-stress questionnaire (REST-Q), can serve as an important tool to monitor training loads and players' recovery, thus maximizing dose-responses of the training stimulus.

However, for a team competing in seasonal championships, the coaching staff is presented with the challenge of making an optimal training schedule every single week. In this context, weekly periodization, i.e. tapering, could also refer to the practice of reducing training load in the days leading up to the weekly competition. To date, there is little scientific information available to guide coaches in prescribing efficient short-term tapering strategies for team sports players during the competitive week aimed at peaking performance on the match day.

Only one study[4] has looked at internal training load (iTL) using sRPE and heart rate (HR) monitoring methods, and it showed that, in the weeks with two games (i.e. Euroleague and Serie A1), the sRPE obtained on Tuesdays and Wednesdays were 748±71 and 275±54 AU, respectively. The short-term tapering assumed that Monday was the day-off and Thursday the match-day in Euroleague. However, the aforementioned study did not present any external load data and indicators of physical status (i.e. condition) with respect to the accumulated training load. To date, no studies examining the relationship between prescribed external training loads in micro-cycle periods have been conducted.

Numerous methods can be used to monitor the physical status of athletes. There are objective methods, such as heart rate monitoring and saliva measures[5], blood testing[6] or jumping performance[7,8], as well as subjective methods, such as various questionnaires[8-10], which could be easily implemented in everyday training. One of the questionnaires, known as Total Quality Recovery Scale (TQR), has demonstrated sufficient reliability in team sports[11].

At the moment, information on accelerometer–based data in top-level basketball is limited, especially with respect to weekly periodization and distribution of load. Therefore, the aim of this study is to compare the load of the training sessions leading up to the first match of the week, considering both external (eTL) and internal training load parameters. Furthermore, the perception related to recovery status on the match day (via TQR questionnaire) will be assessed. The assessment will be used as the indicator in the selection of appropriate training load that secures enough recovery for players' well-being, while avoiding undesired overload and overtraining. The findings of this study could help coaches set appropriate level and intensity of accelerometry-derived training load (TL) in the days leading up to the match, as such data is currently unavailable in the literature.

It was hypothesized that, with the application of a short-term 3-day taper, a progressive decrease in TL prior to the match day will positively affect players' recovery status, which would in turn lead to enhanced physical status and performance in competition.

Material and method

Experimental Approach To The Problem

The research was carried out between December and February of the 2016/2017 season. The players were monitored in basketball training sessions using S5 devices from Catapult Innovations (Melbourne, Australia). Furthermore, sRPE was calculated based on the individual RPE obtained 15-30 minutes after the training session multiplied by the training duration. During that period, the players participated in three to eight training sessions and two or three games every week where the total number of recorded games was 10. The investigation data set consisted of 228 observations, where the numbers of training sessions per player ranged between 11 and 22. The eTL was transferred and managed using the Openfield v1.14.0 software (Build #21923, Catapult, Canberra). The data was subsequently exported to Microsoft Excel for the final selection and analysis of individual eTL and iTL variables.

Participants

A professional male basketball players (age: 25.7 ±3.3 years; height: 199.2 ±10.7 cm; weight: 96.6 ±9.4 kg) who play on the same team were participating in this investigation. The team competes in two basketball championships, ACB (Liga Endesa, Spanish 1st Division) and the Euroleague, in the 2016/2017 season. All of the players were verbally informed of the study requirements and they provided written consent before the study was conducted, all in accordance with the Declaration of Helsink[i]. The Ethics Committee (CEISH) gave its institutional approval before the procedures of this study took place.

Type Of Training Session

The players typically played two games per week, with three team sessions usually conducted before the first game of the week (Euroleague) and only one or none before the second game (ACB League). Only the sessions before the first game of the week were considered in the analysis, due to individual adjustments in team sessions preceding the second game, which depended on the individual effort in the first game. Therefore, the data for the analysis was collected three days before the match day (MD-3), two days before the match day (MD-2) and one day before the match day (MD-1). The 3 consecutive days of practices

Table 1. Usual training tasks.

Task	Description	Day of use
PREPARATION	Warm-up, myo-fascial release and stretching, balance and activation exercises with goal to functionally prepare each player for training demands. Usual time 10-15'.	MD-3, MD-2, MD-1
5x0 HC	No-contact play on half-court for learning and mastering offensive sets. Usual time of play is 15-20", work rest ratio 1:1.	MD-3, MD-1
5x0 FC	No-contact play using full court for learning and mastering offensive sets. Usual time of play is 20-40", work rest ratio 1:1.	MD-3, MD-2, MD-1
SSG 3x3 HC	Contact small-sided game on half-court for learning and mastering tactical rules. Usual time of play is 30-60", work rest ratio 1:1.	MD-2
SSG 4x4 HC	Contact small-sided game on half-court for learning and mastering tactical rules. Usual time of play is 30-60", work rest ratio 2:1.	MD-3, MD-2, MD-1
SSG 5x5 HC	Contact small-sided game on half-court for learning and mastering tactical rules. Usual time of play is 30-90", work rest ratio 1:2.	MD-3, MD-1
SSG 5x5 FC	Contact small-sided game using full court for learning and mastering tactical rules. Usual time of play is 30-120", work rest ratio 1:1.	MD-3, MD-2, MD-1
SHOOTING	Spot-up shooting drills in pairs, low to medium intensity, continuous 5-10'.	MD-3, MD-2, MD-1

SSG is small-sided game, HC is half court, FC is full court, MD-3 is three days prior the match, MD-2 is two days prior the match and MD-1 is one day prior the match.

were proposed by conditioning specialist in order to achieve optimal short-term tapering effect. Only players who complete all three training sessions were included in the analysis.

Table 1 provides the list and brief descriptions of basketball training exercises and drills used in the reference period. After the team preparation, players participated in one of the following: shooting exercises, no-contact drills or small-sided games (SSG).

External Training Load Monitoring

The eTL was monitored using GPS S5 devices (Catapult Innovations, Melbourne, Australia), which include the accelerometer, gyroscope and magnetometer sensors that provide data for inertial movement analysis (IMA). The obtained data included the following variables: player load (PL), player load per minute (PL/min), accelerations (ACC), decelerations (DEC), jumps (JUMP) and changes of direction (CoD).

PL was obtained using the tri-axial accelerometer (100 Hz, Dwell time 1 second) based on the player's three-planar movement, applying the established formula[12,13] previously tested for reliability[14,15], where TE (i.e. typical error) for different ranges of acceleration varies from 0.18 – 0.13[15].

The ACC variable presents inertial movements registered in a forward acceleration vector, where tACC refers to all, and hACC only to high-intensity movements registered within the high band (>3.5 $m•s^{-2}$). The DEC variable refers to inertial movements registered in a forward deceleration vector, where tDEC presents total and hDEC only high-intensity movements registered within the high band (>3.5 $m•s^{-2}$). The jumps were also registered as total jumps (tJUMP) and high-intensity jumps (hJUMP, over 0.4 m), the same as changes of direction, tCoD (total inertial movements registered in a rightward lateral vector), and hCoD (total inertial movements registered in a rightward lateral vector within the high-intensity band). All aforementioned variables were assessed with respect to their frequency.

Considering the varied duration of the sessions, the relative values of the variables were used, obtained by dividing the accumulated values by the minutes of practice duration. The new relative variables for the analysis were: PL/min, hACC/min, hDEC/min, tACC/min, tDEC/min, hCoD/min, tCoD/min, tJUMP/min and hJUMP/min.

Internal Training Load Monitoring

The sRPE method, whose reliability and validity has been confirmed in previous research[16-19] as well as its simple and cost-effective use in practice with team sport athletes[20-22], was used to assess iTL. As suggested by research[17], the RPE values were collected within 15-30 minutes following the training session. The 1-10 RPE grading scale was used. In order to calculate sRPE after all sessions, RPE values were multiplied by training duration in minutes.

Monitoring of Physical Status

The TQR questionnaire[11] was used to assess players' physical status. On the match day, after the morning team shooting practice, players were asked to grade their current physical status on a scale from 1 to 10 (where 1 means very, very poor and 10 very, very good), following this category classification: <6 = an alarming state; 6.1-7.5 = a good state; 7.6-9 = a very good state; and >9.1 = an excellent state.

Statistical Analysis

A data analysis was performed using the Statistical Package for Social Sciences (version 23 for Windows, SPSS™, Chicago, IL, USA). Standard statistical methods were used to calculate the mean (or median) and standard deviations (SD). The data was screened for normality of distribution and homogeneity of variances using Shapiro-Wilk and Levene's tests, respectively. Differences between dependent variables and TQR values in training sessions and on the match day were analyzed using one-way ANOVA, followed by Bonferroni's post hoc test (Kruskal Wallis test followed by Mann-Whitney U test, with Bonferroni correction of alpha, in this case, dividing alpha by three comparisons). The effect size (ES) was calculated using the method proposed by Batterham and Hopkins[23]. The effect values lower than 0.2, between 0.2 and 0.5, between 0.5 and 0.8, and higher than 0.8 were considered trivial, small, moderate, and large, respectively. The $p<0.05$ criterion was used for establishing statistical significance.

Results

The duration (mean, standard deviation and confidence interval at 95%, in hours:minutes:seconds) of the sessions were 1:23:37±0:11:40 (1:19:56-1:27:18), 1:14:43±0:12:37 (1:12:07-1:17:20) and 0:58:25±0:07:57 (0:56:48-1:00:02) for MD-3, MD-2 and MD-1, respectively. A significant difference was found between all of the days.

Figure 1 shows values for PL (in AU) on each day of the week. The differences were statistically lower for training sessions closer to the match day (MD-3>MD-2>MD-1), where the values were as follows: 436.6±70.8, 358.4±51.1 and 253.2±58.7, respectively (ES: 1.27 for MD-3 *vs.* MD-2; 1.91 for MD-2 *vs.* MD-1; 2.82 for MD-3 *vs.* MD-1). Furthermore, the PL/min values for MD-3, MD-2 and MD-1 were significantly different, 5.3±0.7, 4.9±0.8 and 4.3±0.7, respectively (ES: 0.53 for MD-3 *vs.* MD-2; 0.80 for MD-2 *vs.* MD-1; 1.43 for MD-3 *vs.* MD-1).

Table 2 shows absolute values of other external training load variables (mean, standard deviation and confidence interval at 95%) for each

Figure 1. Median, ±standard deviation, confident interval at 95% for a) total PL (Player Load) in arbitrary units (AU) and b) PL/min (Player load per minute) in arbitrary units per minute (AU/min) regarding to the day of the week (MD-3 is match day minus 3, MD-2 is match day minus 2 and MD-1 is match day minus 1).

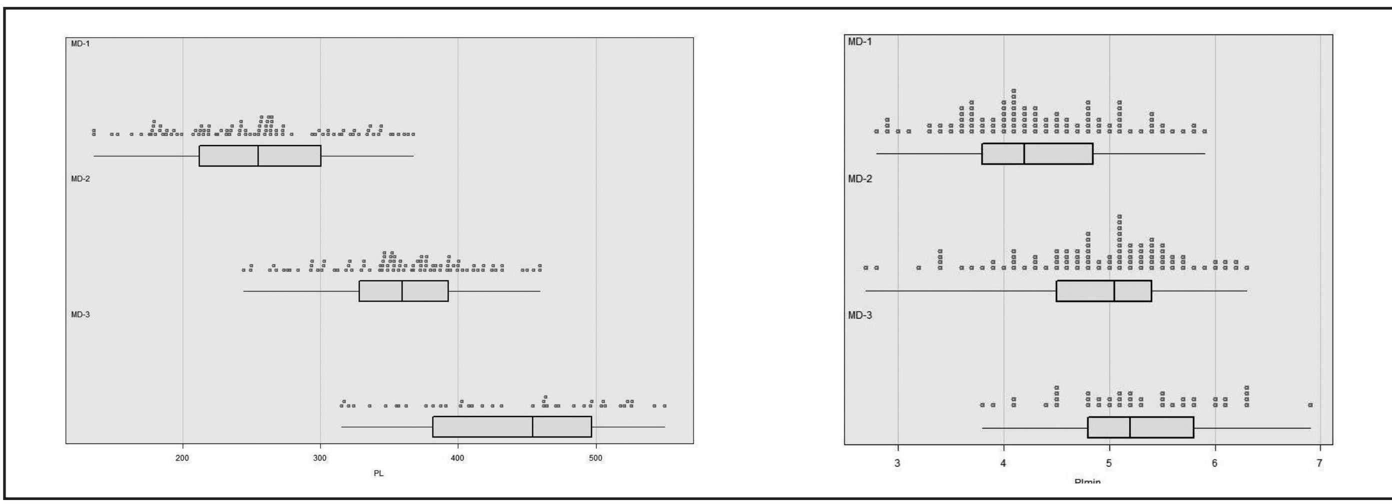


Table 2. Mean, ±standard deviation, confident interval at 95% (in brackets) and effect size (ES) for absolute external training load variables.

Variables	MD-3	MD-2	MD-1	ES
hACC (n)	10.8±5.5[2,1] (9.0-12.5)	8.0±3.9[1] (7.2-8.8)	4.1±3.0 (3.4-4.7)	A=0.59, B=1.12, C=1.51
tACC (n)	72.8±22.9[2,1] (65.6-80.0)	62.2±21.0[1] (57.8-66.5)	33.3±15.2 (30.2-36.4)	A=0.48, B=1.58, C=2.03
hDEC (n)	16.8±8.2[2,1] (14.2-19.4)	12.0±6.1[1] (10.7-13.2)	7.3±4.4 (6.4-8.2)	A=0.66, B=0.88, C=1.44
tDEC (n)	125.9±28.6[2,1] (116.8-134.9)	101.2±23.4[1] (96.4-106.1)	71.4±25.7 (66.1-76.6)	A=0.95, B=1.21, C=2.00
hCoD (n)	33.1±12.7[2,1] (29.1-37.1)	26.6±12.0[1] (24.1-29.1)	15.0±8.3 (13.3-16.7)	A=0.53, B=1.12, C=1.69
tCoD (n)	480.0±103.7[2,1] (447.2-512.7)	374.8±67.1[1] (360.9-388.7)	247.7±80.3 (231.3-264.0)	A=1.20, B=1.72, C=2.50
hJUMP (n)	17.5±7.3[1] (15.2-19.8)	14.8±6.1[1] (13.5-16.0)	10.2±5.3 (9.1-11.2)	B= 0.81, C=1.14
tJUMP (n)	58.2±17.6[1] (52.7-63.8)	55.5±16.2[1] (52.2-58.9)	42.7±21.3 (38.4-47.0)	B= 0.68, C=0.79

3 means > MD-3, 2 means > MD-2, 1 means > MD-1, A means MD-3vsMD-2, B means MD-2vsMD-1 and C means MD-3vsMD-1. tACC is total forward acceleration, hACC is total forward acceleration within the high band (>3.5 $m \cdot s^{-2}$), tDEC is total deceleration, hDEC is total deceleration within the high band (<-3.5 $m \cdot s^{-2}$), tCOD is total rightward lateral movements, hCOD is total movements registered in a rightward lateral vector within the high band, tJUMP is total jumps, and hJUMP is jumps done at the high band (above 0.4 m).

Figure 2. Median, ± standard deviation, confident interval at 95% for a) sRPE (session RPE) in arbitrary units (AU) and b) sRPE in arbitrary units per minute (AU/min) regarding to the day of the week (MD-3 in match day minus 3, MD-2 in match day minus 2 and MD-1 in match day minus 1).

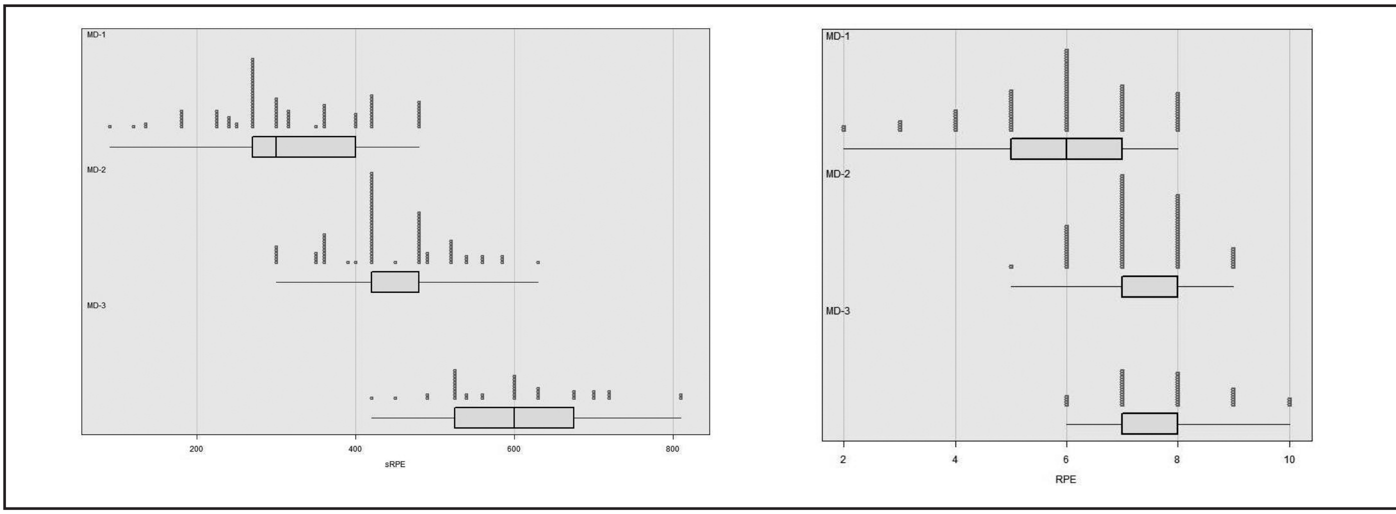


Table 3. Mean, ±standard deviation, confident interval at 95% (in brackets) and effect size (ES) for relative (per minute) external training load variables.

Variables	MD-3	MD-2	MD-1	ES
hACC/min	0.14±0.07^{2,1} (0.12-0.17)	0.11±0.05^{1} (0.10-0.12)	0.05±0.04 (0.05-0.06)	A=0.49, B=1.33, C=1.58
hDEC/min	0.22±0.1^{2,1} (0.19-0.26)	0.16±0.08^{1} (0.14-0.18)	0.10±0.06 (0.09-0.11)	A=0.67, B=0.85, C=1.46
tACC/min	0.98±0.31^{2,1} (0.88-1.07)	0.83±0.28^{1} (0.77-0.89)	0.45±0.20 (0.40-0.49)	A=0.51, B=1.56, C=2.03
tDEC/min	1.69±0.38^{2,1} (1.57-1.81)	1.36±0.31^{1} (1.29-1.42)	0.96±0.34 (0.89-1.03)	A=0.95, B=1.23, C=2.02
hCoD/min	0.44±0.17^{2,1} (0.39-0.50)	0.36±0.16^{1} (0.32-0.39)	0.20±0.11 (0.18-0.22)	A=0.48, B=1.17, C=1.68
tCoD/min	6.43±1.39^{2,1} (5.99-6.87)	5.02±0.90^{1} (4.84-5.21)	3.32±1.08 (3.10-3.54)	A=1.20, B=1.71, C=2.50
tJUMP/min	0.68±0.27 (0.64-0.71)	0.78±0.24^{1,3} (0.71-0.85)	0.74±0.22^{3} (0.70-0.79)	A= -0.39, C= -2.24
hJUMP/min	0.18±0.09 (0.17-0.19)	0.23±0.10^{1,3} (0.20-0.26)	0.20±0.08^{3} (0.18-0.21)	A= -0.53, C= -0.23

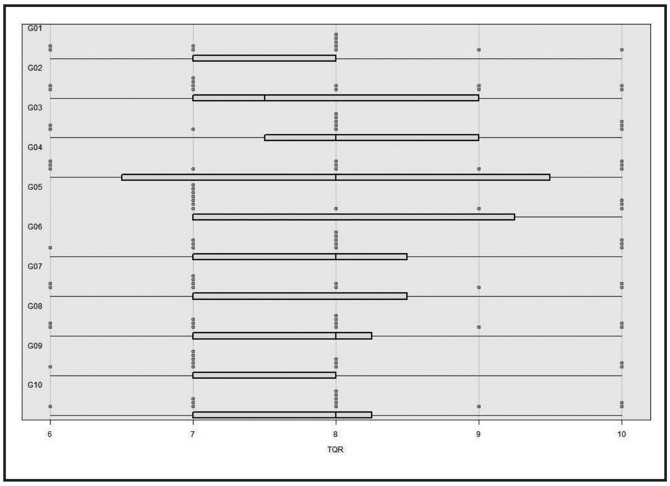
3 means > MD-3, 2 means > MD-2, 1 means > MD-1. A means MD-3vsMD-2, B means MD-2vsMD-1 and C means MD-3vsMD-1. tACC is total forward acceleration, hACC is total forward acceleration within the high band (>3.5 $m{\bullet}s^{-2}$), tDEC is total deceleration, hDEC is total deceleration within the high band (<-3.5 $m{\bullet}s^{-2}$), tCOD is total rightward lateral movements, hCOD is total movements registered in a rightward lateral vector within the high band, tJUMP is total jumps, and hJUMP is jumps done at the high band (above 0.4 m).

type of session in the week. In most variables, there was a statistically significant difference between the days MD-3 > MD-2 > MD-1. Only JUMP variable showed no difference between MD-3 and MD-2, while both days differed from MD-1.

When variables were expressed in minutes of practice (Table 3), almost all of the variables showed the same pattern, with statistically significant differences between MD-3 > MD-2 > MD-1. Interestingly, tJUMP/min and hJUMP/min showed no difference between MD-3 and MD-2, while both days showed a difference when compared to MD-1.

As for internal variables, the training load (sRPE) variable showed a statistically significant difference between days MD-3 > MD-2 > MD-1; 598.2±90.5 (569.6-626.7) AU, 441.4±73.4 (426.1-456.6) AU and 312.0±92.8 (293.1-330.9) AU, respectively (ES: 1.90 for MD-3 *vs.* MD-2, 1.55 for MD-2 *vs*. MD-1 and 3.12 for MD-3 *vs*. MD-1). The intensity variable RPE showed no differences between MD-3 and MD-2 with values 7.8±1.1 (7.4-8.1) AU and 7.3±0.9 (7.1-7.5) AU, respectively. However, the results for MD-1 were 6.0±1.4 (5.7-6.3) AU, what significantly differentiates from previous two days (1.10 for MD-2 *vs*. MD-1 and1.43 for MD-3 *vs*. MD-1) (Figure 2).

Figure 3. Median, ± standard deviation, confident interval at 95% for team's TQR scores prior the match (G presents a game, while the number classifies games from the first to the tenth).



Finally, Figure 3 presents the average scores in TQR questionnaire for all of the match days in the reference period. The average values from the first to the last game were as follows: 7.7 (6-10), 7.8 (6-10), 8.1 (6-10), 8.0 (6-10), 8.0 (7-10), 8.1 (6-10), 7.7 (6-10), 7.8 (6-10), 7.7 (6-10) and 8.0 (6-10). The average for all of the match days was 7.9 (±1.31), positioning the team in the category of a very good state. There were no significant differences in the recovery status (TQR questionnaire results) between all match days in the reference period.

Discussion

The main aim of the present study was to describe differences between training sessions leading up to the first match of the week with respect to both eTL and iTL parameters. To the best of the authors' knowledge, this is the first study investigating short-term tapering in the elite basketball setting. The results showed differences in almost all variables (in both load and intensity) between the training sessions analyzed (MD-3>MD-2>MD-1). Furthermore, the TQR scores on the match day did not indicate any abnormality in players' optimal state of recovery. In particular, the results of the present study contributed to the improvement of specific periodization strategies with respect to different training durations, load and intensity.

Monitoring TL in basketball players is crucial in planning appropriate training programmes[24] and exposing players to adequate monotony and strain in order to reduce injury risk[25]. Additionally, in previous research on effects of specific periodization strategies to avoid overtraining syndrome or under-stimulation, it was concluded that training session duration and intensity manipulation is a very important component of tapering[2]. Experts[1] suggested that, out of the three main factors in tapering – training intensity, frequency and volume –, a decrease in the latter factor had the strongest effect on enhanced performance. In the present study, a decrease in the training duration (i.e, volume) in the days leading up to the match follows general tapering principles, where training intensity was kept at the high level when SSG were used but general training volume was decreased due to shorter training time. Additionally, from Table 1. it can be observed that 3vs3 SSG was not perfromed one day before the offical game, as it was physically more exhausting than the other drills. However, tapering included only three-day cycles and can therefore be considered as a short-term taper.

The majority of external load variables (i.e. hACC, tACC, hDEC, tDEC, hCoD and tCoD) revealed the same pattern in their inter-day relationships as the global variables, PL and sRPE. In connection with that finding, the authors suggest that these variables could be the most important eTL variables in prescribing load in basketball training sessions. Only two eTL variables of the same construct (i.e. hJUMP and tJUMP) showed different relationships between the days, with no difference found between MD-3 and MD-2, while both days differed from MD-1. This finding could be ascribed to different shooting drills, which significantly affected both hJUMP and tJUMP variables. In the future, it is important to differentiate the jumps accumulated in SSG and those from the other tasks, such as warm-up or spot-up shooting. When the total number of ACC, DEC, CoD and JUMP variables is considered in basketball training, regardless of the day, it is important to recognize that the CoD variable had the highest values by far. For that reason, CoD also had the highest impact on load accumulation.

PL, a global eTL variable, shows significant differences between all of the days, starting from MD-3, which showed the highest value (436.6±70.8 AU), through MD-2 with a moderate value (358.4±51.1 AU), and finally, MD-1 with the lowest value (253.2±58.7 AU). These findings confirm previous research into short-term tapering in other team sports[7]. Unfortunately, eTL data on daily loads and short-term tapering in basketball does not exist.

With respect to iTL variables, the present study found that sRPE shared a very strong inter-day relationship as PL, unlike a previous study[26] on elite basketball players, which found only a moderate relationship (r=0.49). sRPE, a measure of internal training load, was the highest (598.2±90.5 AU) on MD-3, followed by 441.4±73.4 AU on MD-2 and was the lowest (312.0±92.8 AU) on MD-1. These findings support the previous study on elite basketball players[4]. However, Manzi's study covered only two days leading up to a Euroleague game, since MD-3 was a day without physical activities (i.e. day-off). Over these two days, the players accumulated on average 748±71 AU on MD-2 and 275±54 AU on MD-1, with players participating in both resistance (explosive weights) and technical training on MD-2, and in tactical team training on MD-2. A significant drop in load was applied in both cases, which supports the importance of the tapering concept of training volume decrease.

The PL/min variable, which can be considered a variable representing the intensity of work, shows a downward trend, with MD-3 showing the highest value of 5.3±0.7, MD-2 a moderate value of 4.9±0.8, and MD-1 the lowest value of 4.3±0.7 (all in AU per min). Even though Pyne *et al.*[1] suggested that training intensity should be maintained for an optimal taper, it is important to know that longer rest periods were used on MD-2 and, even more so, on MD-1 in order to decrease the metabolic stress, which could explain the significant drop in PL/min values, despite the fact that almost all of the SSGs were used in all of the days leading up to the match. Additionally, the shooting drills were used in greater volume on MD-2 and MD-1 when compared to MD-3, what could further impact the PL/min values. With respect to the above said, the intention in practices was to maintain high intensity in competitive tasks, such as SSG, but this information was not provided in the current study.

Another intensity variable, the subjective RPE, did not show the exact same pattern as PL/min, and significant difference were not found between MD-3 and MD-2. However, both days differed from MD-1. This finding could be ascribed to the accumulated fatigue from MD-3, which is the most demanding day, having a direct impact on the next session on MD-2. However, a well-planned decrease in training volume and load did not have an impact on the residual fatigue on MD-1, but it did lead to a good readiness to play on the match day.

In order to evaluate the physical status (i.e. state of recovery and well-being) of players and their adaptation to training load prior to the match, a simple TQR questionnaire was used, as has been the practice in other team sports recently[27]. The team played 10 games in the reference period, with team scores ranging from 7.7 to 8.1 AU, which positions them in the category of very good physical status. There was no disturbance in the recovery status (as expressed by the TQR questionnaire) in any of the weeks prior to the matches (Figure 3). As suggested by Nunes *et al.*[3], overloading leads to poorer recovery and physical status of players. However, we hereby propose that short-term tapering using the loads specified in this study could improve players' physical status and enable them to be in good physical condition for the competition.

Even though it is important for all coaches to strive for better scores by applying different methods of both training and recovery, it is also important to understand that it is very difficult to constantly maintain an excellent physical status. Playing modern basketball at the elite level requires the players to play 2-3 games per week, and sometimes take several flights a week, early in the morning or late at night, changing the sleeping environment on a weekly basis. These are only some of the factors that interrupt players' circadian rhythm. However, it is important to consider the findings by Rabbani & Buchheit[5], who state that fitter player may experience less wellness impairment when traveling than their less fit counterparts. Moreover, members of the coaching staff should establish a positive working environment, so that players are surrounded with positive energy and maintain healthy mentality in challenging moments on a daily basis.

Therefore, as the team in this investigation constantly averaged in the 'very good state' category, the authors concluded that the accumulated training load presented could be appropriate. Additionally, to keep the players in an optimal physical condition, it is important to maintain a sound acute: chronic workload ratio between micro-cycles, while considering both training and game loads. As suggested by previous research[28], it is better to maintain a high chronic load, because, in congested fixture, players are ready to support a high amount of load. In basketball, this idea has great importance for all players, especially those with more playing time.

This study accentuates the short-term tapering as a basic principle in weekly training load management. As the results of this study show, external and internal variables are complementary methods for monitoring training load. These methods are probably more effective than using only sRPE training load and training volume when the physical fitness level of players is to be assessed[29]. In order to perform at the optimal level in competitions, players need to accumulate a high amount of load, but with a particular distribution. It can be suggested that players experience a decrement (p.e.≈42%, ≈34% and ≈24% in MD-3, MD-2 and MD-1, respectively) in training load in the three days prior to the match, which leads to the enhancement of their physical status, as a result of the so-called supercompensation phenomenon[2]. In elite basketball, as this dose-response investigation presents, a progressive decrease in training loads three days before the match could be an appropriate way of physical conditioning in a preparation of a team for competitive tasks.

One of the limitations in the current study was the lack of comparison group. However, that kind of experimental design is not available when the study is conducted in top-level performance teams. Additionally, head coach's philosophy and training planification principles influenced the load distribution presented in the study. In the future, research in elite basketball should examine the effectiveness of different models of load distribution prior to the match day in correlation with both physical and key performance indicators in games.

Conclusion

Training load management is a crucial factor that leads to either enhanced or decreased physical condition in competitions. Basketball is an intermittent sport where accelerometry – derived data on individual accelerations, decelerations, jumps, changes of direction and PlayerLoad – provides a stable and clear platform for tracking and analyzing training load. Therefore, if training load is appropriately selected, coaches can find the most effective micro-tapering models prior to the match. According to the findings of this study, the accumulated PL of ≈1048 AU with ratio of ≈ 42%, 34% and 24% in MD-3, MD-2 and MD-1 respectively, could be appropriate load distribution, as it leads to a very good physical status on the match day. Moreover, the current study demonstrates that the use of different approaches to monitor training load provides a better micro-cycle (i.e. week) assessment and implementation of the short-term tapering prior to the games at the elite basketball level. Complementary monitoring of both external and internal loads provides a comprehensive insight about training demands and psycho-physiological responses in players. Successful training load monitoring across the pre- and in-season phases should be performed for two main reasons; to decrease injury risk and provide optimal level of stress and adaptation that leads to enhanced physical and competitive performance. Nevertheless, solely monitoring of training load is not enough to ensure a good management of the load. Complementary to load monitoring methods, coaches should assess players' state of recovery and readiness to play. In this paper, use of the TQR questionnaire was presented. However, complementary use of subjective and objective (e.g. creatin kinease values, heart rate, jumping performance) methods is advised. The practical implications may be further enhanced by understanding players' mental and physical states regarding the day of the week and its proximity to the match-day. Only in this way, coaching staff will manage to optimize the players' performance. Therefore, future research in basketball should provide more information on a) the accelerometry-derived game load, so that even better relationships can be established between training and competitive demands and b) the effects of sleep quality and mentality during travels on players' readiness and performance in competitions.

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Conflicts of interest

The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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Original article

Psychological vulnerability to injury. Profiles depending on sporting modality

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Summary

In the competitive sports field is necessary to create a profile of "risk to the injury" useful and effective that allows to elaborate specific intervention programs. The purpose of this study was to relate the number of sports injuries (severity of injury) to the different degrees of vulnerability to injury of athletes (high, medium and low vulnerability), based on the sports modality under the differentiation between opposition or individual sport (federated athletes of athletics, swimming and tennis) and contact sport with opposition and cooperation or collective sport (federated athletes of football, basketball and handball).
Total sample of this study was 452 individual and collective athletes (284 men and 168 women). For the evaluation of the psychological variables, Resistant Personality Scale, the SCAT and Competitiveness Scale-10 was used. A cluster analysis was carried out and 3 profiles of vulnerability to injury were obtained, establishing a high vulnerability profile that confirmed the hypothesis (increases the vulnerability to injury to a less resistant personality and motivation oriented to success and greater competitive anxiety and oriented motivation to avoid failure).
Among the main conclusions is that being an individual or collective athlete influences the relationship between any profile of vulnerability and the number of minor injuries, the number of minor injuries being higher in collective athletes. On the other hand, athletes, in both modalities, who are in a medium vulnerability, have a greater number of mild and moderate injuries, and athletes who are in a high vulnerability have a greater number of serious injuries and very serious.

Key words:
Athletes. Hardiness. Competitiveness. Competitive anxiety.

Vulnerabilidad psicológica a la lesión. Perfiles según la modalidad deportiva

Resumen

En el ámbito deportivo competitivo se hace necesaria la creación de un perfil de "riesgo a la lesión" útil y eficaz que permita elaborar programas específicos de intervención. En este estudio se planteó como objetivo relacionar el número de lesiones deportivas (gravedad de lesión) con los diferentes grados de vulnerabilidad a la lesión de los deportistas (vulnerabilidad alta, media y baja), atendiendo a la modalidad deportiva bajo la diferenciación entre deporte de oposición o individual (deportistas federados de atletismo, natación y tenis) y deporte de oposición-cooperación de contacto o deporte colectivo (deportistas federados de fútbol, baloncesto y balonmano).
La muestra total del estudio fue de 452 deportistas individuales y colectivos (284 hombres y 168 mujeres). Para la evaluación de las variables psicológicas se utilizó la Escala de Personalidad Resistente, el SCAT y la Escala de Competitividad-10. Se realizó un análisis de conglomerados y se obtuvieron 3 perfiles de vulnerabilidad a la lesión, estableciéndose un perfil de vulnerabilidad alta que confirmaba la hipótesis (aumenta la vulnerabilidad a la lesión a menor personalidad resistente y motivación orientada al éxito y a mayor ansiedad competitiva y motivación orientada a evitar el fracaso).
Entre las principales conclusiones se destaca que ser deportista individual o colectivo influye en la relación entre cualquier perfil de vulnerabilidad y el número de lesiones leves, siendo el número de lesiones leves superior en deportistas colectivos. Por otro lado, puede que los deportistas, en ambas modalidades, que se sitúen en una vulnerabilidad media, posean mayor número de lesiones leves y moderadas, y que los deportistas que se sitúen en una vulnerabilidad alta posean un mayor número de lesiones graves y muy graves.

Palabras clave:
Deportistas. Personalidad resistente. Competitividad. Ansiedad competitiva.

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Introduction

It can be claimed that injury is one of the most important obstacles to the successful performance of an athlete. Perhaps the most frequent and important risk within competition sport, given the physical and psychosocial repercussions, is suffering from an injury. On many occasions the huge demand for effort and the high level of exigence - characteristic of all sporting activity - sometimes result, perhaps in excess, in multiple traumas and injuries that force the athlete to suspend or reorganise his/her activities. In turn, if we take into account the results provided by Antonelli and Salvini[1] from their comparison between the different specialities, upon discovering that there are significant differences between athletes depending on the speed or resistance tests, if the characteristics of the tests are extrapolated to other sports, it could be said that there may be a specific vulnerability profile depending on the speciality.

Analyses performed for a study in 2018 by Reigal, Delgado, Raimundi and Mendo[2], revealed that the group of triathletes studied achieved higher scores than the athletes in the negative and positive coping test, attention test, motivational level and attitude test. They also displayed higher scores than footballers in the negative and positive coping test. In terms of the group of golfers, they scored more in all the IPED (Psychological Inventory of Sports Performance), and less in motivational levels. In general, higher scores were shown among triathletes than in the other sports analysed.

As systematised by Antonelli and Salvini[1], there are psychological differences for different disciplines, among which are the skiers (three types are identified: speed, cross-country and jumps). Likewise, there are also different profiles that can leave the athlete more vulnerable to injury, for example, in the study by Coulter, Mallet and Gucciardi[3] on American footballers, the results revealed that athletes with less mental strength and with a tendency for risk-taking, were more likely to play with minor injuries that could later become more serious.

On the other hand, the study on resistant personality is interesting, as indicated by Jones[4], as one of the least-used and applied terms in Sports Psychology. This study follows the approach of resistant personality according to Kobasa[5] within existing theory, defining it as a construction of 3 factors (control, commitment and challenge): "a person's basic stance towards his or her place in the world that simultaneously expresses commitment, control and readiness to respond to challenge".

In terms of the study of competitive anxiety, the hypothesis that different researchers have in general adopted, is that athletes with high levels of competitive anxiety will have a higher probability of becoming injured in stressful situations[6-10]. On the other hand, the relationship between sporting injuries and competitiveness and motivation for achievement in sport has also been studied[11,12].

The starting point is the hypothesis that the sporting modality causes differences in personality traits. However, does practising a certain sport require the athlete to have specific personality characteristics, or at least one factor of predisposition? Moreover, how does one become less vulnerable to injury in certain sports? Within the competitive sporting field it is necessary to create a useful and effective "injury risk" profile that enables specific injury prevention programmes to be developed. In this study the idea was to explore samples of different sporting modalities within the competitive sphere, using different assessment instruments that included scales focused on different aspects of personality. The objective proposed was to relate the number of sporting injuries (seriousness of injury) with the different degrees of vulnerability to injury of the athletes (high, medium and low vulnerability), adhering to the following criteria: team sport, individual sport. According to the International Bibliography, the hypothesis proposed was that the subjects with the following vulnerability to injury would acquire more injuries (high vulnerability): low resistant personality, high competitive anxiety, low motivation geared towards success and high motivation aimed at avoiding failure.

Material and method

Design

Following Ato, López and Benavente[13] the strategy used in this study is associative, comparative and cross-cutting. The design used in the research study was cross-cutting, descriptive, correlative and not randomised. The dependent and independent study variables were: a) Frequency or number of injuries depending on the seriousness of the injury (mild, moderate, serious and very serious), b) Sporting modality (individual and team sport) and c) Degree of psychological vulnerability to injury (high, medium and low).

Sample

The total study sample included 452 subjects (46 uninjured), 284 males (39 uninjured) and 168 females (7 uninjured). The average age of the males was 21.77 years (DT=4.81) and the average age of the females was 20.55 years (DT=4.39). The study comprised opposition sport athletes [federated athletics athletes (76), swimming (87) and tennis (91)], 143 males (125 injured) and 111 females (90 injured), and contact opposition-cooperation sport athletes [federated football athletes (92), basketball (43) and handball (63)], 141 males (137 injured) and 57 females (54 injured). Table 1 displays the distribution between injured and uninjured players, depending on the vulnerability profile, the type of sporting modality and sex.

Instruments

To assess resistant personality, an adaptation of the Resistant Personality Scale (RPS) by Jaenes, Godoy and Román[14] was used. The RPS is an instrument comprising 30 items: 10 for each of the dimensions that make up the structure of the resistant personality (commitment, control and challenge), for which the responses are presented in a graduated way in Likert type format. It is based on the Spanish version of the P*ersonal Views Survey* (PVS, Hardiness Institute). Moreover, the RPS was adapted in terms of content to the sporting context, changing the vocabulary and

Table 1. Recount of injured and uninjured athletes by vulnerability profile and depending on the type of sporting modality and sex.

	Individual sport				Team sport			
	Uninjured		Injured		Uninjured		Injured	
	Male	Female	Male	Female	Male	Female	Male	Female
Low vulnerability	15	16	51	43	0	1	22	8
Medium vulnerability	1	3	45	20	2	2	99	42
High vulnerability	2	2	29	27	2	0	16	4

the statements of the items to reflect a content linked to the sporting sphere. Specifically, a factorial analysis was performed from which the following sub-scales were established: control (items 4, 16, 24 and 5), commitment (20, 17 and 10), challenge (9 and 11). A Cronbach alpha coefficient was obtained for the RPS scale of 0.58.

The *Sport Competition Anxiety Test* (SCAT) by Martens[15] was used to assess competitive anxiety. The SCAT is an adding instrument that is useful for assessing the trait of competitive anxiety, characteristic of athletes, and different to a general anxiety trait. Specifically, it assesses the athlete's tendency to perceive the stressful situation of sporting competition as a threat and to react with anxiety. It comprises 15 items on a Likert type scale, with three response options (never, sometimes, almost always). In this research study, a high Cronbach coefficient of 0.73 was obtained.

To assess competitiveness, the Remor Competitiveness-10 Scale was used[16]. This self-report questionnaire comprises 10 questions about the respondent's motivation linked to sporting competitiveness, designed to assess motivation to succeed, motivation to avoid failure, and competitiveness in adult individuals that partake in sporting activity. The response format used is the Likert type (1= Almost Never, 2=Sometimes, 3=Often). Due to reliability problems, items 1 and 10 were removed so that two sub-scales were established: success motivation scale (items 2, 3, 5 and 8), and the motivation scale for avoiding failure (4, 6, 7 and 9). A Cronbach alpha of 0.54 and 0.53 was obtained respectively

To assess sporting injury (history of injuries, frequency and seriousness), a self-report Questionnaire was used *ad hoc* for the study, incorporating suggestions from other authors[17,18].

Procedure

Training sessions were attended and before starting the questionnaire administration process the athletes were asked to give their consent, informing them of the confidentiality and anonymous nature of the data, and requesting them to sign the informed content document. The surveys were given out in accordance with the Helsinki Declaration (2013 revision), via informed consent.

To establish the levels of low and high resistant personality, competitive anxiety and motivation geared towards success and motivation aimed at avoiding failure, a frequency analysis was applied, in which subjects with higher levels were defined as high, whilst those with lower levels were defined as low. The combination of the 4 variables, each of which possess 2 categories (low and high), led to the defining of 16 profiles. Later, an analysis of conglomerates was performed for the 16 profiles, obtaining 4 blocks (of which one block was ruled out for only comprising one subject), finally obtaining 3 blocks or degrees of vulnerability to injury:

- Low vulnerability (more resistant personality, high competitive anxiety, lower motivation geared towards success and greater motivation aimed at avoiding failure). The subjects with this profile should have more mental strength and more tools to face risk situations, but they could acquire injuries as they could also generate unsuitable behaviour.
- Medium vulnerability (less resistant personality, greater competitive anxiety, greater motivation geared towards success and lower motivation aimed at avoiding failure). The subjects with this profile should generate suitable behaviour, but they could acquire injuries given that their motivation geared towards success generates more risky situations.
- High vulnerability (less resistant personality, greater competitive anxiety, lower motivation geared towards success and greater motivation aimed at avoiding failure). The subjects with this profile should generate unsuitable behaviour, will probably have more injuries because being in a state of concern produces more tension and stress, thus increasing the number of injuries.

Statistical analysis

A descriptive study was carried out of the different study variables. To perform the statistical calculations the IBM SPSS Statistics version 23.0 package was used. To assess the standard nature of the scale variables, the Chi-square test was used, as well as the Kolmogorov-Smirnov statistics test for the categorical variables. In order to compare the number of injuries among athletes that fulfilled the psychological vulnerability to injury profile with those that did not, the Student *t* test was used for independent samples. Next, in order to verify that the sporting modality variable influenced the relationship between the "number of injuries and vulnerability" variables, an analysis of variance was applied of the two factors (2x3), using the Bonferroni test to analyse the comparisons *post-hoc*. In all cases, a significance level of $p<0.005$ was used.

Results

After applying the statistical Chi-square test to determine the normality of the categorical variabilities, the distribution of the data is considered normal (p>0.05), therefore, the tests performed with these variables are parametric. In turn, to assess the normality of the scale variables, and after applying the Kolmogorov-Smirnov statistical test for a sample, normality was also determined (p<0.05).

Table 2 displays the number of injuries by seriousness and vulnerability to injury, differentiated by sporting modality.

Upon analysing the values obtained in the "number of mild injuries" variable, the effect of the interaction of the sporting modality factor by Type of Vulnerability (2x3) can be seen as statistically significant ($F_{2.46}$=6.125, p=0.002). Therefore, it can be indicated that being an individual or team sport influences the relationship between the vulnerability profile and the number of mild injuries. Specifically, for athletes that practice team sports there are statistically significant differences in the number of mild injuries depending on the vulnerability group ($F_{2.446}$=5.754, p=0.003), with differences apparent between the high vulnerability group and the medium vulnerability group (p=0.003) and between the high vulnerability group and the low vulnerability group (p=0.012). On the contrary, for individual athletes no statistically significant differences can be seen in the number of mild injuries by vulnerability group ($F_{2.446}$=1.650, p=0.193). In any case, the average number of mild injuries is higher in team sports than in individual sports, regardless of the type of vulnerability, with statistically significant differences appearing in high vulnerability ($F_{1.446}$=29.983, p=0.000), in medium vulnerability ($F_{1.446}$=5.911, p=0.015) and in low vulnerability ($F_{1.446}$=7.769, p=0.006).

Moreover, upon analysing the values obtained in the number of moderate injuries variable, the effect of the interaction of the sporting modality factor by Type of Vulnerability (2x3) was not considered to be statistically significant ($F_{2.446}$=1.289, p=0.276). Therefore, it can be indicated that being an individual or team sport does not influence the relationship between the vulnerability profile and the number of moderate injuries. Specifically, for athletes that practice individual sports there are differences tending towards significant in the number of moderate injuries depending on the vulnerability group ($F_{2.446}$=2.861, p=0.058), with differences appearing between the high vulnerability group and the low vulnerability group (p=0.054). On the contrary, for team sport athletes no statistically significant differences can be seen in the number of moderate injuries by vulnerability group ($F_{2.446}$=0.965, p=0.382). In any case, the average number of moderate injuries is higher in team sports than in individual sports, regardless of the type of vulnerability, with statistically significant differences appearing in high vulnerability ($F_{1.446}$=19.436, p=0.000), in medium vulnerability ($F_{1.446}$=69.521, p=0.000) and in low vulnerability ($F_{1.446}$=60.143, p=0.000).

Moreover, upon analysing the values obtained in the number of serious injuries variable, the effect of the interaction of the sporting modality factor by Type of Vulnerability (2x3) was not considered to be statistically significant ($F_{2.446}$=0.673, p=0.511). Therefore, it can be indicated that being an individual or team sport does not influence the relationship between the vulnerability profile and the number of serious injuries. Specifically, for athletes that practice individual sports there are statistically significant differences in the number of serious injuries depending on the vulnerability group ($F_{2.446}$=10.575, p=0.000), with differences appearing between the high vulnerability group and the low vulnerability group (p=0.000). On the contrary, for team sport athletes no statistically significant differences can be seen in the number of serious injuries by vulnerability group ($F_{2.446}$=0.938, p=0.392). In any case, the average number of serious injuries is higher in team sports than in individual sports (apart from high vulnerability, for which individual sports reveals a higher average) regardless of the vulnerability type, with no statistically significant differences apparent or tendencies towards significance.

With regards to the values obtained in the number of very serious injuries variable, the effect of the interaction of the sporting modality factor by Type of Vulnerability (2x3) was not considered to be statistically significant ($F_{2.446}$=0.649, p=0.523). Therefore, it can be indicated that being an individual or team sport does not influence the relationship between the vulnerability profile and the number of very serious injuries. Specifically, for athletes that practice individual sports there

Table 2. Relationship between frequency and seriousness of injury and the vulnerability profile depending on sporting modality.

No. injuries	Individual			Team		
	Low V. (n=88)	Medium V. (n=147)	High V. (n=49)	Low V. (n=68)	Medium V. (n=67)	High V (n=33)
Mild	0.98 ± 1.31	1.53 ± 1.48	0.98 ± 1.21	2.19 ± 1.72	2.31 ± 2.61	3.95 ± 5.31
Moderate	0.50 ± 0.78	0.62 ± 0.92	1.03 ± 1.11	2.70 ± 1.34	2.35 ± 1.69	2.59 ± 3.21
Serious	0.24 ± 0.65	0.52 ± 0.81	0.81 ± 0.87	0.45 ± 0.62	0.64 ± 0.83	0.72 ± 1.16
Very serious	0.04 ± 0.30	0.05 ± 0.23	0.26 ± 0.48	0.09 ± 0.30	0.14 ± 0.45	0.22 ± 0.42
Total	1.77 ± 1.67	2.73 ± 1.69	3.10 ± 1.70	5.45 ± 2.09	5.44 ± 3.88	7.50 ± 9.00
Injury rate	0.54 ± 0.53	0.61 ± 0.38	0.87 ± 0.46	1.68 ± 0.96	1.60 ± 1.19	1.77 ± 1.83

are statistically significant differences in the number of very serious injuries depending on the vulnerability group ($F_{2.446}$=7.208, *p*=0.001), with differences apparent between the high vulnerability group and the low vulnerability group (*p*=0.001) and between the high vulnerability group and the medium vulnerability group (*p*=0.007). On the contrary, for team sport athletes no statistically significant differences were seen in the number of very serious injuries by vulnerability group ($F_{2.446}$=0.748, *p*=0.474).

The average number of very serious injuries is higher in team sports than in individual sports (apart from high vulnerability, for which individual sports reveals a higher average) regardless of the vulnerability type, with no statistically significant differences apparent or tendencies towards significance.

In summary, the average number of mild, moderate, serious and very serious injuries is higher among team athletes than among individual athletes, but being an individual or team athlete does not influence the relationship between the vulnerability profile and number of moderate, serious and very serious injuries. On the other hand, being an individual or team sport does influence the relationship between any vulnerability profile and the number of mild injuries. In team sports differences can be seen between the high and medium vulnerability groups and between the high vulnerability and low vulnerability groups for mild injuries. In turn, among individual athletes differences can be seen between the high and low vulnerability groups for moderate, serious and very serious injuries, and between the high and medium vulnerability groups for very serious injuries.

Discussion

Junge[19] indicates the existence of an "injury prone" personality profile, though he acknowledges that there are subjects with a greater tendency to take high-risk decisions. In turn, Thomson and Morris[20] indicate that athletes that outwardly display a high degree of anger, increase their risk of acquiring an injury, opposed to those that direct their anger inwardly. On the other hand, according to the Global Psychological Model of Sporting Injuries (GPMSI) by Olmedilla and Garcia-Mas (2009, quoted in Garcia-Mas, Pujals, Fuster-Parra, Nuñez and Rubio, 2014[21]) the consequent variables of a sporting injury are: the use of confrontation strategies, the causal attributions of the injury for the athlete, the perception of risky behaviour and the tendency to carry it out.

For this study it was considered necessary to create a useful and effective "risk of injury" profile, so as to design specific intervention programmes and to give the athlete an idea of his/her psychological vulnerability to injury profile. The results show that the vulnerability profile proposed in this study (subjects with low resistant personality and motivation geared towards success, high competitive anxiety and motivation aimed at avoiding failure would acquire more injuries), apart from team athletes with vulnerability to serious injury profiles, it appears that no case has been confirmed regardless of the nature of the injury.

According to the results of this study, being an individual athlete (opposition sports) or a team athlete (opposition-cooperation contact sports) does influence the relationship between any vulnerability profile, high (0.98/3.95), medium (1.53/2.31) and low (0.98/2.19) vulnerability and the number of mild injuries, with team sports being more vulnerable to suffering from mild injuries, aligned with some research studies that indicate that team sports - particularly in which there is contact - entails a higher risk of injury[22,23]. On the other hand, it could be that team athletes are more prone to suffering from mild injuries, regardless of their vulnerability profile (high, medium or low).

In a study that analysed the role of personality on injuries among elite athletes using the 16PF-5 and an injury register, the results indicated significant correlations between the number of injuries and the Tension and Boldness scales[24]. Moreover, in the study by Berengüí, López, Garcés de los Fayos and Almarcha[25], the personalities of 48 athletes from Olympic wrestling, Canoeing and Taekwondo were measured, using the EPQ-R, the Revised Ensenck and Eysenck Personality Questionnaire. This instrument is based on the Eysenck theory, and identifies three fundamental dimensions of personality: Extraversion, Neuroticism (emotionality), and Psycoticism (tough-mindedness). The verification is interesting of how the Neuroticism dimension correlated to the number of injuries acquired, with the individuals scoring the highest in this dimension described as anxious, very emotive, unstable and insecure[24]. Along the same lines, Appaneal and Perna[26] indicate that athletes with a pessimistic profile, and athletes with a high degree of daily stress experience more illness/injury symptoms than those with a low score. A fair explanation could be that athletes that have specific traits could be more prone to become injured[24] given that in Table 2 team athletes were more prone to suffering mild injuries regardless of their vulnerability profile (high, medium or low).

Finally, it is worth highlighting the influence of other variables that could modify the seriousness of the injury, the typology of the injury, the time within the season, sex, age, the phase of the season or the different competitive levels[27]. In the study about profiles of vulnerability to sporting injury, the seriousness of it could be key to determining a low or high risk of suffering from some kind of sporting injury in a specific sport, in a study about resilience levels based on sporting modality, it was clearly revealed that resilience capacity depends on individual factors[28]. More research is required in this line of study: discovering the aspects that make a player more vulnerable is vital, and not just for the health of the player, as it could also lead to a significant breakdown of the team structure.

In this study the objective proposed was to relate the number of sporting injuries (frequency and seriousness) with the different degrees of vulnerability to injury of the athletes (high, medium and low vulnerability), adhering to the following criteria: team sport, individual sport. Fulfilling the hypothesis proposed in this study implies having more injuries.

The following conclusions can be established:

- It is perhaps probable that athletes that fulfil the hypothesis and that possess these traits (lower resistant personality, greater competitive anxiety, lower motivation geared towards success and greater motivation aimed at avoiding failure), may be more prone to acquiring a serious injury (team athletes).
- Being individual or team athletes influences the relationship between any vulnerability profile and the number of mild injuries, with

the number of mild injuries being higher among team athletes than among individual athletes, with differences appearing in team athletes between the high and medium vulnerability group and between the high and low vulnerability group. Perhaps, differently to individual athletes, team athletes that are positioned in any vulnerability profile could be more vulnerable to acquire a mild injury.

– The results are probably linked to the nature of the seriousness of the injury, i.e. athletes in both modalities that are positioned in a medium vulnerability profile, and athletes that are positioned in a high vulnerability profile, may suffer from a greater number of serious and very serious injuries.

The results of this study could provide an approximation to the psychological vulnerability to injury profile of the athlete, and could also be used to identify individuals with a high degree of risk to injury. They could also identify the factors that lead to a greater degree of vulnerability to injury of the athlete, and consequently, be used to design intervention programmes that reduce the risk of suffering from sporting injuries.

Conflict of interest

The authors claim to have absolutely no conflict of interest.

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Hormonal changes in acclimatized soldiers during a march at a high altitude with mountain skis

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Summary

Background: The aim of the present study is to identify the physiological impact of acute exposure to high altitudes on special acclimatized troops of the Chilean Army. Twenty-nine soldiers carried out a nocturnal winter march on mountain skis at an initial altitude of 2,800 m and up to 3,640 m. Two separate blood measurements were taken. The first one was taken the day before the march (Pre-sample) and the second one just after returning to the base camp (Post-sample). All subjects had been acclimatized prior to the study.
For hypothesis comparison purposes, the normality of the distribution was tested using the Shapiro-Wilk test. To determine if there were significant differences between the Pre and Post tests, a paired-samples Student t-test was applied for the variables with a normal distribution, and the Wilcoxon test was applied for the variables without a normal distribution. In all cases, a level of significance of 95% (p<0.05) was taken into consideration.
Results: Exposure of acclimatized troops to altitudes of 2,800 m to 3,640 m has an impact on the endocrine parameters and on the reduction of cortisol (p<0.01), total testosterone (p<0.0001), free testosterone (p<0.0001) and the free testosterone-cortisol ratio (p<0.01). Likewise, an increase in total leukocytes (p<0.0001), neutrophils (p<0.0001), monocytes (p<0.0001) and basophils (p<0.001), as well as a decrease of eosinophils (p<0.0001) and lymphocytes (p<0.01), was observed. No hematological changes were detected.
Conclusions: Endocrine changes were observed during high-altitude winter marches on mountain skis carried out by acclimatized Special Operation Troops, resulting in decreased cortisol and free and total testosterone levels. A stress condition due to the high altitudes also affected the anabolic/catabolic environment, which manifested as a significant decrease in the free testosterone/cortisol ratio. No hematological changes were identified. Marked changes were observed in some white cell series.

Key words:
Cortisol. Testosterone. Special mountain troops. High-altitude.

Cambios hormonales en soldados aclimatados durante una marcha en gran altitud con esquí de montaña

Resumen

Introducción: El objetivo del presente estudio es identificar el impacto fisiológico (con especial atención a los parámetros endocrinos y hematológicos) de la exposición aguda a gran altitud (GA) en tropas especiales aclimatadas del Ejército de Chile. Veintinueve soldados llevaron a cabo una marcha nocturna con esquí de montaña invernal a una GA de 2.800 m. hasta 3.640 m. Se tomaron dos muestras de sangre. La primera muestra fue tomada el día antes de la marcha (Pre test) y la segunda muestra justo después al regresar al campamento base Post test (a los 2.800 m). Todos los sujetos se encontraban aclimatados antes del estudio. Para cada análisis se testeo la normalidad de las distribuciones empleando el test de Shapiro-Wilk. Se calculó el promedio y la desviación estándar para cada medición. Para determinar si existían diferencias significativas entre el pre y post test se aplicó la prueba de t-Student pareada para las variables con distribución normal y el test de Wilcoxon para las variables que no tenían distribución normal. En todos los casos se consideró un nivel de confianza de 95% (valor p < 0,05).
Resultados: La exposición de las tropas aclimatadas a GA tiene un impacto en los parámetros endocrinos y en la reducción de cortisol (p <0,01), testosterona total (p <0,0001), testosterona libre (p <0,0001) y el ratio testosterona libre-cortisol (p <0.01). Asimismo, se observaron un aumento de leucocitos (p <0,0001), neutrófilos (p <0,0001), monocitos (p <0,0001) y basófilos (p <0,001), así como una decrease de eosinófilos (p <0,0001) y linfocitos (p < 0.01). No se observaron cambios en la serie roja.
Conclusiones: La marcha invernal nocturna con esquí de montaña en GA para tropas de operaciones especiales aclimatadas presento cambios endocrinos con disminución del cortisol, testosterona libre y total. Una condición de estrés por la marcha en GA también afectó al ambiente anabólico/catabólico, lo que se ve reflejado en una disminución significativa en el cociente testosterona libre/cortisol. No se observaron cambios hematológicos. Se observaron cambios significativos en algunas células de la serie blanca.

Palabras clave:
Cortisol. Testosterona. Tropas especiales de montaña. Gran altitud.

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Introduction

The preparation of soldiers for combat at high altitudes and the likelihood of future deployments that may be unpredictable and thus provide little time for preparation largely depend on soldiers' physical acclimatization in the shortest possible time. High-altitude environments cause additional impact on the stress of military operations.

The British Army addressed the issue of altitude adaptation by implementing training strategies at an adequate intensity[1]. Likewise, a literature review from the U.S. Army found that an altitude exposure equal to or higher than 4,000 m and a daily exposure duration of at least 1.5 hours repeated over a week or more are required to have a high probability of developing altitude acclimatization[2]. For special operations units, acclimatization is even more important, given that rapid deployments to high-altitude (HA)[3] mountainous regions are usually for complex missions and with short preparation time.

Reduced oxygen levels at high altitudes imply a reduction in both alveolar and arterial oxygen partial pressure[4], producing a leftward shift of the hemoglobin disassociation curve[5] through time, as a compensation mechanism to the hypoxia, thus producing changes in the blood plasma volume and erythropoietic response[6-8].

The oxyhemoglobin disassociation curve during acute hypoxia is shifted to the left due to alkalosis and a decreased arterial CO_2 pressure, product of an acute ventilatory response, which in turn implies a decreased capacity for hemoglobin to release oxygen[9]. During chronic hypoxia exposure, the disassociation curve is shifted to the right; due to the increment in production by the erythrocytes of 2,3-Bisphosphoglyceric acid (2,3DPG) metabolites, a decrease in pH (renal metabolic compensation of respiratory alkalosis) and an increase in arterial CO_2 pressure[10]. This rightward shift implies a desaturation of oxygen by the hemoglobin, which facilitates the availability of this gas to the tissues. This phenomenon is known as the Bohr effect[11,12].

Results of studies on the impact of hypoxia on hormonal responses differ. In the case of cortisol, literature findings show contradicting results. While some authors have observed increased resting cortisol concentrations in HA environments[13-15], other studies have not found raised levels of resting cortisol[16,17]. Similar differences in cortisol values were found when the exposure times to HA differ. Some authors have observed that with progressive ascents, resting cortisol levels do not vary[18], whereas other studies report that subjects who are rapidly exposed to hypoxic conditions, whether through hypobaric chamber, vehicle or helicopter for a quick ascent, show a rise in cortisol levels[13,19,20].

A similar controversy arises with testosterone concentrations at HA. Some studies have reported a decrease in testosterone levels during mountain climbing programs[21], while other investigators postulate a rise in testosterone during acute exposure to HA[22]. It has been observed among the military population that intermittent exposure to altitudes of 5,300 m for 6 months initially reduces testosterone levels, which then progressively increase after the exposure to hypoxia[23].

Regarding the responses induced by training at high altitudes in some cells of the white cell series, Klokker (1993)[24] found an increase in leukocyte concentrations under hypobaric conditions over a period of 20 minutes due to higher concentration of lymphocytes. However, according to Niess, (2003)[25], the concentration of neutrophils increases after extensive intermittent training at an altitude of 1,800 m, compared to such training at sea level. Umeda (2011)[26] observed a variety of significant changes related to the different neutrophil subpopulations studied post-exercise and attributed these changes to a combination of internal and external factors.

With respect to the red blood series at high altitudes, some studies have reported that high-performance athletes versus non-trained subjects may show hematological anomalies and reduced hemoglobin levels either near or below the inferior limit of the normal range[2,27].

Other studies have shown that some cells of the red series increase after three weeks of biathlon training[7]. Alternatively, Hematy (2014)[28] noted significant changes in red blood cells when observing subjects at the start of an ascent to 1,830 m and then 24 and 48 hours after the stay at 1,830 m (after returning from 4,000 m).

One of the stressors experienced by soldiers in the Chilean Army is the winter marches on mountain skis at different geographical altitudes. However, their physiological impact has not been addressed experimentally.

The aim of the present study is to identify the physiological impact of a nocturnal winter march on mountain skis at high altitude on Special Operation troops of the Chilean Army with special emphasis on endocrine and hematological parameters.

Material and method

Twenty nine soldiers (25.7 ± 4.50 years of age, 76.9 ± 7.12 kg weight and 178 ± 0.05 cm tall) participated in a nocturnal winter march on mountain skis in the region of Portillo, Chile, ascending from 2,800 m to 3,640 m and back to 2,800 m. Each soldier was loaded with 28 kg of equipment. The duration of the march was 5 hours and 35 minutes from base camp (2,800 m) up to (3,640 m) and back. The distance travelled was 20,6 km with an average slope of 9.3% and a maximum of 27,4%. The average environmental temperature during the march was -3 ºC to -12 ºC. The initial atmospheric pressure was 554 mmHg at 2,800 m. All subjects had been residing at base camp, located at 2,800 m altitude; for twelve weeks prior to carrying out the march, so they were acclimatized prior to the study. All subjects were informed of every aspect of the study and gave their written consent. The study was approved by the ethics committee of the Hospital Militar de Santiago, Chile and was carried out in compliance with the requirements of the Helsinki Declaration[29].

Two separate blood samples were taken at 06:00 hours. The first measurement was taken prior to the march (Pre) and the second after the march was completed (ascent to 3,640 m and return to the camp at 2,800 m) (Post).

All blood samples were taken by military nurses and they were obtained by venipuncture following the procedure stipulated in the Sampling Manual of the Clinical Laboratory of Hospital Militar de Santiago Chile.

The analytical processing of the blood measurements was performed in the Lab Core under the fully automated platform "LAB CELL" (Siemens) interfaced with Advia 2120, Advia 1800 and Advia Centaur XP equipment. Samples for blood count were collected in BD Vacutainer with EDTA and processed using optical laser-based and impedance flow cytometry. Samples for cortisol and testosterone (total and free) were collected in BD Vacutainer with clot activator and gel for serum separation. Samples were processed using chemiluminescence methodology for cortisol and total testosterone, and radioimmunoassay (gamma counter) for free testosterone.

Systolic and diastolic arterial pressures were measured manually via a sphygmomanometer (blood pressure kit, CEISO, USA, 2014). Mean arterial pressure (MAP) was calculated using the following formula: [(systolic – diastolic)/3] + diastolic[30]. Arterial oxygen saturation (SaO_2) was measured with a portable device (Nonin CMS50D, USA, 2014).

Prior to testing, weight and size were measured with a Tanita weighting machine (Tanita Ironman BC1500, Japan, 2015). Tympanic temperature was taken before and after the march via an infrared thermometer. (Boeringher, Germany, 2015).

Dehydration was calculated through the weight loss percentage.

Statistical analysis

For hypothesis contrast purposes, the normality of the distribution was tested using the Shapiro-Wilk test. Averages and standard deviations were calculated for each measurement. To determine if there were significant differences between the Pre and Post tests, a paired-samples Student *t*-test was used for the variables with a normal distribution, and the Wilcoxon test was used for the variables without a normal distribution. In all cases, a level of significance of 95% ($p < 0.05$) was taken into consideration.

Results

Table 1 shows Pre and Post data for SaO_2, MAP, temperature and weight with the value of p. All the changes were significant.

From the changes in weight, the level of dehydration induced by the march was calculated at 2.9%.

Figure 1 shows the changes in cortisol, free testosterone, total testosterone and the free testosterone-cortisol ratio. All the changes were significant.

Figure 2 shows the results of red blood cells, erythrocytes, hemoglobin, hematocrit, and medium corpuscular volume (MCV) Pre and Post march. Significant changes are only observed in the MCV between the Pre and Post measurements.

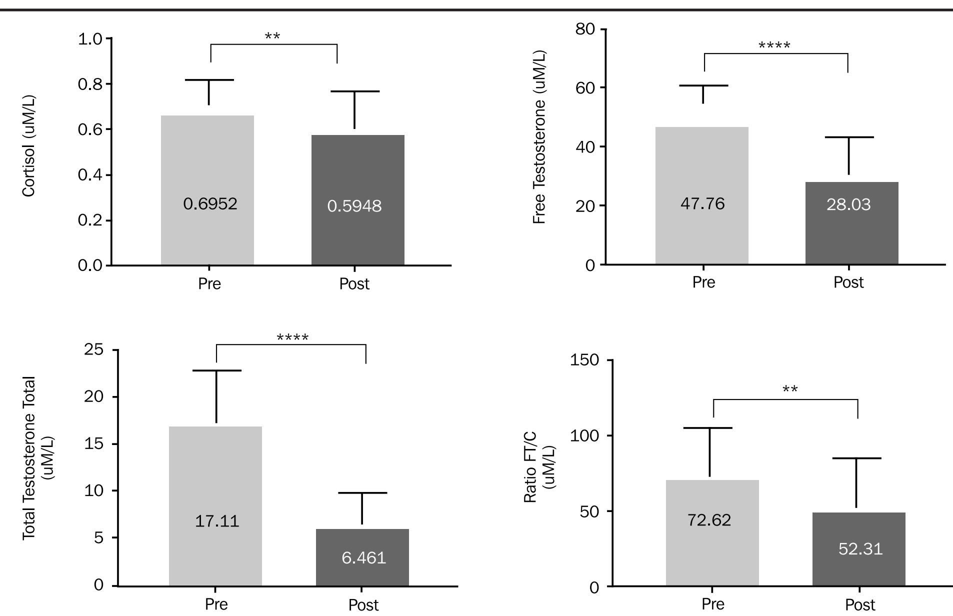
Figure 3 shows changes in total leukocytes, neutrophils, lymphocytes, monocytes, eosinophils and basophils, all of which were significant between the Pre and Post situation.

Table 1. Shows pre and post saturation data, mean arterial pressure, temperature and weight with the value of p.

	Pre		Post		Pre *vs* Post
	Avg.	SD	Avg.	SD	*p*
Sa02 (%)	96.79	1.85	94.93	2.21	0.001
MAP (mmHg)	85,7	8,4	89,5	11,4	No significativo
Temperature (°C)	35.9	0.36	36.3	0.38	0.023
Weight (kg)	76.90	7.12	74.64	7.03	<0.0001

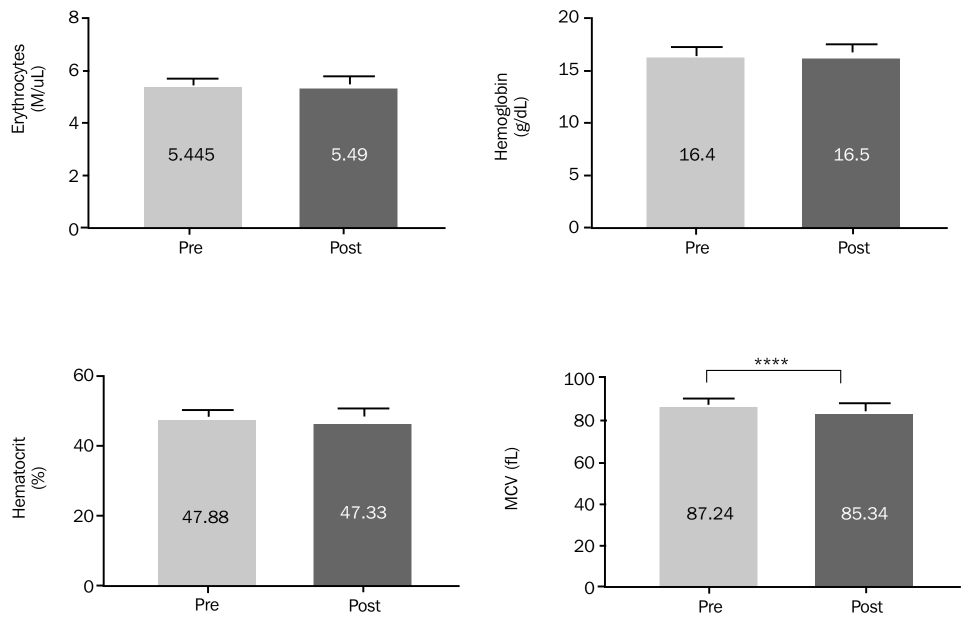
Changes in oxygen saturation, mean arterial pressure, temperature and weight caused by the HA march. (*=p<0.05 **p<0.01; ***p<0.001; ****p<0.0001).

Figure 1. Changes in cortisol, free testosterone, total testosterone and the free testosterone-cortisol ratio. All the changes were significant.



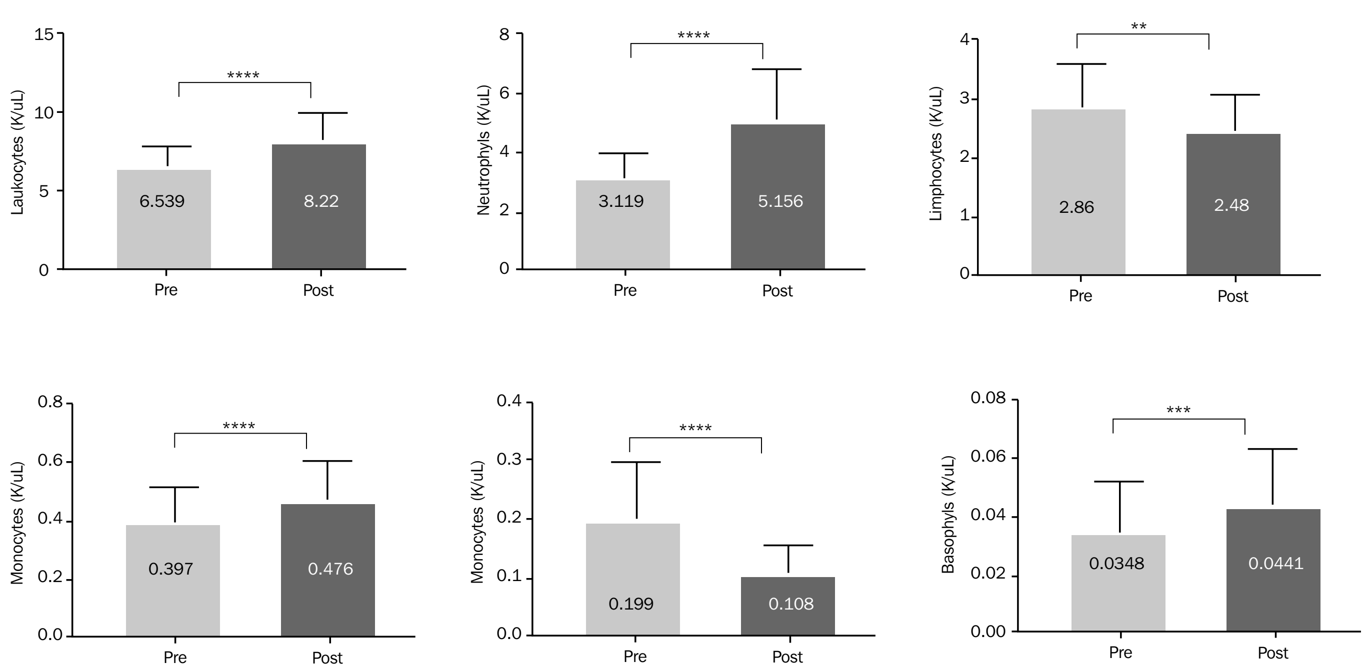
*= p <0,5; **p <0.01 ***p <0.001; ****p <0.0001

Figure 2. Changes in red blood cells, Erythrocytes, hematocrit, MCV and hemoglobin caused by the HA winter march.



*= p <0,5; **p <0.01 ***p <0.001; ****p <0.0001

Figure 3. Changes in Leukocytes, Neutrophils, Monocytes and Eosinophils caused by the HA winter march.



*= p <0,5; **p <0.01 ***p <0.001; ****p <0.0001

Discussion

The main finding of this study is that a nocturnal winter march with exposure from 2,800 m to 3,640 m among acclimatized Special Operation Troops has an impact on the endocrine and white cell series.

At the end of the march, significant weight loss was observed between the Pre- and Post march situations (2.9%), as well as significant oxygen desaturation and a significant increase in body temperature (Table 1). In our data, the resulting effect of a nocturnal march on mountain skis supposes an increase of energy exertion on the aerobic and anaerobic systems due to the slopes previously described, as well as muscle wear upon descent on skis, carrying military equipment. These conditions may explain the increase in the temperature of the subjects Post arrival at base camp (2800 m). The decreases in SaO_2 could be explained by the reduction of the partial pressure of O_2 at these altitudes, whereas the capacity of the hemoglobin to bond with oxygen may be seen to be affected[11,12]. This has also been observed in studies conducted on football players acclimatized to high altitudes[4] and players coming from low altitudes, not acclimatized to high altitudes[10].

With regard to cortisol, a significant decrease was observed after the march (Figure 1). Similar results have been observed in other studies. Woods (2012)[18] showed a salivary cortisol decrease during a six-hour march from 1,900 m, to 3,400 m and 4,270 m. Mc Lean (1989)[16] demonstrated a reduction in basal cortisol with submaximal exercises over 15 days at 4,450 m. Even after eight weeks of mountain training and an ascent to over 7,546 m, basal cortisol levels decreased in comparison to the values before training[21]. In contrast, Benso (2007)[17] did not observe any changes in cortisol levels after gradual exposures from sea level to 5,400 m and above 8,000 m.

It appears that the determining factor of the changes of cortisol at HA is the gradual altitude exposure. Acute exposure to altitude seems to increase cortisol levels[13-20]. Nevertheless, various studies have shown that if subjects who are previously acclimatized to the altitude practice physical activity, cortisol levels decrease[17,18,21,31]. In this study, the subjects remained at the base camp located at 2,800 m for a period of 12 weeks, and their cortisol levels decreased after the march at 3,640 m. It would appear that the gradual exposure and acclimatization at the base altitude and the response to physical exercise have a predominant role in reducing cortisol levels.

Testosterone, both free and total (protein-bound), decreased with the march (Figure 1), an expected finding that supports the stress conditions induced by the exercise and hypoxia exposure. This finding was further supported by the free testosterone/cortisol ratio, in which a marked decrease was observed (Figure 1). Nevertheless, the results obtained do not correspond to the high testosterone values documented in high-performance athletes who were overtrained[22,32,33]. Results similar to those of this study were observed in post training and post-high-altitude ascents when compared to the conditions prior to training[21]. Other authors[17,23,34] have also observed decreases in testosterone one and three months after expeditions above 7,800 m. The testosterone data of this study tend to be consistent with the bibliography, which refers to decreased testosterone levels in high-altitude conditions.

From a hematological perspective, no changes were observed in the red blood cell indices tests performed after the march (erythrocytes (Er), hemoglobin (Hb) and hematocrit (Hct) (Figure 2), as was expected for subjects with an acclimatization period of 12 weeks. This finding is consistent with those of other studies that have observed that after 21 days of training at altitudes of 1,500 m and 1,816 m, no significant differences in hemoglobin or hematocrit are registered[35]. Likewise, these results are also consistent with the findings of studies by Rietjens, *et al* (2002)[36], who observed that training over two weeks at altitudes of 1,500 m and 1,850 m initially caused significant increases in Hb, Hct and MCV; however, training at 2,600 m did not produce a considerable increase in the value of such variables, being in the lower extreme of the normal range. Regardless, the data in this study are not consistent with those of Heinicke (2003)[7] or Hematy (2014)[28], who observed increases in the red blood count over periods of up to three weeks at altitudes of 1,800 m and 4,000 m. Only mean corpuscular volume (MCV) (Figure 2) had a significant decrease in the Pre- and Post test values. Although the authors have not found a satisfactory answer for this change, these results are consistent with those of the studies by Sewchand (1980)[37], who reported a noticeable decrease (12-14%) in the MCV of subjects after five hours of exposure to low pressure. However, their MCV returned close to baseline values after 40 hours.

The red blood count response in this study would seem to be essentially determined by the altitude acclimatization process. In our opinion, the absence of changes in the red series may be due to a hemodilution effect seen in marathon runners[38] and to the acclimatization of the soldiers during the period prior to this study.

In relation to the white cell series (Figure 3), a significant increase was observed in leukocytes, neutrophils, monocytes and basophils, as well as a marked decrease in lymphocytes and eosinophils. Changes in leukocyte concentrations are interesting because stress is commonly associated with immunosuppression and, therefore, a high risk of acquiring infectious diseases[39]. Thake (2004)[40] observed similar results to those found in our study, in particular in relation to some cells of the white cell series through laboratory testing of long- and short-duration exercises equivalent to 4,000 m, which resulted in relative lymphopenia and a decrease in eosinophils. Likewise, Niess (2003)[25] observed increases in neutrophils post-exercise, which were markedly more pronounced at 1,800 m than at sea level. The investigation by Umeda (2011)[26] is also quite interesting, as he found significant results in various neutrophil immune functions after carrying out different types of exercises, attributing the increases and decreases to the balance between external factors (e.g., intensity and exercise modality) and internal factors (e.g., physical pain and fatigue).

Although these findings relate to a global count of white cell series, and the authors have not delved into subpopulation studies, the data in this study coincide with the literature in terms of the expected changes post-exercise under acclimatization conditions.

The main limitation of this study lies in the inability to differentiate the effect of the physical work load carried out from the additional stressors (such as the cold, sleep deprivation or accumulated fatigue). An additional constraint was raised by the non-monitoring of liquid intake, the degree of dehydration was only measured through weigh-ins pre and post march.

It would be interesting to include a psychological evaluation with the purpose of identifying the appropriate stress management mechanisms of those subjects with fewer changes in their testosterone and cortisol hormones, as well as heart rate variability (HRV) measurements as an indicator of sympathetic stress (Naranjo *et al*., 2015)[41].

Conclusions

A nocturnal winter march on mountain skis, with combat equipment at high altitudes and a 840 m slope, produced endocrine changes in acclimatized Special Operations Troops, resulting in decreased cortisol and free and total testosterone levels. Stress due to the HA march also affected the anabolic/catabolic environment, which manifested as a significant decrease in the free testosterone/cortisone ratio. No significant decrease was found in red blood cells, hemoglobin or hematocrits, which may be due to a hemodilution effect and the acclimatization of the subjects. Marked changes were observed in some white cell series. The Leukocyte population increased considerably during the winter march, specifically, there was a marked increase in neutrophil and monocyte, while also accompanied by a consistent decrease in lymphocyte.

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Ethical approval Committee

Santiago´s Military Hospital/ HOSMIL-DIVDOC.

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Effect of creatine supplementation on anaerobic capacity: a meta-analysis

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Summary

The purpose of the present meta-analysis was to integrate and summarize the results of different studies as well as to examine the moderating variables in the effect of creatine (Cr) supplementation on anaerobic capacity. Eighty-one studies on creatine supplementation were retrieved by searching several databases, and 17 that met the criteria were included. Random effects models using the standardized mean difference effect size (*ES*) were used to pool results. A total of 131 *ES* were coded, representing 1447 participants (nG_{Ex}=889; nG_{Pl}=559). A statistically significant moderate overall *ES* was found for the experimental group (G_{Ex}) (*ES*=0.34, p<0.001; CI: 0.24-0.44). Also, a statistically significant small overall *ES* was found for the placebo group (G_{Pl}) (ES=0.13, p>0.05; CI: 0.02-0.24). A statistically significant difference was found between both groups ($F_{(1, 129)}$=9.56, p<0.05, α=0.05). The heterogeneity analysis reported low heterogeneity (Q= 96.95; p= 0.083; α= 0.10), and low inconsistency (I^2=18.51%) in the experimental group. Nine moderator variables were analyzed, Pearson correlation analysis were used when variables were continuous and variability analysis (ANOVA) when variables were categorized. Only the variable which described how supplementation was offered was significant (load *ES*=0.37; load + maintenance *ES*=0.22; $F(_{1-77})$=6.22; p=0.015), suggesting a positive effect on load phase, but not on load plus maintenance. Not found significant differences in sex, skill level of the athlete, type of sport, doses, type of performance assessment. In conclusion, supplementation with creatine had a moderate effect on anaerobic capacity.

Key words:
Creatine. Anaerobic capacity. Meta-analysis. Supplementation.

Efecto de la suplementación con creatina en la capacidad anaeróbica: un meta-análisis

Resumen

El objetivo del presente meta-análisis fue integrar y resumir los resultados de distintos estudios, así como examinar las variables moderadoras en el efecto de la suplementación con creatina (Cr) sobre la capacidad anaeróbica. Para ello se localizaron 81 artículos completos de diversas bases de datos electrónicas, donde solo 17 cumplieron con los criterios de inclusión. Para calcular el Tamaño de Efecto (*TE*) se utilizó el modelo de efectos aleatorios. Se codificaron un total de 131 *TE*, que representan 1447 sujetos (nG_{Ex}= 889; nG_{Pl}= 559). El *TE global* del grupo experimental (G_{Ex}) fue moderado (*TE*=0,34, p<0,001; IC: 0,24-0,44), en tanto que el TE del grupo placebo (G_{Pl}) fue pequeño (*TE*=0,13, p>0,05; IC: 0,02-0,24); siendo significativamente diferentes entre sí ($F_{(1,129)}$=9,56, p<0,05, α=0,05). El análisis de heterogeneidad indicó que los TE de los artículos incluidos en el grupo experimental son homogéneos (Q= 96,95; p=0,083; α= 0,10), con una baja variabilidad (I^2=18,51%). Se utilizó la correlación de Pearson para determinar el efecto de las variables moderadoras continuas y el análisis de variabilidad, para variables categóricas. Se evaluaron nueve variables moderadoras, de las cuales únicamente la forma en la que se dio la suplementación fue significativa (carga *TE*=0,37; carga + mantenimiento *TE*=0,22; $F_{(1-77)}$= 6,22; p=0,015), sugiriendo que el efecto es positivo durante la fase de carga, no así cuando existe carga + mantenimiento. No hubo diferencias significativas en las variables moderadoras de sexo, nivel de entrenamiento, tipo de deporte, la dosis brindada, ni en la forma de medición del rendimiento físico. En conclusión, existe un efecto moderado de la suplementación con Cr en la capacidad anaeróbica.

Palabras clave:
Creatina. Capacidad anaeróbica. Meta-análisis. Suplementación.

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Introduction

Creatine (Cr) is a natural compound that is endogenously synthesized via glycine, arginine and methionine in the kidney, liver and pancreas. In the kidney, the transaminase enzyme creates ornithine and guanidinoacetate from arginine and glycine. Guanidinoacetate is transported to the liver, where it receives a methyl group of methionine leading to the formation of methyl-guanidoacetic acid (creatine) and adenosine homocysteine. Cr is released into the bloodstream and stored in the skeletal muscle both freely and in phosphorylated form. It plays a fundamental role in regulating adenosine triphosphate (ATP)[1].

When ATP is needed as a source of cellular energy, such as during intense, short-term muscle contraction, Cr reacts with phosphocreatine kinase and ATP to create phosphocreatine (PCr) and adenosine diphosphate (ADP). Through an inverse reaction, ADP and PCr react with the enzyme creatine kinase to regenerate ATP. Therefore, Cr indirectly acts to meet the muscular system's energy needs[1-4].

Fatigue occurring short-duration, maximum-intensity exercise has been associated with depletion of PCr. In this sense, much research has suggested that Cr supplementation improves physical performance. Firstly, by delaying the onset of fatigue by favouring the rate of PCr resynthesis during recovery in maximum-intensity exercises. Secondly, by generating improvements in maximum strength and sprint speed, among others[5-9].

Several meta-analyses on this topic have analysed the effect of Cr supplementation on several variables, some investigating whether Cr favours increased muscle strength and power in healthy adults, finding positive effects in weightlifting when supplementing with Cr in addition to strength training among such individuals[10]. However, such studies mention that there is little evidence to draw conclusions with respect to women or older adults.

Furthermore, Nissen and Sharp[11] performed a meta-analysis on the effect of supplementation with various dietary supplements (including Cr) on muscle mass and strength gains through resistance training, reviewing 18 articles and finding significant increases in both variables, with an effect size (ES) of 0.26 (CI: 0.65-1.02%) and 0.36 (CI: 0.28-0.43%) ($p<0.001$), respectively.

Similar to that meta-analysis, Branch[12] analysed the ES on body composition, duration and intensity of the task, type of exercise (simple, repeated, in laboratory, in the field, using upper or lower extremities), duration of supplementation and the subjects' gender. They found a significantly large ES in lean mass with short-term supplementation, especially in exercises with several repetitions less than 30 seconds long using the upper extremities. However, no effect was found in runners or swimmers, nor did they identify differences between men and women or between trained and untrained subjects.

Gutiérrez *et al.*[13] also performed a meta-analysis studying the effect of Cr supplementation on physical performance, body composition and biochemical variables. In that study, a large and significant effect was found for variables such as peak power, peak force and performing one repetition at maximum effort (1 RM) under both the conditions of supplementation and placebo; a greater effect was revealed in the experimental condition (Cr).

However, those research studies did not account for the effect of the type of Cr used, nor were effects identified with respect to the subjects' gender, the type of physical activity or sport performed, the number of days that supplementation was taken, or the total dose administered. In addition, information regarding Cr supplementation and anaerobic capacity as a specific variable of physical performance has yet to be summarised. For these reasons, this meta-analysis—unlike the existing ones—intends to identify and summarise the effect of Cr supplementation on anaerobic capacity. Following the methodology set forth by Borenstein *et al.*[14], the individual and overall effect size is calculated accounting for such moderating variables as those aforementioned aspects while also considering the reported findings of the different studies used.

Methodology

The present meta-analysis was carried out as per the PRISMA guidelines for reporting of systematic reviews and meta-analyses[15].

Study selection criteria

The inclusion criteria used in elaborating this meta-analysis were: 1) studies of healthy subjects with or without previous training, 2) studies presenting descriptive statistics, 3) studies presenting results of the effect of Cr supplementation on anaerobic capacity, 4) studies reporting the dose of Cr used , 5) studies not carried out with populations on special diets (e.g. vegetarians), 6) no conditions of modified temperature or dehydration, 7) full text in English, Spanish, French or Portuguese.

The quality criteria used were based on the internal validity of the study, including: 1) randomization of subjects, 2) intra-subject studies (pre-post test), 3) presence of an experimental group (Gex) and placebo or control group (GPl), 4) double-blind studies.

Data sources

The literature search was carried out using electronic databases, from 10 August to 1 December 2015. References included in previous meta-analyses, systematic reviews and some relevant articles were reviewed. In cases where we could not find the descriptive statistics of articles of interest or their full-text version, we requested such information from the respective author; only two articles were obtained in this way. In total, 84 complete articles were used, of which only 17 studies were meta-analysed.

Seven electronic databases were used: Sport Discus, Pub-Med, Science Direct, Springer Link, Medline, Proquest and Academic Search Complete.

The keywords used were: "effect of", "creatine", "supplementation", "performance" and their combinations in English and Spanish.

Selection of studies and data coding

The selection of studies and coding of their respective data of interest was carried out by one person. A second person reviewed the previous process and, in consensus with a third person, all identified inconsistencies were resolved. In doing so, a database previously developed in the Microsoft Excel 2013® program was used. The analysis of the moderating variables took into account: subject characteristics, measurement of physical performance, Cr supplementation characteristics and placebo characteristics. Table 1 details the aspects that were considered in coding these variables.

Methodological quality of the studies

We used a modified version of the scale developed by Jiménez *et al.*[16], which consists of five items used to evaluate criteria of internal validity in experimental studies, namely: 1) the randomization process is described and is adequate, 2) the study had a placebo or control group, 3) there were pre-test and post-test measurements and 4) the existence and management of experimental mortality was reported.

Studies with a score of four were considered to be of "excellent" quality, scores of three "good" quality, scores of two "regular" quality and scores of one "poor" quality.

Procedure for calculating individual effect sizes

The ES of Cr supplementation on anaerobic capacity was calculated as the change between the pre-test and the post-test measurement in the given variable. Calculating the ES of each study and the global ES was done by following the procedure suggested by Borenstein *et al.*[14] for the random-effects model. The analyses were performed using the Microsoft Excel® program, with confidence intervals of 95%.

Heterogeneity and bias

The heterogeneity of the included studies was assessed using Cochran's Q test, while inconsistency was assessed using the I^2 statistical test. Significance for the Q test was established at $p \leq 0.10$ due to its lack of statistical power. I2 values of less than 25% are considered to represent very low inconsistency; between 25 and 50%, low inconsistency; between 50 and 75%, moderate inconsistency; greater than 75%, highly inconsistent. A funnel plot and Egger's test were performed through the RStudio program to assess general bias as they indicate the possibility of not including all relevant studies in the meta-analysis. Publication bias was assessed through the effect of archived papers[17].

Table 1. Moderating variables.

Areas of interest	Coding scheme
Subject characteristics	Sample size, age, gender, condition (experimental, placebo or control), level of physical activity (trained, untrained), type of physical activity/ sport performed.
Physical performance measurement	Measurement type.
Cr supplement characteristics	Type, duration (days), total dose (g), supplementation phase (loading, maintenance, both).
Placebo characteristics	Type, duration (total days), total dose (g), supplementation phase (loading, maintenance, both).

Data analysis

With the obtained information, a Pearson correlation (r) was performed in the cases where the measurement scale of the variables was continuous, while a one-way analysis of variance for independent groups (ANOVA) was performed in cases where variables were categorical, with a significance level of 0.05. The global ESs were calculated using the Microsoft Excel 2013® program, while statistical analysis (correlations and ANOVA) was performed with the IBM-SPSS 20.0® program. In the case of the moderating variables, only those that presented an ES with *n* greater than three were analysed.

Results

Studies included

Of the 81 articles reviewed, only 17 met the inclusion criteria. While one article did not have a GPI, the necessary information on various types of Cr was available, owing to which it was used in this study[18]. A diagram depicting the selection of included studies is shown in Figure 1 and their characteristics are shown in Table 2.

In the case of a study that presented two experimental conditions and a control condition, this condition was not considered in the analysis as it was the only study with this characteristic[19]. The flowchart for the selection of studies is shown in Figure 1, while Table 3 presents a description of the main characteristics of the studies included in this meta-analysis.

Of the 17 articles, a total of 131 ES were obtained (80 ES from the experimental condition and 51 ES from the placebo condition), encompassing a total of 1,447 subjects, the distribution and characteristics of whom are presented in Table 2.

The quality of the included studies was considered "good" according to the scale used to evaluate their internal validity, as shown in Figure 2, where the distribution of articles according to quality level is depicted.

Individual effect size

As demonstrated in the forest plots in Figure 3, the distribution of individual ESs is mostly greater than zero, as well as the global ES of Cr supplementation in anaerobic capacity (95% confidence intervals).

Figure 1. Flowchart for selection of articles, based on Prisma 2009[20].

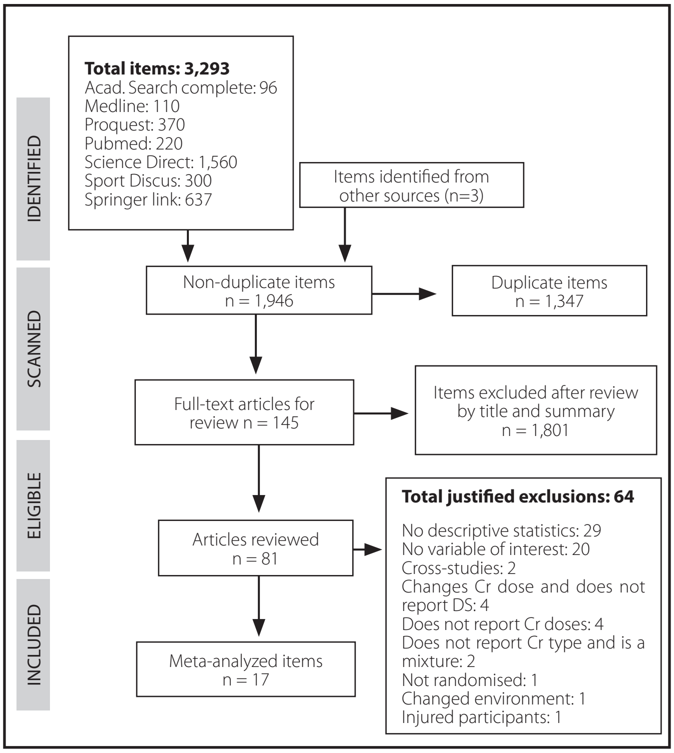


Figure 2. Distribution of the quality of analysed studies.

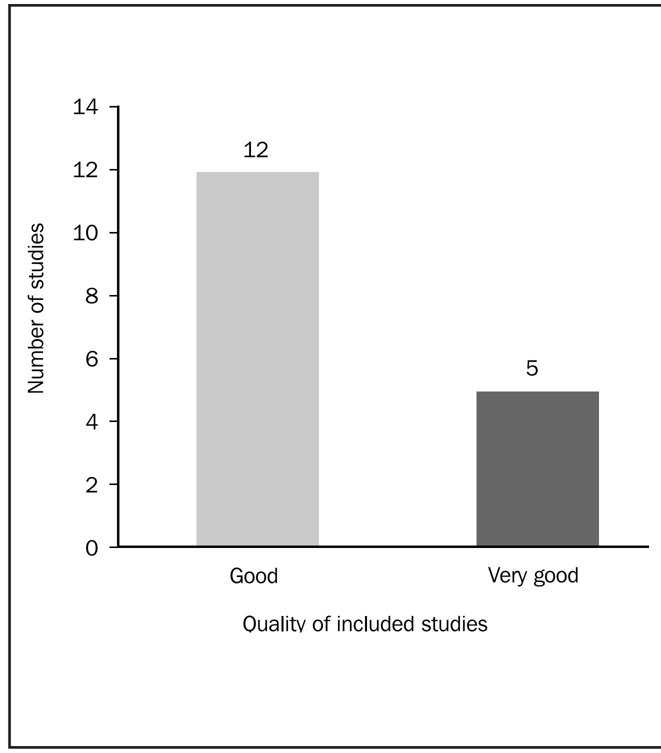
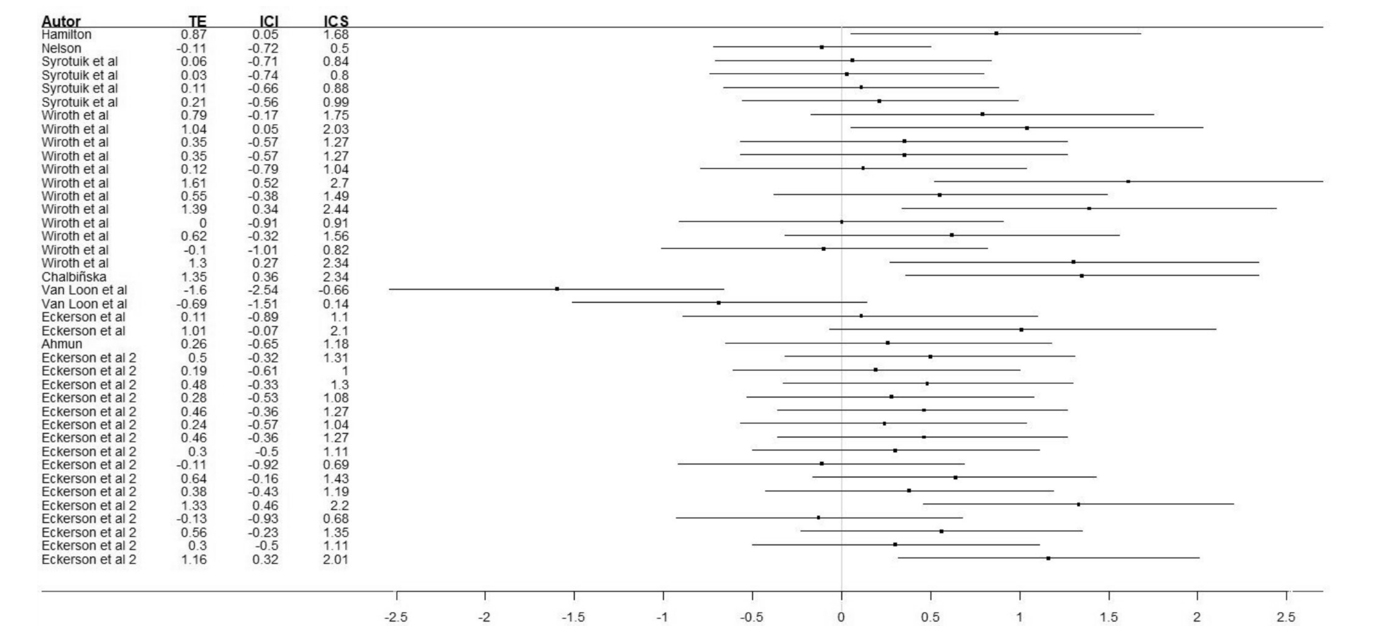


Table 2. Characteristics of meta-analysed studies.

Author	Year	N	Gender	Age	Training Level	PA / Sport	Total days	Total g	Supplem. Time	Cr Type
Hamilton[21]	2000	24	F	22.5	T	Throwing	7	175	Loading	CrM+sucrose
Nelson, *et al.*[22]	2000	36	B	NR	UT	Recreational	7	175	Loading	CrM+2,12 g sucrose
Syrotuik, *et al.*[23]	2001	22	B	23.0	T	Row	5	100	Loading	CrM
Wiroth, *et al.*[24]	2001	42	M	65.1	T	NR	5	225	Loading	CrM
Chalbińska[25]	2001	16	M	22.5-25.3	T	Row	5	100	Loading	CrM
Van Loon, *et al.*[26]	2003	20	M	21.3-20.6	UT	NR	42	174	L-M	CrM+15g GLu+10 g Mal
Eckerson, *et al.*1[27]	2004	10	F	22.0	T	NR	2 5	40 100	Loading Loading	 Cr+18 g dextrose
Ahmun[28]	2005	14	M	20.6	T	Rugby	5	100	Loading	CrM
Eckerson, *et al.* 2[29]	2005	61	F	21.0	T	NR	2 2 6 6	40 40 120 120	Loading Loading Loading Loading	CrCit+dextrose CrCit+PNA+dextrose CrCit+dextrose CrCit+PNA+dextrose
Hoffman, *et al.* 1[30]	2005	20	M	21.7	T	NR	6	18	Loading	Cr+P+fructose+gel
Hoffman, *et al.* 2[31]	2006	22	M	NR	UT	Strength/power	70	735	L-M	CrM
Reardon, *et al.*[32]	2006	13	M	NR	T	NR	7	140		CrM+maltodextrin
O'Connor, *et al.*[19]	2007	22	M	24.5	T	Rugby	42	126		3gCr+3gHMB+6gCHO
Azizi[33]	2011	20	F	20.9	T	Swim	6	120	Loading	CrM
Jagim, *et al.*[18]	2012	35	M	25.5	T	Counter-resistance	7 7 7	140 140 10,5		CrM KA-H (eqCrM) KA-L (eqCrM)+5 g dext
Sterkowicz, *et al.*[34]	2012	10	M	20.4	T	Judo	42	210		CrMaleate
Deminice, *et al.*[35]	2013	25	M	17.1	T	Football	7	151		NR

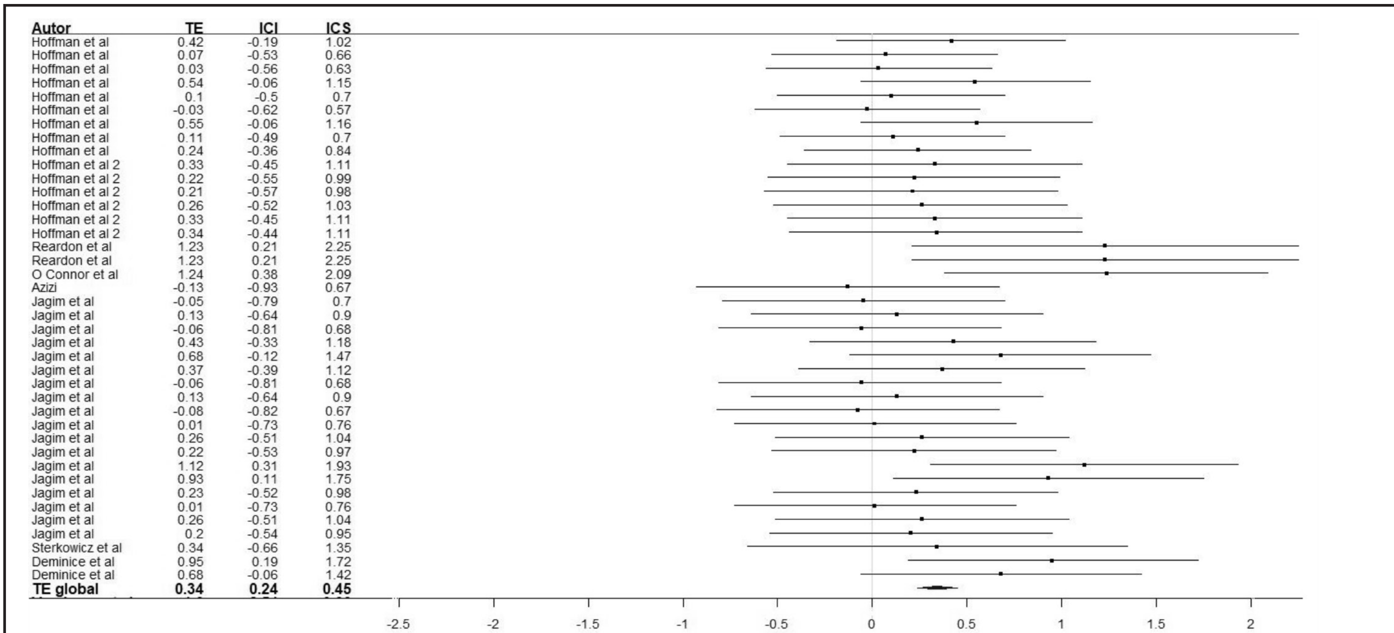
B: Both; F: Female; M: Male; T: Trained; UT: Untrained; CrM: Creatine Monohydrate; HMB: Hydroxymethylbutyrate; CrCitPNa: Creatine Citrate+Sodium Phosphate, PKA-H equivalent to CrM; KA-L: equivalent to CrM+dextrose.

Figure 3a. Forest plot depicting the distribution of individual ES of Cr supplementation and its effect on anaerobic capacity (n=80).



ES: Effect size: ICI: inferior confidence interval; ICS: superior confidence interval.

Figure 3b. Forest plot depicting the distribution of individual ES of Cr supplementation and its effect on anaerobic capacity (n=80)



ES: Effect size: ICI: inferior confidence interval; ICS: superior confidence interval.

Global effect size

The global ES of G_{Ex} was moderate (ES = 0.34, *p*<0.001; IC: 0.24-0.44), while ES in the placebo group G_{Pl} was small (ES= 0.13, *p*>0.05; IC: 0.02-0.24). This constitutes a significant difference among both groups ($F_{(1, 129)}$= 9.56, $p<0.05$, α= 0.05), as can be observed in Table 4.

Analysis of heterogeneity and bias

As evidenced in Table 4, Cochran's Q test revealed significance in G_{Ex} (p=0.083; α= 0.10) but not in G_{Pl} (p=0.50). This demonstrates that the ES of the articles included in the first group are homogeneous, presenting low variability (I^2=18.51%).

Table 3. Characteristics of subjects included in individual effect sizes according to condition (experimental or placebo).

	Characteristic Placebo	Experimental Condition
n	889	558
Age (years)	26.48	30.35
Weight (kg)	77.72	77.42
Gender		
Men (nES)	53	40
Women (nES)	20	4
Mixed (nES)	7	7

Table 4. Significance of global effect sizes calculated per group (experimental and placebo).

	Experimental	Placebo
N studies	17	16
N ES	80	51
N (studies)	442	
ESg	0.34*	0.13
p	<0.001a	>0.05
IC	0.24 – 0.44	0.02 – 0.24
Q	96.95	49.22
p	0.083b	0.50
I^2	18.51	0
K_0	52	--

[a]α=0.05; [b]α= 0.10; Standard Deviation; CI: Confidence interval.

Moreover, according to the analysis of publication trends, 52 non-significant effect sizes are required to reduce the overall ES obtained in the G_{Ex} to a small one (Table 4).

An asymmetrical dispersion of the individual TeS can be appreciated in the funnel plot (Figure 4). This was confirmed by Egger's regression analysis as it is significant (*p*=0.027 with $\alpha \leq 0.05$), which indicates the presence of bias.

Moderating variables

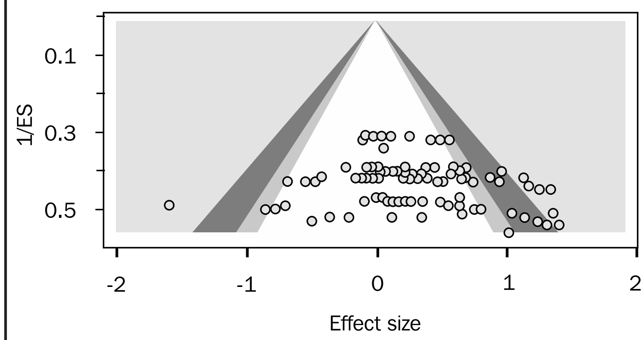
Moderating variables were analysed with the purpose of independently analysing the characteristics that could better explain the global ES.

To determine the effect of the moderating variables, correlation analysis (Pearson) or analysis of variance (ANOVA) were performed for continuous and categorical variables, respectively, using the SPSS statistical software® version 20.0.

Of the moderating variables analysed, only the form of supplementation was significant (*p*=0.01) (Table 5).

In the gender variable, despite the fact that there were no significant differences between them ($F_{(2-77)}$=0.22; *p*=0.81), the ES was moderate and significant in studies where men and women were individually analysed (*p*<0.01 in both cases) and was not in those with a mixture of genders (*p*=0.25), showing, moreover, a greater trend in the group of women.

Figure 4. Funnel plot of ES of Cr supplementation on anaerobic capacity.



(t=2.23, gl=129, p=0.027 with $\alpha \leq 0.05$).

Also, the training level was not significant ($F_{(1-78)}$=0.13; *p*=0.71). However, the group of trained subjects showed a significant moderate effect size (ES=0.34; *p*<0.01); this was not so in untrained subjects, for whom the ES was non-significant (ES=0.30; *p*=0.45).

In addition, the type of sport or activity performed was analysed and no significant differences were obtained ($F_{(4-75)}$=0.27; *p*=0.89). However, like the previous cases, subjects who played force-power sports with a ball (football, rugby, football) and exercised recreationally obtained a significant moderate ES (*p*<0.05).

Regarding the way of measuring physical performance, there were no significant differences between the analysed methods ($F_{(1-78)}$=0.10; *p*=0.75); in both cases the ES was moderate (ergometers: ES= 0.32, others: ES= 0,60; *p*<0.05).

The ES among the types of Cr analysed was not significant ($F_{(7-72)}$= 1.73; *p*= 0.12). Table 5 shows that only two of the nine classified types of Cr (equivalent to 1.5 g Cr monohydrate (CrM) and other types) did not present a significant ES, while seven types (others: CrM, Cr phosphate + fructose + gel, 5g Cr Citrate (Cr Cit) + 18 g dextrose, 5 g Cr Cit + 4 g Na^+ and K^+ + 18 g dextrose, equivalent to 1.5 g CrM, 5g CrM + 10 g sucrose, 10.5 g CrM + 3.2 g β-alanine) did present a moderate ES (*p*<0.05).

Regarding the form of supplementation, only variables with an nTE>3 were analysed. Significant differences were found between the loading and loading + maintenance phases ($F_{(1-77)}$= 6.22; *p*= 0.015), with a higher ES when there was only a loading phase (ES=0.34; *p*<0.01) than those including the phase of loading + maintenance (ES=0.22; *p*=0.13) (Figure 5).

No relationship was found between ES and age (r= 0.18; *p*= 0.14), total days of supplementation (r= -0.22; *p*= 0.54), and the total dose of Cr (g) (r=-0.02; *p*= 0.84).

Table 5. Significance of effect sizes of Cr supplementation on anaerobic capacity, according to moderating variables

	nTE	TE	IC	*z*	F	*r*	p
Subject characteristics							
Age	71	0.33	0.23 – 0.43	6.58		0.18	0.14
Sex	80	0.34	0.24 – 0.44	6.79	0.22		0.81
Male	53	0.32*	0.19 – 0.44	5.07			
Female	20	0.42*	0.25 – 0.59	4.85			
Mixed	7	0.29	-0.08 – 0.66	1.52			
Level of training	80	0.34	0.24 – 0.44	6.79	0.13		0.71
Untrained	10	0.30	-0.26 – 0.87	1.06			
Trained	70	0.34*	0.25 – 0.43	7.25			
Type of sport/activity	80	0.31	-0.25 – 0.87	1.06	0.27		0.89
Individual	7	0.47	0.04 – 0.90	2.13			
Not performed	10	0.30	-0.26 – 0.87	1.06			
In team with ball	10	0.48*	0.26 – 0.69	4.37			
Recreational	14	0.28*	0.09 – 0.47	2.88			
Strength-Power	39	0.32*	0.20 – 0.44	5.28			
Physical performance							
Measurement type	80	0.34*	0.24 – 0.44	6.79	0.10		0.75
Ergometers	76	0.32*	0.22 – 0.42	6.38			
Others (RAST, dynamometer)	4	0.60*	0.12 – 1.07	2.47			
Supplementation characteristic							
Type of creatine	80	0.34*	0.24 – 0.44	6.79	1.73		0.12
Cr Monohydrate	19	0.22*	0.07 – 0.38	2.88			
Cr phosphate + fructose + gel	9	0.22*	0.07 – 0.36	2.98			
5 g Cr Cit + 18 g dextrose	8	0.28″	0.10 – 0.47	3.06			
5 g Cr Citr + 4 g Na^+ phosphate and K^+ +18 g dext	8	0.57*	0.28 – 0.86	3.80			
Equiv. 5 g Cr Monohydrate	6	0.38*	0.12 – 0.64	2.88			
Equiv 1.5 g Cr Monohydrate	6	0.22	-0.13 – 0.58	1.24			
5 g CrM + 10 g Sucrose	12	0.62*	0.31 – 0.93	3.94			
10.5 g CrM+3.2 g β-Alanine	3	0.29*	0.25 – 0.34	12.67			
Others	9	0.41	-0.25 – 1.07	1.20			
Total days of supplementation	80	0.34*	0.24 – 0.44	6.79		-0.22	0.54
Supplementation type	79	0.34*	0.24 – 0.44	6.73	6.22		0.01*
Loading	59	0.37*	0.36 – 0.47	6.84			
Loading + Maintenance	20	0.22	-0.01 – 0.45	1.88			
total g (total dose)	80	0.34*	0.24 – 0.44	6.79		-0.02	0.84

* Significance with α= 0.05.

(RAST: *Running Based Anaerobic Sprint Test;* Cr: Creatine; Cit: Citrate; dext: Dextrose; CrM: Creatine monohydrate; Glu: Glucose; Other types of Cr: CrM+2.12 g sucrose, CrM+1gmaltodextrine, 3gCr+3 gHidroxi-Methyl-Butyrate+6 g CHO, Cr+18 g dext, CrMaleate, CrM+15 g Glu+10 g Maleate, 10.5 g CrM+3.2g β-Alanine).

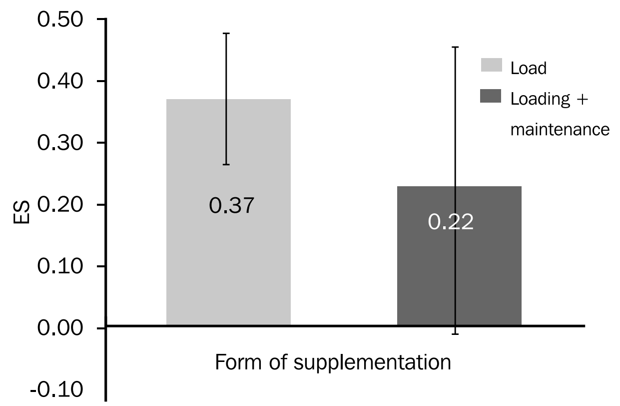
Discussion

This meta-analysis found a moderate-small global ES (ES=0.34) in anaerobic capacity following consumption of Cr according to Cohen's36 conventions, where an ES of 0.20 or less is small, around 0.50 is moderate and 0.80 or higher is large.

The overall ES was different between conditions (experimental > placebo) ($F_{(1, 129)}$= 9.56, p<0.05, α=0.05), with significance in the G_{Ex} but no significance in the G_{Pl}. This is contrary to the meta-analysis of Gutiérrez *et al.*[13], in which improvements were noted in both groups in variables such as peak power, total work, peak strength and 1RM.

The test for heterogeneity (Cochran's Q) proved to be non-significant, meaning that the individual ESs analysed are homogeneous. Thus, this analysis was performed for the purpose of observing any specific behaviour in the variables and to explain the global ES.

Figure 5. Difference in ES according to supplementation type.



Loading n= 59; loading + maintenance n = 20 F1-77= 6.22; p= 0.015.

Subject characteristics

This meta-analysis showed no gender-related differences (*p*=0.81), showing improvements in the ES of anaerobic capacity for both men and women (ES=0.32 and 0.42, respectively).

Similar to this study's findings, Ledford and Branch[37] conducted a double-blind study on nine physically active women who were given 20g/day x 5 days of CrM or a placebo (Polycose), measured at day 5, in addition, leaving a washout period of 95 ± 3 days (without treatment, making measurements). Those authors used the *Wingate Test* (WT) to measure peak power (PP) and work capacity (WC), finding no improvement (G_{Ex} PP: CrM: 540 ± 30, 484 ± 23, 435 ± 19 W *vs*. G_{Pl}: 522 ± 30, 481 ± 22, 403 ± 32 W; between treatments p=0.30; treatment-measurement: *p*=0.39; CT: CrM: 12.39 ± 0.67; 10.60 ± 0.50; 9.56 ± 0.59 kJ *vs*. GPl: 12,09 ± 0,32; 10,60 ± 0,54; 9.39 ± 0,67 kJ; between treatments *p*=0.76; treatment-measurement=0.66).

Eckerson *et al*.[29], in a cross-sectional double-blind study of 31 men and 30 women, aimed to determine the effect of supplementation with three treatments (creatine phosphate (CP), Creatine (Cr) and a Placebo (Pl= dextrose)) on working capacity (WC) through the critical power test, which was performed pre-treatment and two and six days after supplementation. That study found no differences in WC or significant interactions between measurements and treatments in women, while men significantly improved WC with significant interactions between measurements (23.8% after two days and 49.8% after six days of supplementation) *vs*. a placebo. When analysing WC between treatments without a group difference, an increase of 13-15% was found for the group with Cr *vs*. the placebo group. However, these results were not significant.

Physical performance

In this study, anaerobic capacity was measured with 76 ES via ergometers (including cycle ergometers, kayak ergometers, rowing ergometers, among others) and four using other methods (dynamometers and the Running-based *Anaerobic Sprint Test* [RAST]). No significant differences were found between the methods (*p*=0.75). However, significance was found in ES, as moderate ES was identified in both cases (ES=0.32 and 0.60, respectively).

In the meta-analysis performed by Dempsey *et al.* [10], which included three studies with a total of nine ES and an *n*= 149 subjects (*n*Cr= 75; *n*Pl= 74), no significant ES was identified in the anaerobic capacity measured by the peak power obtained with cycle ergometers. Similarly, no statistical significance was found when analysing three studies that measured peak torque using dynamometers.

Supplementation characteristics

In the present case, there were no significant differences in ES depending on the type of Cr consumed by the subjects; small to moderate ES were identified (ES=0.22 to 0.62). Similarly, Stout *et al*.[38] conducted a double-blind study over eight weeks with 24 college football players with three treatment conditions: 1) placebo (35 g carbohydrates [CHO]); 2) 5.25 g of creatine monohydrate (CrM) + 1g CHO; or 3) 5.25 g CM + 33 g CHO. These treatments were consumed four times a day for five days and then twice a day until the eight weeks were completed. They resulted in significant improvements in the bench press, vertical jumping and a 100-yard dash, identifying significant differences in the group that consumed CrM + CHO in the vertical jump and 100-yard dash, while the bench press showed significant improvement in all three treatments (*p*<0.01).

Furthermore, Rebello *et al*.[29], conducted a double-blind, placebo-control study on 18 swimmers (6 women and 12 men) distributed in two groups. One group received four daily doses of 5 g of Cr + 20 g of CHO, while the placebo group (Pl) received four doses of 20 g of CHO. In that study, among the findings on performance variables, it is indicated that a high intensity anaerobic resistance test was performed for 30-150 seconds; namely, a 100 m swim at maximum intensity. The results indicated higher lactate levels in Pl *vs*. Cr. While no differences were observed between the groups, some were noted between measurements in the Pl.

The form of supplementation (loading *vs*. loading + maintenance) did show a significant difference between ESs (ES=0.37 *vs*. 0.22, respectively).

Conclusion

Anaerobic capacity is improved by consuming Cr in any of its presentations, in both sexes and in both trained and untrained subjects.

The greatest effect of Cr on anaerobic capacity occurs during the loading phase *vs*. scenarios in which a loading and maintenance phase occurs (ES=0.37 *vs*. 0.22), while the total dose of this ergogenic aid did not show a significant ES (*p*=0.84).

Recommendations

It is recommended that journals request researchers to include descriptive statistics in their manuscripts to favour the inclusion of articles in meta-analyses.

More experimental studies should be performed with specific tests depending on the sport being performed and a detailed description of the test and treatment.

Finally, it is recommended to carry out more studies in women, clearly defining and describing the training, and to perform studies comparing loading or maintenance doses in a period of 28 days or more.

Conflicts of interest

The authors declare no conflict of interests.

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Reproductive dysfunction as a result of physical training: "exercise-hypogonadal male condition"

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Summary

The objective of this short review is to discuss how exercise training in men can result in changes in the reproductive system similar to those observed in women who develop athletic amenorrhea or suffer the Female Athlete Triad. Men chronically exposed to training for endurance sports exhibit persistently reduced basal free and total testosterone concentrations without concurrent luteinizing hormone elevations. These men are deemed to have the "Exercise-Hypogonadal Male Condition" (EHMC). Broadly, dysfunction in the hypothalamic-pituitary-gonadal regulatory axis is associated with either of these states. In women this effect on the axis is linked to the existence of a low energy availability (LEA) state, research in men relative to LEA is ongoing. The exact physiological mechanism inducing the reduction of testosterone in these men is currently unclear but is postulated to be a dysfunction within the hypothalamic-pituitary-gonadal regulatory axis. The potential exists for the reduced testosterone concentrations within EHMC men to be disruptive and detrimental to some anabolic-androgenic testosterone-dependent physiological processes. Findings, while limited, suggest spermatogenesis problems may exist in some cases; thus, infertility risk in such men is a critical concern. Present evidence suggests the EHMC condition is limited to men who have been persistently involved in chronic endurance exercise training for an extended period of time, and thus is not a highly prevalent occurrence. Nevertheless, it is critical that endocrinologist and fertility clinicians become more aware of the existence of EHMC as a potential problem-diagnosis in their male patients who exercise.

Key words:
Exercise-Hypogonadal male condition. Reproductive system dysfunction. Endurance training. fertility. Bone Health.

Disfunción reproductiva por entrenamiento físico: el "hipogonadismo masculino producto del ejercicio"

Resumen

El objetivo de esta breve revisión es describir cómo el entrenamiento físico en hombres puede provocar cambios en el sistema reproductivo similares a los observados en mujeres que desarrollan amenorrea atlética o manifiestan la *tríada de la mujer atleta*. Hombres expuestos sistemáticamente a entrenamientos para deportes de resistencia exhiben concentraciones de testosterona libre y basal reducidas, pero sin manifestar un aumento simultáneo de hormona luteinizante. Esta condición se denomina *"hipogonadismo masculino producto del ejercicio"* (EHMC, por su siglas en inglés). Ambos estados están asociados a una disfunción en el eje hipotalámico-hipofisario-gonadal. En las mujeres, la alteración del eje está vinculada a un estado de baja disponibilidad energética (BDE); en los hombres, la investigación relacionada con la BDE está en curso. El mecanismo fisiológico exacto que induce la reducción de testosterona en estos hombres aún no está claro, pero se postula que es una disfunción dentro del eje regulador hipotalámico-hipofisario-gonadal. Existe la posibilidad de que las bajas concentraciones de testosterona de los hombres con EHMC sean disruptivas y perjudiciales para algunos procesos fisiológicos anabólico-androgénicos dependientes de testosterona. Los hallazgos, aunque limitados, sugieren que en algunos casos pueden existir problemas de espermatogénesis; por lo tanto, el riesgo de infertilidad en tales hombres es una preocupación crucial. La evidencia actual sugiere que el EHMC se limita a hombres que han estado involucrados en entrenamiento de resistencia de manera persistente y durante tiempo prolongado, por lo que el EHMC no es una condición prevalente. De todos modos, es fundamental que médicos endocrinólogos y especialistas en fertilidad estén atentos a la existencia del EHMC como potencial problema – y diagnostico – que pueden padecer sus pacientes deportistas varones.

Palabras clave:
Hipogonadismo masculino producto del ejercicio. Disfunción del sistema reproductivo. Entrenamiento de resistencia. Fertilidad. Salud ósea.

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Introduction

For almost 40 years it has been known that women who do a lot of physical training, particularly when insufficiently nourished, are at greater risk of developing reproductive dysfunction[1-3]; specifically, oligomenorrhea or secondary amenorrhea (athletic amenorrhea)[1,2]. These conditions are associated with varying degrees of reproductive hormone abnormalities (hypoestrogenism), the risk of infertility, decreased bone mineral density and eating disorders, typically known as the female athlete triad (FAT)[1,2]. Until recently it was thought that such reproductive disorders related to exercise were specific to females. In the last two decades, however, evidence has built up to suggest that men can also suffer from similar reproductive disorders; that is, they are likely to develop what is called 'exercise-hypogonadal male condition' (EHMC)[4-6].

The purpose of this brief review is to provide an overview of EHMC and the physiopathogenic mechanisms which are probably involved, drawing parallels with what is already known about FAT.

Foregoing research

Retrospective and cross-sectional studies show that baseline testosterone levels are lower in male athletes who train systematically, specifically on those who do long-term endurance sports such as the marathon, long-distance triathlon and Olympic-style race walking[5-9]. The subjects of these studies are typically athletes who have trained consistently for several years (≥ 5-15)[10-15]. They report that the levels of testosterone (free and total concentration) in these athletes barely reach 50-85% of the levels found in male controls of the same age who do not do exercise[10-17].

Prospective studies in which blood samples have been collected at rest over periods of days, weeks and months while participants follow strenuous endurance training regimes have also found their testosterone levels are reduced. However, the findings of these prospective studies are less convincing than those reported by the retrospective studies[7,18-21]. The differences in the state of initial training of the participants or the specifics of the training programmes used in the different prospective studies could be behind these discrepancies[6,16]. For a definitive explanation of the origin of such inconsistencies, more comprehensive and longer-lasting prospective studies would be needed; such studies, however, are often difficult to implement.

Male endurance athletes with low testosterone levels usually present other reproductive hormone abnormalities. The most common are abnormalities in basal prolactin levels and baseline concentrations of luteinizing hormone (LH) and/or in its pulsatile characteristics[13,22,23]. These alterations in LH suggest the existence of a disruption in the hypothalamic secretion of gonadotropin-releasing hormone (GnRH)[13;] as is the case with many women with reproductive dysfunction related to exercise[1,2]. These alterations in LH and GnRH are indicative of a dysfunction in the hypothalamic–pituitary–gonadal axis (HPG; testicular in man, ovarian in women), which controls the reproductive system[8,24]. Taking into consideration the specifics of the reproductive endocrine system according to sex, decreased testosterone levels at rest in male athletes is analogous to lower levels of oestrogen-progesterone found in female athletes with reproductive dysfunctions related to exercise[25-30].

Mechanisms of dysfunction in the hypothalamic-pituitary-gonadal axis which lead to EHMC

The studies aimed at elucidating the physiological mechanism underlying the dysfunction of the HPG axis in men with EHMC have focused on whether the origin of the disorder is central (hypothalamic-pituitary) or peripheral (testicular). The former have examined the glandular secretion of LH and/or prolactin (PRL), while the latter have examined the secretion of testosterone. Since alterations in the release of LH-PRL had previously been studied in female athletes with reproductive disorders[1,13,31,32], the studies with male athletes took those conducted with women as a model.

Regarding the central mechanisms, the studies show that men with EHMC display extreme PRL release from the pituitary gland in response to endogenous or exogenous stimuli[33-35]. Attenuated release of LH can also be seen in response to analogous endogenous or exogenous stimuli[33]. Similar findings had previously been reported in female athletes with reproductive dysfunction (oligomenorrhea or athletic amenorrhea)[31,32]. It should be pointed out that due to sex-specific aspects of the HPG axis, not all changes in reproductive hormones observed in male and female athletes fully coincide. Furthermore, the type and nature of the research protocols and demographic differences between the male and female athletes studied have given rise to some variability in the findings.

With respect to peripheral mechanisms, the studies have demonstrated that men with EHMC show lower secretion of testosterone from the testes in response to an exogenous stimulus[33,36]. When compared with sedentary controls, there is a reduction of 15-40% in testicular testosterone secretion in response to the same stimulus dose. It is still unclear whether this attenuated secretion is due to a decrease in the sensitivity of the glandular receptor or to alterations in some subsequent event of the steroidogenic process for the synthesis of testosterone[6].

Loucks' work clearly shows that a state of low energy availability (LEA) is a key trigger for female athletes to develop FAT and related reproductive disorders[1]. LEA occurs when energy intake is insufficient to maintain the necessary functions of the body and those involved in physical training; this usually happens when caloric intake is <30 kcal/kg^{-1} FFM/day^{-1} [1]. Evidence that LEA in men is a causal factor in the development of EHMC is less definitive. However, Hooper et al. recently published convincing findings supporting this possibility; although it should be borne in mind that the number of subjects in the study was relatively small[37]. Therefore, it is unclear to date whether LEA is the chief cause of the development of either FAT or EHMC; that is to say, more studies are needed, particularly involving men.

Physiological impact of low testosterone in men

The low basal testosterone level that men with EHMC present with could affect physiological processes which depend on testosterone. There is evidence, for example, of a decrease in spermatogenesis and oligozoospermia conditions in athletes with EHMC[16,38,39]. There are also studies which report reduced sexual desire in endurance athletes[6,40,41]. It is likely that a disturbance in sperm production increases the risk of infertility in men with EHMC[6,8,41]; in the case of women, several studies have shown a strong relationship between athletic amenorrhea and fertility problems[1,2].

Study of the effects that the low testosterone levels of men with EHMC produce on other androgenic-anabolic processes -such as protein synthesis and the development of muscle mass- is limited. In all events, we put forward the hypothesis that the lower testosterone levels that these athletes exhibit could bring the benefit of a lower total muscle mass, something which could be advantageous in endurance sports (a lower body mass results in a lower oxygen requirement and, therefore, lower energy expenditure)[7,42].

One matter which calls for further research is the relationship between low testosterone, reduced bone mineral density and osteopaenia in athletes with EHMC. In the clinical field, there is evidence indicating that men with hypogonadism and hypotestosteronaemia may suffer severe bone mineral loss[43-46]. To date, the data on changes in bone mineral content in athletes with EHMC are somewhat contradictory, although convincing case studies have been published[47,48].

It should be noted that the prevalence of EHMC would appear to be low considering the population of male endurance athletes (15-25% according to existing estimates)[49]. This could be due to the fact that only a small percentage of these athletes train intensely and consistently long enough to display symptoms.

Conclusion

Persistent physical training, specifically that associated with endurance sports, negatively affects the principal male hormone (testosterone) and other reproductive hormones (LH and PRL). This reproductive endocrine status has been named 'exercise-hypogonadal male condition'[4-6]. The mechanism involved in this hormonal diminishment is still unclear, but would seem to be related to a dysfunction of the HPG axis caused by years of continuous exposure to significant amounts of physical training and it may also be associated with LEA. Studies in men with EHMC suggest that training of this nature disturbs testosterone-dependent anabolic or androgenic processes.

Although the prevalence of EHMC is relatively low, it is recommended that sports doctors and particularly endocrinologists and fertility specialists be mindful of the existence of EHMC. The evidence indicates that doctors may need to incorporate strategies within their procedures to assess and perhaps treat EHMC, especially given concerns about the potential problem of infertility.

Conflict of interest

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

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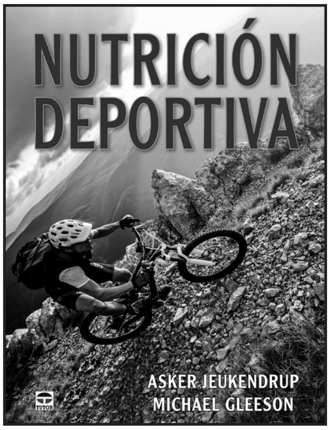


NUTRICIÓN DEPORTIVA

Por: A. Jeukendrup y M. Glesson
Edita: Tutor S.A.
Impresores 20. P.E. Prado del Espino. 28660 Boadilla del Monte. Madrid.
Telf: 915 599 832 - Fax: 915 410 235
E-mail: edicionestutor.com Web: www.editorestutor.com
Madrid 2019. 640 páginas. P.V.P.: 95 euros

Nutrición deportiva expone los principios, antecedentes y fundamentos de las pautas actuales de alimentación para deportistas. Proporciona los conocimientos básicos de la nutrición y expone los procesos fisiológicos que ocurren en las células y los tejidos, y la forma en que estos procesos se integran en todo el organismo. Además, a través de la utilización de una base fisiológica, ofrece una visión en profundidad de la ciencia que respalda la nutrición deportiva.

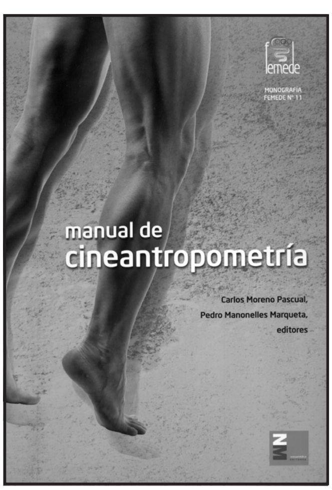
Este libro cuenta con más de 320 gráficos, figuras y tablas de apoyo al texto principal, recuadros explicativos de los temas seleccionados y un extenso glosario con la definición de términos de nutrición, fisiología y metabolismo. Sus capítulos están organizados secuencialmente, lo que facilita una mayor comprensión a medida que se introducen en él temas más avanzados. A las materias imprescindibles que trata (fuentes de combustible para el músculo y el metabolismo del ejercicio, micronutrientes: vitaminas y minerales, suplementos nutricionales, composición corporal, control de peso, trastornos de la alimentación en los deportistas, etc.) se suman las actualizaciones de esta edición, que mantendrán al día a los lectores sobre los últimos hallazgos en nutrición deportiva.

EL CALENTAMIENTO, ES AL MISMO TIEMPO MOTIVADOR Y EDUCATIVO

Por: Des Ryan
Edita: Tutor S.A.
Impresores 20. P.E. Prado del Espino. 28660 Boadilla del Monte. Madrid.
Telf: 915 599 832 - Fax: 915 410 235
E-mail: edicionestutor.com Web: www.editorestutor.com
Madrid 2019. 224 páginas. P.V.P.: 19,95 euros

Este es el primer libro que describe la ciencia del calentamiento y proporciona directrices para maximizar su eficacia deportiva. Con el uso del sistema RAMP-Raise (aumentar), Activar, Movilizar y Potenciar – verás por qué el calentamiento es más que una simple preparación para la sesión de trabajo posterior; es un factor clave en el desarrollo deportivo y puede mejorar las destrezas técnicas y capacidades de movimiento necesarias para destacar en el deporte. Este es el sistema recomendado por la United Kingdom Strength and Conditioning Association (UKSCA) y se incluye entre los recursos profesionales desarrollados por la National Strength and Conditioning Association (NSCA).

El calentamiento proporciona una serie completa de actividades para crear calentamientos RAMP eficaces incluyendo, entre otros, cinco programas modelo de calentamiento RAMP adecuados para diversos deportes y niveles de entrenamiento, más de 160 diagramas y fotografías para ilustrar 113 rutinas y ejercicios, y buscadores de rutinas y ejercicios para encontrar sin esfuerzo los ejercicios mejor adaptados a determinadas necesidades.



MANUAL DE CINEANTROPOMETRÍA

Por: Carlos Moreno Pascual, Pedro Manonelles Marqueta
Edita: Nexus Médica Editores.
Barcelona, 2011. 436 páginas.

La Cineantropometría ha alcanzado un gran desarrollo y aplicación. Esta obra viene a sustituir la primera edición y su posterior re-impresión porque el avance de este apartado de la Ciencia ha venido a superar con creces lo expuesto en ellos. Elaborado por destacados profesionales, recoge en su índice general los temas: Pasado, presente y futuro de la Cineantropometría (por Mª Dolores Cabañas y Jordi Porta); Bases anatómicas y puntos de referencia (por Miguel del Valle); Material antropométrico (por Angel Herrero de Lucas); Protocolo de medición (Por Alicia Canda); Error de medición (por José Ramón Alvero); Composición corporal (por Francisco José Berral); Somatotipo (por Mª Teresa Aragonés); Proporcionalidad corporal: historia y presente (por Jordi Porta y Mª Dolores Cabañas); Cuerpo y función: alometría y deporte (por Delfín Galiano, Mª Carmen Vargas y Jordi Porta); Aplicaciones de la Cineantropometría (por Carlos Moreno); La Cineantropometría en la edad infantil (por Begoña Manuz y Pedro Manonelles). Al final en un anexo aparecen los Valores de referencia (por José Ramón Alvero).

2019		
1º Congreso Mundial de Educación Física (FIEP)	30 Septiembre - 4 Octubre Santiago del Estero (Argentina)	web: http://www.fiepargentinaoficial.com/
IX Congreso de la Sociedad Cubana de Medicina Física y Rehabilitación	1-4 Octubre La Habana (Cuba)	web: http://www.rehabilitacioncuba.com
11th European Congress on Sports Medicine	3-5 Octubre Portorose (Eslovenia)	web: http://www.efsma.eu
I Congreso de Reeducación Funcional Deportiva CERS-INEFC	4-5 Octubre Barcelona	web: http://inefc.gencat.cat/ca/inefc/jornades_congressos/congres-cers-2019/informacio
6th Annual Congress on Medicine & Science in Ultra-Endurance Sports	11-13 Octubre Cape Town (Sudáfrica)	web: https://ultrasportsscience.us/congress/
13th European Nutrition Conference On Malnutrition In An Obese World	15-18 Octubre Dublín (Irlanda)	web: www.fens2019.org
Jornadas SAMEDE: deporte y deportistas en situaciones especiales	18-19 Octubre Almería	web: https://www.jornadassamede.es/
50 Congreso Nacional de Podología y VI Encuentro Iberoamericano	18-19 Octubre Santander	web: https://50congresopodologia.com/
World Congress of Tennis Medicine and Sports Science	18-19 Octubre Estocolmo (Suecia)	web: www.shh.se/stmswc2019
41 Congreso Internacional SEMOOYM	24-26 Octubre Elche	https://www.semooym.org
Congreso Internacional de Fisioterapia	25-26 Octubre Toledo	web: congreso@coficam.org
10th International Physical Education and Sports Teaching Congress	31 Octubre-3 Noviembre Antalya (Turquía)	web: https://2019.tubed.org.tr/en/
5th World Conference on Doping in Sport	5-7 Noviembre Katowice (Polonia)	web: http://www.wada-ama.org
Jornadas Andaluzas de Podología	8-9 Noviembre Sevilla	web: www.colegiopodologosandalucia.org
15º Congreso Internacional de Ciencias del Deporte y la Salud	8-9 Noviembre Pontevedra	web: www.victorarufe.com
Jornadas Andaluzas de Podología	8-9 Noviembre Sevilla	web: www.colegiopodologosandalucia.org
26th Word Congress TAFISA	13-17 Noviembre Tokyo (Japón)	web: www.tafisa.org
XVII Simposio Internacional Clinica Cemtro: Nuevos horizontes sobre cirugía mínimamente invasiva en cirugía ortopédica y traumatología" "Medicina Regenerativa en el Aparato Locomotor"	14-16 Noviembre Madrid	web: https://www.clinicacemtro.com/
2019 FIP World Congress of Podiatry Conference	14-16 Noviembre Miami (EEUU)	web: www.podiatry2019.org
International Sport Forum on Strength, Conditioning and Nutrition	15-16 Noviembre Madrid	web: https://congress.esns.academy/

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2019 Southeast Asian Games Scientific Conference	22-24 Noviembre Angeles (Filipinas)	web: https://www.2019seag-apcess.com
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56 Congreso Argentino de COT	28 Noviembre-1 Diciembre Buenos Aires (Argentina)	web: www.congresoaaot.org.ar
X Congreso Peruano de Medicina del Deporte	29-30 Noviembre Lima (Perú)	web: www.facebook.com
2020		
V Congreso Internacional de Readaptación y Prevención de Lesiones en la Actividad Física y el Deporte	Enero Valencia	web: https://congresojam.com/
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37º Congress International Society for Snowsports Medicine-SITEMSH	1-3 Abril Andorra la Vella (Principat d'Andorra)	E-mail: andorra2020@sitemsh.org
9º Congrés Societat Catalana de Medicina de l'Esport-SCME	3-4 Abril Andorra la Vella (Principat d'Andorra)	E-mail: andorra2020@sitemsh.org
25th Annual Congress of the European College of Sport Science	1-4 Julio Sevilla	E-mail: office@sport-science.org
32nd FIEP World Congress / 12th International Seminar for Physical Education Teachers /15th FIEP European Congress	2-8 Agosto Jyväskylä (Finlandia)	Información: Branislav Antala E-mail: antala@fsport.uniba.sk
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XXXVI Congreso Mundial de Medicina del Deporte	24-27 Septiembre Atenas (Grecia)	https://www.fims2020.com/

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XVIII Congreso Internacional SEMED-FEMEDE	Murcia	web: www.femede.es
2021		
Congreso Mundial de Psicología del Deporte	1-5 Julio Taipei (Taiwan)	web: https://www.issponline.org/index.php/events/next-world-congress
26th Annual Congress of the European College of Sport Science	7-10 Julio Glasgow (Reino Unido)	E-mail: office@sport-science.org
22nd International Congress of Nutrition (ICN)	14-19 Septiembre Tokyo (Japón)	web: http://icn2021.org/
European Federation of Sports Medicine Associations (EFSMA) Conference 2021	28-30 Octubre Budapest (Hungría)	web: http://efsma.eu/
Congreso Mundial de Podología	Barcelona	web: www.fip-ifp.org
2022		
8th IWG World Conference on Women and Sport	5-8 Mayo Auckland (N. Zelanda)	web: http://iwgwomenandsport.org/world-conference/
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Curso dirigido a los titulados de las diferentes profesiones sanitarias y a los titulados en ciencias de la actividad física y el deporte, destinado al conocimiento profundo de los aspectos fisiológicos y de valoración funcional del ciclismo.

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Curso dirigido a médicos destinado a facilitar al médico relacionado con la actividad física y el deporte la formación precisa para conocer los elementos necesarios para la obtención de los elementos energéticos necesarios para el esfuerzo físico y para prescribir una adecuada alimentación del deportista.

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Curso dirigido a los titulados de las diferentes profesiones sanitarias (existe un curso específico para médicos) y para los titulados en ciencias de la actividad física y el deporte, dirigido a facilitar a los profesionales relacionados con la actividad física y el deporte la formación precisa para conocer los elementos necesarios para la obtención de los elementos energéticos necesarios para el esfuerzo físico y para conocer la adecuada alimentación del deportista.

Curso "ALIMENTACIÓN Y NUTRICIÓN EN EL DEPORTE" Para Diplomados y Graduados en Enfermería

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Curso "CINEANTROPOMETRÍA PARA SANITARIOS"

Curso dirigido a sanitarios destinado a adquirir los conocimientos necesarios para conocer los fundamentos de la cineantropometría (puntos anatómicos de referencia, material antropométrico, protocolo de medición, error de medición, composición corporal, somatotipo, proporcionalidad) y la relación entre la antropometría y el rendimiento deportivo.

Curso "CINEANTROPOMETRÍA"

Curso dirigido a todas aquellas personas interesadas en este campo en las Ciencias del Deporte y alumnos de último año de grado, destinado a adquirir los conocimientos necesarios para conocer los fundamentos de la cineantropometría (puntos anatómicos de referencia, material antropométrico, protocolo de medición, error de medición, composición corporal, somatotipo, proporcionalidad) y la relación entre la antropometría y el rendimiento deportivo.

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   The acknowledgments will appear at the end of the text.

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