ISSN: 0212-8799

184
Volumen 35(2)
March - April 2018

Archivos de medicina del deporte

Órgano de expresión de la Sociedad Española de Medicina del Deporte

ORIGINAL ARTICLES

REVIEWS

ARCHIVOS DE MEDICINA DEL DEPORTE

UCAM
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Consejo Superior de Deportes

Sociedad Española de Medicina del Deporte

Archivos de medicina del deporte

Revista de la Sociedad Española de Medicina del Deporte

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

Edita
Sociedad Española de Medicina del Deporte
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Publicidad
ESMON PUBLICIDAD
Tel. 93 2159034

Publicación bimestral
Un volumen por año

Depósito Legal
Pamplona. NA 123. 1984

ISSN
0212-8799

Soporte válido
Ref. SVR 389

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

Calidad de Revistas Científicas Españolas
FECYT 2016

La Revista Archivos de Medicina del Deporte ha obtenido el Sello de Calidad en la V Convocatoria de evaluación de la calidad editorial y científica de las revistas científicas españolas, de la Fundación Española para la Ciencia y la Tecnología (FECYT).

Archivos
de medicina del deporte
Volumen 35(2) - Núm 184. March - April 2018 / *Marzo - Abril 2018*

Summary / Sumario

Health and Medicine in the Future: Change through Sports Medicine – Sports Medicine in Change

Salud y Medicina en el futuro: Cambio a través de la medicina deportiva - Medicina deportiva en el cambio

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Sports Medicine is a branch of medicine concerned about effects of inactivity, physical activity, movement, exercise, sports and training on the human body at all ages, in healthy and diseased subjects. The main objectives of sports medicine include prevention of many diseases, especially of cardiovascular diseases by physical activity but also prevention of sports injuries, the therapeutic use of physical activity as therapy of different diseases and in rehabilitation after recovery from diseases, surgery or other interventions in internal medicine and traumatology.

Sports medicine is also concerned with providing training recommendations to athletes of all categories ranging from leisure time to top athletes.

The rapid development of science in sports medicine has revealed new fields of activity which will broaden the spectrum of sports medicine.

Genomics and sports medicine

There are many aspects of genomics and sports medicine. For instance, the diagnosis of occult genetic diseases potentially leading to sudden cardiac arrest or death is of great importance. Genetic diseases include heart muscle diseases such as cardiomyopathies or electrical diseases such as abnormalities e.g. long QT-syndrom. Diagnostic testing for genomic abnormalities may be essential and life saving in athletes and their family members, even if conducted as postmortal molecular autopsy.

The prediction of eligibility, endurance or strength and the search for talents among young athletes in certain sports disciplines based on genomic diagnostic examination such as genomics or DNA analysis is neither acceptable from an ethical point of view nor reliable from a genomic scientific point of view to date.

However, in times of *Crispr/Cas9*[1] this aspect should be carefully observed in the future.

A question which remains unanswered is whether genomic analysis may by successful in the search for doping as has been suggested[2]. If this comes true, genomic testing should be strongly promoted by sports organisations such as the IOC or WADA.

Personalisation of sports medicine

A trend towards individual diagnostic testing and more importantly, therapy tailored to the individual has widely emerged in recent research and practical medicine as a way to improve treatment in an individual sports person or patient.

The development of the *exercise prescription for health* (EPH) project has shown to enable individualized recommendations for regular physical activity tailored to existing diseases and type of training.

EPH recommendations follow the FITTprinciple (Frequency; Intensity,Time,Type of sports) extended by formulas facilitating the prescription on an individual basis. Such an approach is a significant step towards individualizing the training recommendation and may enhance adherence to regular physical activity. Therefore, exercise prescription for health is a Europe-wide initiative with a strong motivational component. To avoid any harm to the athlete, a standardized preparticipation examination as developed by the EFSMA is strongly recommended for all sports physicians. This EFSMA recommendation may therefore be a forerunner for personalised medicine[3].

Digitization and sports medicine

There is no doubt that digitization is one of the most significant developments in all areas of economy and medicine to date. The EFSMA therefore tries to introduce digitization by means of digitized ECG recording in all European countries together with digitized history and physical examination of all athletes. The next step is to implement a

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central data storage either by browser or by cloud. By this approach and given the cooperation of all European federations, a large database can be established. This will allow prospective evaluations for each country but especially for prospective studies with large numbers in sports medicine. There is still such analysis on early detection of inborn diseases in young recruits from Switzerland with excellent results[4]. Such a database may also enable all sports physician in Europe to obtain expert information regarding difficult interpretation of athlete's ECG and other findings via the secretary of EFSMA as a kind of second opinion.

Sports medicine as a mother for physical activity in other medical disciplines

A meticuluous observation of all internal medicine disciplines across the world clearly reveal that physical activity is gaining huge importance in most disciplines, e.g. but not only sports cardiology, sports neurology or sports oncology.

Besides the established disciplines of traumatology and orthopaedics, sports medicine has also been introduced as part of the treatment pillars in psychiatry, paediatrics, obstetrics (sports in pregnancy) as well as pneumology. Furthermore, pre-conditioning, another current development may demand sports medicine support. More and more physicians use exercise training as a pre-treatment prior to surgery, e.g. bypass surgery, but also in other fields of interventional medicine. In addition, early mobilization of inpatients starting with physical training already while still in hospital demands treatment by a sports physician. Accordingly, the presence of a sports medicine consultancy in every single hospital should be highly considered.This physician should also recommend physical activity after discharge of the patient by an exercise prescription similar to prescription of medication or other measures.

Last but not least, these portrayed new developments must be supported by ethical standards and official sport society statements. This especially concerns athletes of all categories as has been stated by the new declaration of Geneva[5].

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Frequency of High Intensity Circuit Training and diet. Effects on performance and health in active adults: Randomized Controlled Trial

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Received: 14.06.2017
Accepted: 04.09.2017

Summary

Introduction: High intensity circuit training (HICT) has been proven to be one of the most efficient methods to improve physical and physiological parameters using short training sessions. The objective of this study was to discern the effects of a 6-week HICT program in active persons, modifying the training frequency.
Methods: Group A trained two days a week (n=7), group B trained 3 days a week (n=7), while the control group did not perform any training (n=7). All groups followed a diet program adapted to the strength training requirements. The training sessions were comprised of 4 series of 10 self-loading exercises, including sprints and supporting materials, with 1-2 minute rests between series, exerting an 80-95% maximum cardiac frequency intensity. A 1:1 training load density was used, with 20-25 second intervals between work and recovery.
Results: Groups A and B significantly improved in body composition and strength tests (bench press and back squats), compared to the control group as well as in the intragroup analysis when comparing before and after the intervention. However, no significant differences were observed when comparing the two experimental groups. No changes in blood pressure were observed in any inter- or intragroup analysis.
Conclusion: An adapted nutritional program and a 2-day/week HICT program seems to be sufficient in order to obtain significant improvements in strength and body composition in healthy active subjects, although blood pressure was not affected.

Key words:
Body composition.
Muscle mass. Fat mass.
Circuit training.
Functional training.

Frecuencia de entrenamiento en circuito de alta intensidad y dieta. Efectos sobre rendimiento y salud en adultos activos: Ensayo Controlado Aleatorizado

Resumen

Introducción: El entrenamiento en circuito de alta intensidad (HICT) ha demostrado ser uno de los métodos de entrenamiento más eficaces por la mejora de parámetro físicos y fisiológicos utilizando cortos periodos de entrenamiento. El objetivo de este estudio fue conocer los efectos de un programa de 6 semanas de entrenamiento HICT en personas activas, modificando la frecuencia de entrenamiento.
Método: El grupo A entrenó con una frecuencia de 2 días a la semana (n=7), el grupo B (n=7) 3 días a la semana y el grupo control no realizó ningún entrenamiento (n=7). Ambos grupos siguieron un programa dietético adaptado a los requerimientos de los entrenamientos de fuerza. Realizaron un mismo entrenamiento compuesto de 4 series de 10 ejercicios con auto-cargas, con material auxiliar y carreras, con descanso de 1 y 2 minutos entre las series, a una intensidad entre el 80-95% de la FC máx. Se utilizó una densidad de la carga de entrenamiento de 1:1 con intervalos de trabajo y recuperación de 20 a 25 segundos.
Resultados: Los grupos A y B mostraron, en comparación al grupo control, mejoras en la composición corporal y en los test de fuerza (*press* de banca y sentadilla) antes y después de la intervención con HICT. Sin embargo, no se obtuvieron diferencias cuando se compararon los resultados obtenidos entre ambos grupos experimentales. Las diferencias se observaron frente al grupo control, ya que tanto el grupo A como el grupo B mostraron mejoras significativas en la composición corporal y la fuerza. La presión arterial no presentó diferencias en las comparaciones inter e intragrupo.
Conclusión: Un programa dietético nutricional adaptado y una frecuencia de entrenamiento de HICT de dos días parece ser suficiente para obtener mejoras en la fuerza y la composición corporal, aunque no para mejorar la presión arterial en sujetos sanos activos.

Palabras clave:
Peso corporal.
Masa muscular. Masa grasa.
Entrenamiento en circuito.
Entrenamiento funcional.

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Introduction

High intensity circuit training (HICT)[1] is a training method where high intensity repetitions are performed, followed by complete pauses or active recoveries before commencing another repetition at the same programmed intensity[2]. The activities are generally of short duration but vigorous, with complete rests or low-intensity exercises performed between series. This method dramatically stimulates the body and causes a physiological readjustment, as well as requiring significantly less time and fewer exercises[3].

The most relevant responses or acute effects that occur during and after HICT exercises are the use of fat as energy substrate as well as other physiological adaptations, such as increased catecholamine and cytokine production[4]. At the peripheral level, both blood vessels and muscles develop functional and structural adaptations[5,6]. In this sense, HICT is becoming of increased interest for glycaemic control in type II diabetes, having a higher and more prolonged post-exercise hypoglycaemic effect than moderate intensity exercises of the same or longer duration[7]. Other chronic adaptations include increased resting glycogen storage[1] and improved resting blood pressure levels[8].

In this context, HICT can exert significant changes in adult body composition, especially regarding fat mass. This morphological change is one of the most health-related factors, as lower fat mass is associated with decreased mortality and co-morbidity risks[9]. Furthermore, these changes can be further enhanced with a nutritional-diet intervention, as combining exercise with an individualized adapted diet can positively affect body compositions of strength-related athletes[10].

The ACSM (American College Sports Medicine) recommendations regarding sports practice[11] present healthy sports practice guidelines, and grades them in relation to the level of scientific evidence (graded A-D). These recommendations include those related with frequency, intensity, training type, volume, etc. In this sense, regarding resistance training, there is no consensus if 2 or 3 days/week training is preferable. Certain authors, such as Westcott and colleagues[12] have already questioned this and have tried to study their effects on body composition and blood pressure, among other parameters, in resistance training but not HICT.

Therefore, the aim of this study is to understand the effect HICT exerts on sports performance variables, body composition and blood pressure. To this end, two different HICT programmes with different weekly frequencies were compared, with the hypothesis that increasing the number of training days per week, at the same duration, the subjects would obtain better results in the variables studied.

Material and method

Design

A quasi-experimental design was performed for 6 weeks in 2 experimental groups and one randomized control group (blind distribution). The variables (explained below) were assessed in all the subjects one week before the intervention, as well as week 0 and 7, performed by the same researcher using the same protocol and at the same moment of the day.

Sample

The volunteers were taken from different sports centres in Spain, Región de Murcia, choosing from adult males. A meeting was held with the interested collaborators to inform of the research, the conditions and requirements, as well as the possible benefits and inherent risks of the training program. Ethical approval was given by the Ethical Committee of San Antonio Catholic University of Murcia in Spain, and was performed in accordance with the ethical standards of the committee responsible for human experimentation (institutional and national) and with the Helsinki Declaration of 1975 revised in 2008.

The inclusion criteria were: functionally independent males of 21-40 years of age; no muscular, ligament, bone, nerve or articular pathology that may interfere with the training program; no cardiovascular or cardiorespiratory problems. Also, the volunteers must be considered to be physically active for the past 5 years, based on the definition published in Martin *et al.*[13], where an active individual is that who exercises or trains (aerobic, resistance or mixed) at least 3 times a week in non-consecutive days, and must have at least 5 years of experience in resistance training.

The exclusion criteria are: under pharmacological treatment or supplements; performs other sports activities that may influence in the results of the study; does not respect the training program or attend the training sessions; does not fulfil one of the inclusion criteria.

A total of 21 male volunteers were selected. A simple randomized sampling was performed to group the volunteers into two experimental (n=7 each) and one control group (C, n=7) (Figure 1). Both experimental groups performed the same HICT training program, with the only difference being the number of weekly sessions (2 per week in Group A, 3 per week in Group B). The program lasted a total of 6 weeks. Group C did not perform any physical exercise. Because all participants used smartphones, the physical activity of the control group and the experimental groups outside the intervention program were controlled by "Google fit" app (step count) free for iOS and android.

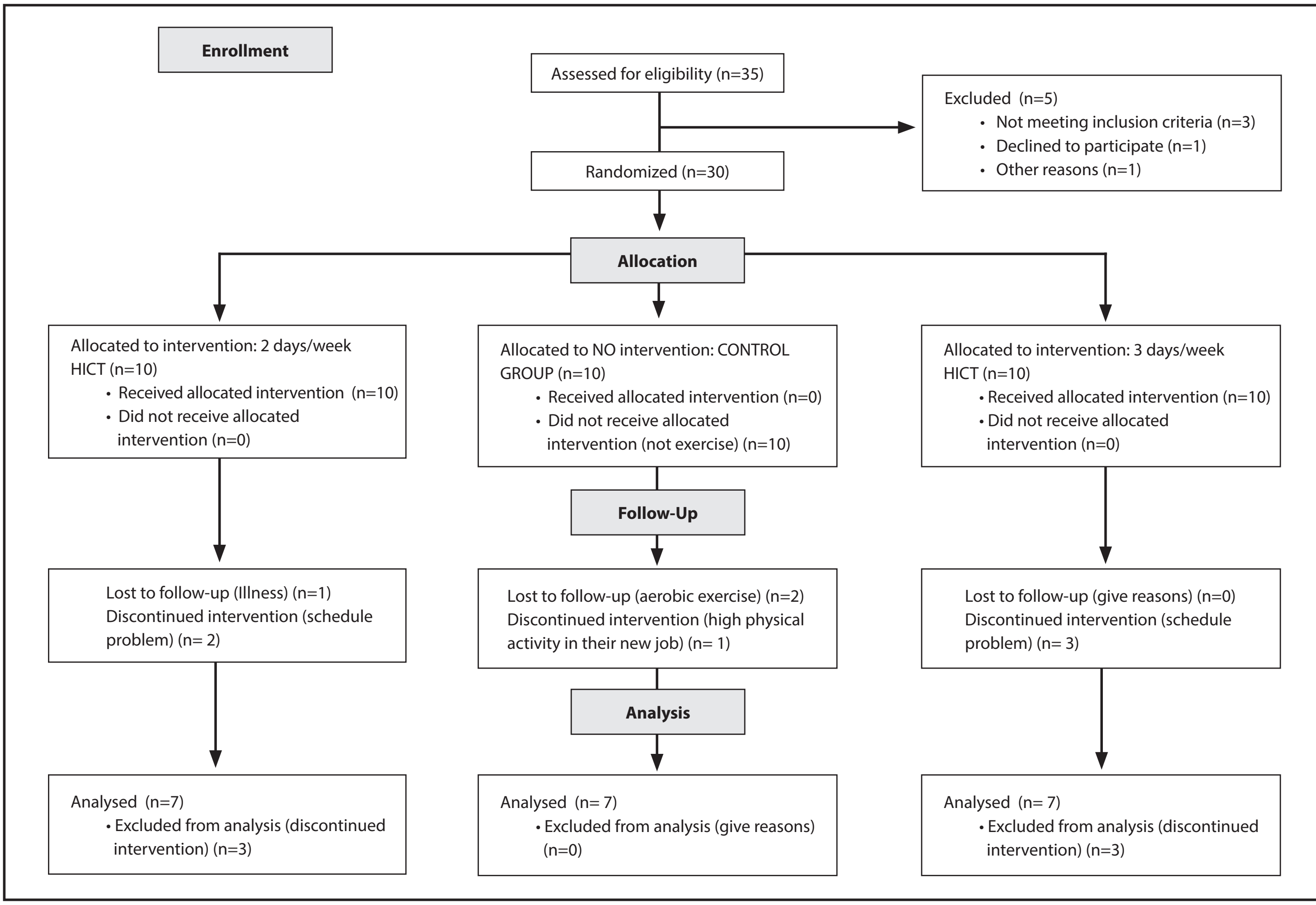
Body composition

The ISAK protocol was used in order to normalize the body composition values of the volunteers[14]. The anthropometric variables[10] used to estimate fat mass (percentage and weight) using Carter´s formula were measured with the following materials: Harpenden plycometer (Baty International Ltd., West Sussex, United Kindom) with a 2 mm precision and flexible metallic metric tape with 1mm precision; weight was measured using a digital scale[15] Tanita BC-418 MA (Tanita Corporation, Arlington Heights, IL) with a 100 g precision. Standing height without shoes was measured using a Seca 202 stadiometer (Seca, Hamburg, Germany) to the nearest 0.1 cm.

Blood pressure

Arterial blood pressure was measured in all the participants at the beginning and end of the intervention. This was performed at rest, with the volunteers seated for at least 10 minutes. The measurement was performed with a digital tensiometer (Omron MX3 Plus, model HEM-742-E)[16], following the recommendations published in Schoenfeld *et al.*[17]

Figure 1. Consort flow diagram.



Strength test

The 1 REP MAX (1RM) bench press and squat tests were performed following NSCA recommendations described by Schoenfeld in 2016[18].

Maximum cardiac frequency

Cardiac frequency was measured using Polar Team for Apple systems and Polar H7 Bluetooth pulsometers[19].

Diet program

All the participants of the experimental groups and control group followed the same diet program, adapted to their energy requirements[14]. Before commencing the training intervention, the control and experimental groups assisted a nutritional education workshop to inform them of the diet plan. The diet plan consisted in 2 g/kg body weight proteins, 5-8 g/kg body weight carbohydrates and 1 g/kg body weight lipids[20]. An isocaloric diet was provided, with no energy restriction. All the participants were given indications as to what foods could be consumed and when to eat. A dietitian was provided for the participants to contact in case of any doubt.

Training program

The training program lasted 6 weeks. Group A performed 2 HICT sessions per week at a 1:1 density, group B performed 3 sessions, while Group C did not perform any training.

The duration of the intervals was established at 20-25 seconds of effort, with an intensity of 80-95% HRmax.

Metabolic exercises were performed, with self-loads. These exercises were organized into 3 exercises for upper body muscle groups, 3 for lower hemisphere muscles, 2 for core muscles (abdominal and lumbar) and 2 running muscle groups. Also, they were divided in calisthenics, with materials and runs.

Therefore, a total of 10 exercises were performed, with a focus on metabolic exercises with self-load, multi-muscle, poly-articulate, and of intramuscle coordination. The participants were supervised by a graduate in Sports Science in order to ensure that the voluntary fatigue was achieved in a safe manner, and that proper resting periods were performed. The total training time was of approximately 50 minutes (4 series).

The training session commenced with a general warm-up, consisting in a continuous run, adding dynamic exercises every 3 minutes.

Afterwards, 2 minutes of vegetative activity was performed, at a 50-60% maximum CF intensity. Dynamic stretching of the muscle groups to use in the training session was executed. Once the training session was completed, 2 progressive 10-15 metre sprints were performed, with no rests between them. See Annex for the specifications of the training program.

Statistics

The SPSS® software (version 24.0 IBM for Windows) was used for the statistical analysis. Results were presented as mean ± standard deviation (SD). Were performed descriptive analysis, Kolmogorov-Smirnov normality distribution test, T-test for related samples, and inter-subject one-way ANOVA as well as post-hoc tests (Tukey and Games-Howell) depending on if the variances were homogenous. Parametric tests were used as the data analysed presented a normal distribution. The 95% confidence interval (95% CI) were calculated. Level of significance was fixed at $p < 0.05$.

A correlation analysis for each group was performed separately, and a linear regression was assessed with the variables that presented a certain level of significance. Effect Size (ES) was calculated according to Cohen guidelines[21]. Threshold values for Cohen ES statistics were >0.2 (small), >0.6 (moderate), and >1.2 (large).

Results

The descriptive analysis of the samples divided by groups and moment (pre or post-intervention) is shown in Table 1, as well as the results of the inter-group and intra-group means.

The comparison analysis of related samples indicated that both groups presented significant differences after the 6-week HICT intervention. On one hand, group A significantly improved in the reduction of triceps skinfolds (95%CI=[0.23736 -3.04836]; ES=0.319), as well as in the abdominal (95%CI=[0.41479-6.44236]; ES= 0.463) and total sum of the 6 folds (95%CI=[3.02456-17.97544]; ES=1.388). Also, decreased fat

Table 1. Description data of the sample and significative results after related sample comparison and differences between groups.

	GROUP A (n=7): 2 HICT sessions		Group B (n=7): 3 HICT sessions		Group C (n=7): Control	
	Pre-Intervention	Post-Intervention	Pre-Intervention	Post-Intervention	Pre-Intervention	Post-Intervention
	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD	Mean SD
Age	31.1 ± 7.9	31.1 ± 7.9	27.4 ± 5.9	27.4 ± 5.9	30.8 ± 5.8	30.8 ± 5.8
Body composition						
Weight (kg)	77.2 ± 8.1	77.2 ± 7.0	70.5 ± 7.1	70.0 ± 6.5	77.5 ± 8.3	77.6 ± 8.3
Height	178.1 ± 10.9	178.1 ± 10.9	172.1 ± 2.7	172.1± 2.7	179.4 ± 9.3	179.4 ± 9.3
BMI (kg/m^2)	24.4 ± 1.3	24.4 ± 1.6	23.9 ± 2.7	23.7 ± 2.5	24.3 ± 1.4	24.3 ± 1.5
Waist (cm)	82.6 ± 6.1	81.4 ± 5.8	78.9 ± 5.6	78.4 ± 6.1	82.7 ± 6.3	83.3 ± 6.8
Hip (cm)	96.5 ± 5.3	95.9 ± 3.4	67.4 ± 39.2	92.1 ± 4.3	96.4 ± 5.2	96.5 ± 5.3
Waist-Hip Ratio	0.8 ± 0.0	0.8 ± 0.0	0.8 ± 0.0	0.8 ± 0.0	0.9 ± 0.0	0.9 ± 0.0
Triceps skinfold (mm)	13.2 ± 5.3	11.6 ± 4.7[*a]	12.5 ± 4.7	8.8 ± 3.4[**a]	13.2 ± 5.3	13.4 ± 5.2
Subescapular skinfold (mm)	13.6 ± 5.0	11.5 ± 2.5	11.3 ± 1.6	10.6 ± 2.1	14.6 ± 5.0	14.8 ± 5.0
Supraespinal skinfold (mm)	15.2 ± 3.3	14.6 ± 2.7	15.1 ± 1.9	14.0 ± 1.7[*]	16.2 ± 3.7	16.4 ± 3.5
Abdominal skinfold (mm)	24.1 ± 8.0	20.6 ± 7.1[*a]	22.6 ± 7.9	19.6 ± 8.1[*a]	22.1 ± 9.0	22.4 ± 9.1
Thigh skinfold (mm)	15.4 ± 6.0	14.0 ± 7.1	14.6 ± 3.9	13.9 ± 4.3	17.0 ± 5.8	17.2 ± 6.3
Calf skinfold (mm)	9.4 ± 4.1	8.1 ± 2.6	10.3 ± 4.6	7.4 ± 2.9[*]	9.7 ± 4.4	9.7 ± 4.0
Skinfold sum of 6 (mm)	80.9 ± 27.9	70.4 ± 22.5[*a]	76.4 ± 19.5	64.1 ±18.1[**a]	81.2 ± 28.1	82.4 ± 28.1
Fat mass (%)	11.1 ± 2.9	10.0 ± 2.4[*a]	10.6 ± 2.1	9.3 ± 1.9[**a]	14.8 ± 4.2	15.0 ± 4.2
Fat mass (kg)	8.6 ± 2.7	7.8 ± 2.3[*a]	7.5 ± 1.8	6.5 ± 1.5[*a]	11.6 ± 3.9	11.8 ± 3.9
Strength test Results						
Bench Press RM (kg)	76.3 ± 14.2	85.4 ±11.8[**a]	75.0 ± 17.4	82.9 ±15.2[*a]	74.6 ± 11.2	75.1 ± 13.5
Squat RM (kg)	104.7 ± 19.2	120.0 ± 18.2[*a]	103.7 ± 22.0	121.4± 20[**b]	102.7 ± 21.2	98.9 ± 19.8
Blood pressure Results						
Systolic pressure (mmHg)	138.9 ± 10.3	116.0 ± 46.6	134.7 ± 8.8	130.7± 10.4	139.6 ± 9.3	140.1 ± 9.6
Diastolic pressure (mmHg)	77.0 ± 4.4	62.0 ± 24.7	62.7 ± 25.3	53.7 ± 36.0	78.3 ± 4.4	77.9 ± 5.5

HICT: High Intensity Circuit Training; SD: Standar Deviation; BMI: Body Mass Index; RM: Reptetitium Maximum; *: Significant difference pre vs post test ($p<0.05$); **: Significant difference pre vs post test ($p<0.01$); [a]: Significant difference with Control Group ($p<0.05$); [b]: Significant difference with Control Group ($p<0.01$).

mass was observed, both in kg (95%CI=[0.26181-1.45842]; ES=0.319) and percentage (95%CI=[0.31788-1.88922]; ES=0.413). The strength tests also presented significant differences, with improvements observed in the 1RM bench press (95%CI=[-13.62394 - -4.66177]; ES=0.697), and squat (95%CI=[-25.71796- -4.85347]; ES=0.818). However, no significant differences were observed in the other variables analysed.

On the other hand, group B also presented significant differences in the same skinfolds as group A, as well as in two additional ones: triceps (95%CI=[1.28408 - 6.14449]; ES=0.902), abdominal (95%CI=[0.62703-5.37297]; ES=0.375), supra-spinal (95%CI=[0.13021 - 2.01264]; ES=0.610), leg (95%CI=[0.78559 - 5.07155]; ES=0.754) and the total sum of the six skinfolds (95%CI=[5.28382-19.14475]; ES=0.654). Furthermore, fat mass was significantly decreased, both in kg (95%CI= [0.26473-1.65221]; ES=0.604), and percentage (95%CI= [0.55533-2.01211]; ES=0.649).

Group B also significantly improved after the intervention in 1RM strength tests: bench press (95%CI=[-13.12764 - 2.58664]; ES=0.484), and squat (95%CI=[-24.89231 - -10.53626]; ES=0.842). As in Group A, no significant differences were observed in the other variables analysed.

Group C (control) did not present any significant differences in the intra-group analysis.

The inter-group analysis, comparing the average increase of the variables after the intervention, showed that Groups A and B did not present any significant difference. However, significant differences were observed when the two groups were compared to the control, specifically regarding increased triceps skinfold (Group A: 95%CI=[0.01109-3.632], ES=1.682; Group B: 95%CI=[0.8968-6.9889], ES=2.104); abdominal skinfold (Group A: 95%CI=[0.4801-7.0342], ES=1.682; Group B: 95%CI=[0.0515-6.6056], ES=1.853); total sum of skinfolds (Group A: 95%CI=[2.3194-21.052], ES=2.035; Group B: 95%CI=[4.7174-22.0826], ES=2.509); fat mass percentage (Group A: 95%CI=[0.3053-2.2732], ES=2.208; Group B: 95%CI=[0.5573-2.3816], ES=2.800) and kg of fat mass (Group A: 95%CI=[0.2825-1.7806], ES=2.235; Group B: 95%CI=[0.2611-1.9987], ES=2.056).

With respect to the variables related to sports performance, groups A and B significantly improved after the intervention compared to group C. These variables consisted in increased 1RM in bench press ((Group A: 95%CI=[-15.7534 - -4.5323], ES=2.947; Group B: 95%CI=[-15.4579 - -2.2564], ES=2.162) and squat (Group A: 95%CI=[-34.2487 - -8.037], ES=2.508; Group B: 95%CI=[-32.7647 - -14.3781], ES=3.827).

The correlation analysis indicated that, among the two experimental groups, significant negative correlations were detected in the total sum of skinfolds and 1RM bench press at the end of the intervention (Group A: R=-0.851; p=0.015; Group B: R=-0.761; p=0.047). This was also observed in the percentage of fat mass, where a negative correlation was observed between this variable and 1RM bench press (Group A: R=-0.851; p=0.015; Group B: R=-0.761; p=0.047). Similarly, a significant correlation was detected between 1RM squat and 1RM bench press in group B after the intervention (R=0.871; p=0.011).

Lastly, since a significant correlation was detected between fat mass and 1RM bench press, a linear regression analysis was performed. In this sense, 1RM bench press was used as the dependent variable, and percentage of fat mass or total sum of skinfolds as predictors. The results complied with the model both in Group A (R squared=0.670; p= 0.015; Durbin-Watson=1.798) and B (R squared=0.579; p= 0.047; Durbin-Watson=1.809).

Discussion

The results of the study indicates that a 6-week HICT program is an efficient method to improve maximum strength (1RM) as well as body composition in physically active adult males, independently if the training program is performed 2 or 3 days a week.

Positive results were obtained in the intragroup analysis before and after the intervention, with no significant differences among the two experimental groups, while both significantly improved compared to the control group. These results seem to indicate that a frequency of 2 days/week of HICT is sufficient to obtain positive results in physically active adult males. Despite the short duration of the study (6 weeks), significant results were obtained, and were similar to other studies where a 10-week HICT intervention was used[22], who also reported a 4.2% decrease in fat mass. Similarly, another study, analysing males and females in a 3 sessions/week, 5-week intervention[23], also reported a decrease in fat mass, although in this case the training sessions lasted 20 minutes with a ratio of 15 seconds of exercise and 15 seconds of rest, alternating 2 minutes of battle rope with 2 minutes of kettlebell.

Certain authors consider that the changes in body composition observed with this type of training are mainly due to the anaerobic metabolism, due to its intermittent character and high intensity[24]. On the other hand, other authors[3] postulate that the changes could be due to the increased use of fatty acids and caloric expenditure of this type of training. Other possible reasons reported could be due to the increased use of catecholamines[25] or growth hormone[26], which stimulate lipolysis and subsequently the use of subcutaneous or intramuscular fat. During a HICT intervention, the metabolic adaptations of the skeletal muscle favour lipid oxidation. Tremblay and collaborators[27] have demonstrated that high intensity training sessions increase the activity of muscle glycolytic enzymes, reducing subcutaneous fat while increasing the activity of β hydroxyacyl coenzyme A dehydrogenase, which catalyzes a fundamental step of fat oxidation. Boutcher[28] reported an increase in fat oxidation as a method of eliminating lactate and hydrogens and to resynthesize glycogen. In this sense, it is possible that the metabolism during post-exercise recovery could continue burning calories at the same rate as during the actual exercise[29]. Lastly, it is important to note that a nutritional program intervention with no physical exercise does not improve the body composition of physically active adults.

The applied HICT program corresponded to 20-25 seconds of activity, with the same amount of rests, at a 1:1 ratio, similar to that described by Bisciotti[30]. In this sense, a classic intermittent exercise program with a 1/1-1/2 effort/recovery ratio (6 seconds / 10 seconds – 10 seconds / 10 seconds – 20 seconds / 20 seconds – 30 seconds / 30 seconds) was performed. This results in the cardiac frequency to increase during exercise, reaching at least 70% maximum CF, thus considered as high intensity, as described by the American College of Sports Medicine (ACSM)[31]. Due to the short duration of the rests, the recovery was incomplete, causing the pulse rate to be maintained at a plateau[32]. Also, it is important to note that the training program used follows the ACSM recommendations for cardiovascular exercises (20-60 minutes/session, 3-5 sessions per week)[33].

These results indicate that this innovative training method presents certain advantages over other established ones. By using a HICT method while considering training frequency and number of repetitions, the results show that the participants obtain a better physical condition (regarding strength) and body composition, and in a shorter time period than with other training methods.

The study demonstrates that a 6-week HICT program with strength and resistance self-loading significantly improves maximum strength and local muscle resistance. The maximum strength was measured using 1RM tests in bench press and squat, with a 10% and 20% improvement, respectively, in both experimental groups, being these values statistically significant.

In a similar work, Bucley *et al*,[34] compared 2 groups performing a 6-week HICT program, at a frequency of 3 sessions per week. The first group trained by rowing for 30 minutes, while the second group performed a variety of multidisciplinary exercises at intervals, with 18 repetitions and rests lasting 60 seconds, for a total of 30 minutes. As a result, the first group did not significantly improve in any of the strength tests performed (bench press or squat), while the second group improved by 15% their results in 1RM squat, 70% local muscle resistance in squat, and 12% in 1RM bench press. These results coincide with a previous work by McCarthy, which demonstrated that the strength gained in a concurrent training program (including strength and resistance) are achieved at a frequency of 3 sessions per week or less.

In the present study, significant improvements were detected in 1RM bench press and squat only when the groups were compared before and after the intervention, while no significant differences were observed between groups A and B. However, both groups reported significantly better results compared to group C, who did not perform any HICT.

Similarly, a study published by Dorgo *et al*[35] developed an 18-week training program with a group of adolescents, who performed 10-14 repetitions of 3-4 exercises using different materials (medicine ball, elastic bands, rope…), with a brief 20-30 second rest between each exercise. At the end of the intervention, the experimental group reported a 30% improvement in upper body resistance strength, which is similar to the values obtained in the present study. The same authors also detected an 83% increase in upper body maximum strength at the end of the intervention.

The results obtained in the present study can also be at least partially due to the type of exercises included in the HICT program (push-ups, burpee, bastard, Squat), which are very similar to the movements that are used in the strength tests.

Regarding the limitations of the study, it is important to note that this intervention was performed with a small number of volunteers (3 groups: 2 experimental and 1 control, n=7 each), although each participant was thoroughly supervised during the whole study. In this sense, regarding body composition, the authors contemplate in future studies the possibility of including additional anthropometric variables, such as muscle or bone mass. Other additional variables that could be included are body composition by densitometry, and how strength training may affect certain parameters such as bone mineral content or density. As for blood pressure, it is possible that a longer intervention period may be necessary for HICT to significantly alter this parameter.

As for sports practice, additional tools could be considered for future intervention studies, such as the first beat, which can monitor all the weekly sessions and allow the analysis of the variability in cardiac frequency and compare the effects of the training or even the effects of training and/or rests of the sample studied.

In conclusion, a 6-week HICT program combined with an adapted diet plan results in significant improvements in 1RM bench press, squat and body composition, as well as reducing fat mass. This was observed both comparing before and after the intervention as well as compared to the control group, which did not perform any physical activity. However, no significant improvements were detected regarding blood pressure. Similar results were obtained when the program was performed 2 or 3 days a week. Finally, it is important to note that a protein-rich diet by itself, without physical activity, is not sufficient to improve strength or body composition.

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Rating of perceived exertion and physical performance changes after one circuit training session in hypoxia or normoxia

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Received: 08.05.2017
Accepted: 19.09.2017

Summary

The aim of this study was to analyze the rating perceived exertion and physical performance changes after one session of circuit training in hypoxia (FiO_2= 0.16) or normoxia (FiO_2= 0.21). Eleven resistance-trained young male subjects participated in the study. They performed two circuit training session (hypoxia or normoxia) in randomized order. Three days before the first training session, a familiarization and 6RM test session was performed. After 72 hours of rest, the subjects performed the last training session. The circuit training consisted of two blocks of three exercises (Block 1: bench press, deadlift and elbow flexion; Block 2: half-squat, triceps extension, and ankle extension). Each exercise was performed at 6RM. Rest periods lasted for 35 s between exercises, 3 min between sets, and 5 min between blocks. Rating of perceived exertion (RPE) and peak and mean force, velocity, power and acceleration and time to perform peak power and velocity were determined during all the sets half-squat and bench press exercises. No differences were observed in RPE values between hypoxia and normoxia. Moreover, significant differences were observed in the first trial of half squat in peak acceleration (normoxia = 2.9 ± 0.7 m/s^2; hypoxia = 2.2 ± 1.1 m/s^2; p = 0.037) and peak power (normoxia = 1577.1 ± 587.5 W; hypoxia = 1227.2 ± 636.3 W; p = 0.039) between hypoxia and normoxia. In conclusion, these results indicate that simulated hypoxia during circuit training exercise decreases peak power and peak acceleration but maintains rating perceived exertion of the exercise. These differences must be taken into account to avoid an excessive fatigue.

Key words:
Altitude. Resistance training. Hypoxia. Perceived exertion.

Percepción de esfuerzo y cambios en el rendimiento producidos por una sesión de entrenamiento en circuito en hipoxia o normoxiaia

Resumen

El objetivo del presente estudio fue analizar los cambios en el rendimiento de fuerza y en la percepción de esfuerzo (RPE) producidos por una sesión de entrenamiento de fuerza en circuito en hipoxia (FiO_2= 0,16) o normoxia (FiO_2= 0,21). Once deportistas entrenados en fuerza realizaron dos sesiones de entrenamiento en circuito de forma aleatoria en hipoxia o normoxia. Tres días después de una primera sesión de familiarización en la que se determinaron las cargas, se llevó a cabo la primera sesión de entrenamiento. La última sesión se llevó a cabo 72 horas después. La sesión consistió en dos bloques de tres ejercicios (bloque 1: *press* banca, peso muerto y *curl* de bíceps; bloque 2: media sentadilla, *press* francés y extensión de tobillos) realizando 3 series de 6 repeticiones al 6RM con un descanso de 35 segundos entre ejercicio, 3 minutos entre serie y 5 minutos entre bloques. Se analizó la percepción de esfuerzo (RPE) después de cada serie y los valores medios y máximos de velocidad, aceleración, fuerza y potencia, así como los tiempos obtenidos hasta la máxima velocidad y la máxima potencia en media sentadilla y *press* de banca. Los resultados no muestran diferencias significativas en el RPE entre condiciones. Se observan diferencias significativas entre ambas condiciones en la primera serie de sentadilla en la variable aceleración pico (normoxia = 2,9 ± 0,7 m/s^2; hypoxia = 2,2 ± 1,1 m/s^2; p = 0,037) y en la variable potencia pico (normoxia = 1577,1 ± 587,5 W; hypoxia = 1227.2 ± 636,3 W; p = 0,039). En conclusión, la adición de hipoxia a la sesión de entrenamiento de fuerza afecta a la potencia y a la aceleración pico desarrollada en el ejercicio de sentadilla pero no modifica la percepción de esfuerzo que tiene el deportista.

Palabras clave:
Altitud. Entrenamiento de fuerza. Hipoxia. Percepción de esfuerzo.

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Introduction

Training programs aim to improve the physical condition of athletes. To do so, a range of methodologies[1] are used. Trainers and scientists aim to optimise performance by applying the most effective training methods. In this regard, strength training is becoming increasingly important, both for improving performance and for preventing injuries in any sports discipline[1,2].

Circuit training is a popular working method amongst trainers. This method is characterised by the use of low loads with high volumes in order to achieve improvements in performance based on increased strength and muscle adaptations such as muscular strength or the improvement of the cardiovascular system[3]. Specifically, over the last few years, research is being carried out on high resistance circuit training (HRC), which is a training method that uses higher intensities (6 repetitions maximum (RM) with relatively short recovery times (35'') and a greater cardiovascular load than traditional circuits. HRC offers the possibility to work on different types of exercises at a moderate-high intensity of 6-RM with no decrease in muscle power[4]. Therefore this training method offers similar performance effects to other workout methods, while optimising the training time and applying shorter sessions[5].

Hypoxic training is another very common physical training strategy to improve performance in different individual and group sports. This type of training, in hypoxia conditions, causes greater stress on the anaerobic metabolism[6-8]. In this respect, numerous studies on strength training in hypoxia[9-14] are verifying the impact of these metabolic factors and other mechanisms such as greater fibre recruitment, cytokine production or an increase in hormones to improve strength and generate a greater muscle hypertrophic response through an increased muscle cross-sectional area. Together with these studies, which analyse the physiological responses to IHRT training, another variable which is given great consideration in the studies is the participant's perceived exertion[12,15]. In these studies, no differences in perceived exertion have been found between the different training sessions in hypoxia or normoxia, using traditional training sessions: 3-4 sets of 8-12 repetitions at 70% of 1RM.

Focussing on strength performance, prior studies observed no effect of reduced FiO_2 on jump performance[16] following a jump session in hypoxia (FiO_2 = 13.5% and 16.5% *vs*. 20.9%) or the power and strength generated[17] during a bodyweight squat and deadlift workout (5 sets x 5 reps at 80% of 1RM (FiO_2 =13% and 16% *vs*. 20.9%). Moreover, in the sessions used by these authors, they continue to apply traditional training parameters[17] or through jumps[16].

Based on current evidence, circuit strength training, together with a hypoxic environment, could be a good method to improve performance in shorter training sessions. Even so, further investigation is necessary in order to determine the acute effects and the physiological responses produced by training in hypoxia, given the fact that there are no studies in the literature that consider the added effect of the use of circuit training together with the application of low FiO_2. Therefore, this study was directed at analysing the acute effects on strength performance and on the rating of perceived exertion (RPE) produced by a strength circuit training session in either hypoxia (FiO_2=0.16) or normoxia (FiO_2=0,21).

Material and method

Design

A double-blind comparative crossover study was conducted to determine the cause-effect relationship of the dependent variables and the strength training in hypoxia. The participants completed the circuit training under two conditions: normoxia (N) where the fraction of inspired oxygen (FiO_2) was 0.21 (0 m altitude); and hypoxia (H) where the FiO_2 was 0.16 (2,100 m altitude). During both sessions, the participants breathed through a mask connected to a hypoxia generator (GO_2 Altitude hypoxicator, Biomedtech, Australia).

Participants

Eleven men with prior adaptations to strength training (ages: 24.1 ± 3.6 years; height: 176.6 ± 4.2 cm; weight: 71.1 ± 6.4 kg; fat mass: 12.1 ± 1.6%; 6-RM bench press: 57.6 ± 12.5; 6-RM squat: 96.2 ± 21.2 kg). Participants had no muscle injuries and no altitude exposure in the three months prior to the study. The experimental procedures were explained to the subjects and they signed their informed consent. This study was approved by the ethics committee of the Universidad Católica San Antonio (Catholic University of St. Anthony), Murcia.

Procedure

All sessions were held at the laboratory at a controlled temperature of 21 ± 2 ºC over a 3 week period and were conducted at the same time of day. Participants attended for a total of 3 times. On the first day, the 6-RM test was carried out in order to determine the weights for the various exercises to be performed during the training sessions, based on guidelines from prior studies[4]. During this session, participants were also familiarised with the exercises and tests to be made. Furthermore, a body composition analysis was made with a bioimpedance analyser (Tanita BC-601, TanitaCorp, Tokyo, Japan). Following a 3 day rest, the subjects started to perform the first circuit session, randomly in one of the two conditions (normoxia or hypoxia). After a 72 hour recovery, the participants performed the next session in the other condition (third session). The participants in the study were told to maintain a balanced diet for the duration of the study and they were forbidden to consume caffeine or alcohol at least during the 24 hour period prior to each session.

Experimental protocol

Warm-up

Prior to the training session, the participants were familiarised with the face mask, for 10 minutes. The warm-up session then started, consisting in 5' on a 75w exercise bike, following by 5 minutes of active stretching exercises. This was followed by the specific warm-up based on the following sequence: 10 repetitions at 50% of 6-RM for each exercise with 1 minute recovery; 8 repetitions at 75% of 6-RM with a two minute recovery time, and repetitions to failure with a load of 6-RM. The 6-RM load was adjusted approximately by ±2.5% if the subject performed ± 1 repetition, and was adjusted approximately by ± 5% if the subject performed ± 2 repetitions[18]. The eccentric phase of each movement was controlled using a digital metronome, while the concentric phase was performed at the maximum speed possible. The subjects rested for 5 minutes before starting the circuit.

High intensity circuit

The circuit comprises two blocks of three exercises. 3 sets were performed in the first block, which included bench press, deadlift and biceps curl exercises with a 35 second rest between exercises and 3 minutes between sets. Following a 5 minute recovery period, the second block was started, consisting in half squat, French press and ankle extension (with identical recovery times). The subjects were supervised by an experienced lifter to ensure that voluntary fatigue was safely achieved and with strict technical control[19] (Figure 1).

Measurement protocol

After performing each set, the subjective rating of perceived exertion (RPE) of the subject was measured using the Borg 6-20 scale. Prior to this, the functioning and utility of the scale was explained and all subjects had experience using it. Moreover, measurements were taken of the performance values for the bench press exercises (block 1) and the half squat (block 2), in each set, through a linear encoder (Chronojump, Barcelona, Spain) mounted on the bar. The performance variables analysed were: mean and maximum values for speed, acceleration, strength and power, as well as the times obtained up to the maximum speed and the maximum power.

Statistical analysis

The data set was analysed using the SPSS software, a statistical package for Windows (version 20.0: SPSS, Ine. Chicago, Il., USA). A descriptive analysis was made, obtaining mean values and standard deviation. Shapiro-wilk was then used to perform normality tests. A general linear model analysis was performed, and repeated measurements and pair comparisons (Bonferroni Test). For non-parametric variables, we used the Wilcoxon signed rank tests and the Mann-Whitney U test. The statistical significance cut-off was set at $p \leq 0.05$.

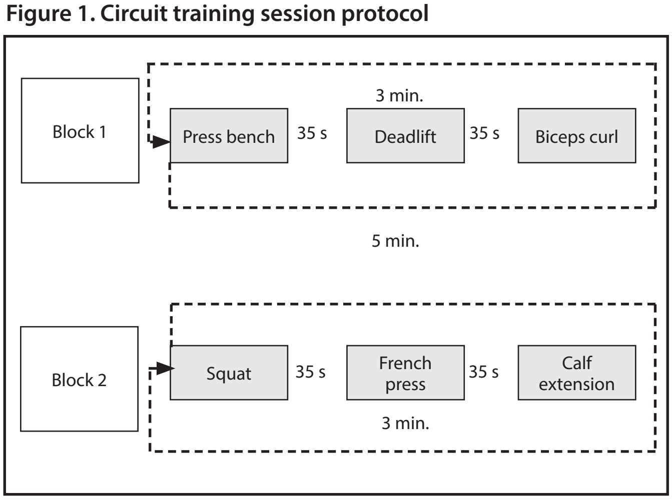
Results

The results shown in Table 1 offer no significant differences in RPE between conditions.

Then, Table 2 shows the mean and peak speed values (m/s), acceleration (m/s^2), strength (N) and power (W) for the press bench and half squat exercises recorded for each set. The time values (s) to reach the power and peak speed can also be observed.

The data show a downward trend in the performance variables for the condition of hypoxia in relation to the condition of normoxia, yet with no statistically significant differences. It is only possible to observe differences between both training conditions in the first squat set for the peak acceleration variable ($p = 0.037$) and the peak power variable ($p = 0.039$).

Figure 1. Circuit training session protocol



Discussion

The primary aim of this study was to analyse the acute effects caused by a circuit strength training session in hypoxia ($FiO_2 = 0.16$) on physical performance variables and the subjective rating of perceived exertion. The main finding of this investigation is that the addition of hypoxia to the strength training session affects the power and the peak acceleration achieved in the squat exercise, yet it does not change the athlete's perceived exertion.

With regard to the RPE variable, our results are in line with the literature that analyses the said variable. Prior studies[12,15,17] observe that there are no differences in the perceived subjective effort, even when the cardiovascular demands are increased. In this study it was possible to observe trends towards greater increases in the variable for perceived exertion following the first HRC block, although with no significant di-

Table 1. Rated perceived exertion values (RPE). Mean (Standard Deviation).

		Block 1			Block 2		
Variable	Condition	Set 1	Set 2	Set 3	Set 1	Set 2	Set 3
RPE	N	10.0 (2.3)	11.0 (1.6)	12.3 (1.7)	10.7 (0.7)	11.5 (1.4)	12.0 (1.7)
	H	11.8 (3.0)	12.4 (2.6)	14.1 (3.8)	12.4 (2.3)	13.7 (3.1)	13.1 (2.6)

RPE: Rating of perceived exertion; N: normoxia; H: hypoxia.

Table 2. Values for the performance variables on the press bench and squats in normoxia and hypoxia. Mean (Standard Deviation).

Variable	Condition	Block 1			Block 2		
		Set 1	Set 2	Set 3	Set 1	Set 2	Set 3
Mean speed (m/s)	N	0.4 (0.1)	0.4 (0.1)	0.3 (0.1)	0.5 (0.1)	0.5 (0.1)	0.4 (0.2)
	H	0.4 (0.2)	0.4 (0.2)	0.3 (0.2)	0.4 (0.1)	0.4 (0.2)	0.3 (0.2)
Mean acceleration (m/s^2)	N	1.4 (0.5)	1.3 (0.3)	1 (0.5)	2.4 (0.8)	2.5 (0.9)	2.4 (1.1)
	H	1.2 (0.7)	1.3 (0.7)	1 (0.9)	1.9 (1)	2.1(1.3)	1.9 (1.1)
Mean strength (N)	N	671.5 (292.8)	638.1 (224.6)	525.9 (226.2)	1587.9 (340.8)	1618.4 (354.1)	1525.8 (560.4)
	H	493.4 (216.4)	501.3 (217.1)	379.7 (287.9)	1354.1 (583.7)	1297.2) (701.7)	1303.6 (700.6)
Mean Power (W)	N	279.3 (118.3)	247.9 (104.4)	180.5 (76.1)	744.3 (230.8)	760.2 (221.4)	728.1 (300.6)
	H	201.1 (89.4)	208.1 (90.3)	159.9 (119.6)	596.4 (280.8)	619.9 (342.2)	599.6 (327.3)
Mean Power (W)	N	0.6 (0.2)	0.6 (0.1)	0.5 (0.2)	0.8 (0.2)	0.9 (0.2)	0.8 (0.3)
	H	0.6 (0.3)	0.6 (0.3)	0.4 (0.4)	0.7 (0.3)	0.7 (0.4)	0.6 (0.4)
Peak acceleration (m/s^2)	N	3.3 (1.5)	3.2 (1.2)	2.5 (1.1)	2.9* (0.7)	3 (0.7)	2.6 (1.1)
	H	2.7 (1.2)	3.2 (1.8)	2.2 (1.8)	2.2* (1.1)	2.3(1.3)	2.1 (1.2)
Peak strength (N)	N	883.2 (360.3)	827.9 (248.1)	673.2 (282.5)	2016.9 (401.3)	2082.8 (449.2)	1926.1 (713.2)
	H	637.2 (270.6)	670.9 (276.1)	497.5 (370.2)	1695.5 (705.1)	1666.1 (887.8)	1656.3 (882.4)
Peak power (W)	N	472.8 (207.1)	404.6 (133.8)	296.6 (119.7)	1577.1* (587.5)	1664.3 (587.8)	1597.6 (670.3)
	H	321.3 (168.5)	335.3 (167.2)	261.1 (209.3)	1227.2*(636.3)	1301.1 (750.1)	1254.8 (726.5)
Time to maximum speed (s)	N	0.7 (0.2)	0.8 (0.2)	0.8 (0.4)	0.5 (0.1)	0.5 (0.1)	0.5 (0.2)
	H	0.7 (0.3)	0.7 (0.3)	0.5 (0.4)	0.5 (0.2)	0.4 (0.2)	0.4 (0.2)
Time to maximum acceleration (s)	N	0.7 (0.2)	0.7 (0.2)	0.8 (0.4)	0.5 (0.2)	0.5 (0.2)	0,4 (0.2)
	H	0.6 (0.3)	0.6 (0.2)	0.5 (0.3)	0.4 (0.2)	0.3 (0.2)	0.3 (0.2)

Block 1: Values of press banca; Block 2: Values of half-squat; *statistically significant differences between H and N $p \leq 0.05$; N: normoxia; H: hypoxia.

fferences. One of the possible reasons for the lower values obtained in the second block could be due to the exercises used and to the greater demand of the exercises in the first block in relation to the second one. Exercises involving a greater number of muscle groups increase oxygen consumption and the muscles' capacity to extract oxygen from blood, causing decreased saturation and an increase in the heart rate[20]. In this respect, in the first block, the exercises used (bench press, deadlift and biceps curl) involve the mobilisation of major muscle groups, while the exercises selected in the second block (half squat, French press and ankle extension) have a lower demand as they only use a single multi-joint exercise. In contrast to these results, other studies do find differences in the RPE between training conditions[21,22]. These contradictory results could be explained by the different training methodology; traditional compared to the high intensity circuit. Therefore, the RPE variable is a good indicator for training in hypoxia, as it provides valuable information on the intensity of the exercise and allows us to control the training load in this environmental condition[23,24].

With regard to the maximum performance values, the results of this study show significant differences in the first half squat set. Prior studies have observed that, in conditions of hypoxia, there is an increase in the concentration of lactate in the blood, the blood pH decreases as does the availability of oxygen[25]. These findings appear to suggest a greater metabolic involvement of anaerobic glycolysis, required to maintain the resynthesis of ATP. So, when the aerobic metabolism is unable to meet the demand for ATP, the breakdown of phosphocreatine and the greater involvement of anaerobic glycolysis help to provide the energy required[26]. On the other hand, the increased metabolic stress and acidosis associated with training in hypoxia[9] together with the short recovery times that we used in the HRC, affect the capacity of the muscles to maintain a balance between ATP utilisation and resynthesis, limiting muscle recovery[27]. This physiological response, as suggested by the studies, could explain this drop in performance observed in our study. However, it is necessary to make an analysis of the said variables, which were not studied in our work. Therefore, the results appear to indicate that the proposed training in hypoxia has a negative impact on the capacity to produce strength peaks in half squats. Therefore, these results should be taken into account when planning strength training in hypoxia, given the fact that muscle power and speed are factors that are modified with hypoxia and this may modify the response to the training[28].

The results obtained in the variables for mean strength, power and acceleration and the times necessary to reach the maximum speed and maximum power show that there are no significant differences between the conditions studied. Even so, the data obtained in the condition of hypoxia tended to be lower than for normoxia. In this respect, our results, despite the clear differences in the tasks proposed between both workouts, appear to be in line with the study by Scott *et al*.[17] who found no significant differences, although they did find lower values in the strength and power variables between hypoxia and normoxia in one session with squat and deadlift exercises with 5 sets of 5 repetitions at 80% of 1RM at 0.16 or 0.13% of FiO_2. This drop in the mean performance variables is associated with an accumulation of products that generates metabolic fatigue and neuromuscular fatigue as well as a drop in phosphocreatine reserves[29]. Moreover, training in hypoxia[30] is also associated with a greater involvement of anaerobic glycolysis which increases the intracellular acidosis and contributes to fatigue[31]. Therefore, the mean performance values for a circuit training session in hypoxia are similar to those for a session in normoxia, which suggests that it can be used without adverse effects and take advantage of the benefits of working in an environment with a low availability of oxygen, which prior studies related to greater muscle hypertrophy[12,15].

This study contributes to the understanding of the acute responses to a circuit training session in hypoxic conditions. It provides evidence as to the potential applicability in endurance sports that use strength training in their training programs. Circuit sessions in hypoxia do not produce the same acute responses in performance variables as the same training under conditions of normoxia. These differences must be taken into account when designing and optimising the training loads. Moreover, it should be borne in mind that the subjects in this study were well-trained athletes and with experience in strength training. Therefore, the results are applicable to athletes seeking to improve their performance in this quality. Due to the high demand for anaerobic glycolysis that this training condition appears to produce, the results of the study can also be applied to team sports players, sprinters or endurance athletes who may want to optimise their strength training sessions so that these are shorter.

To conclude, the results of this study show that a circuit training session in hypoxia ($FiO_2 = 0.16$) does not reduce the mean physical performance of the session or the athlete's perceived exertion, however it does affect the peak acceleration and power achieved during the squat exercise in comparison with the same training in normoxia. It is necessary to continue to investigate strength training in hypoxia and, specifically, circuit training, in order to understand the chronic adaptations in strength, as well as metabolic and morphological adaptations. If the findings of future investigations continue to be in line with our study, then we could be looking at a new strength training methodology, given the fact that it does not reduce the mean physical performance of the session and, on the other hand, the exercise is not perceived as being more intense. Therefore, athletes would benefit from improved performance provided by the medium with the diminished availability of oxygen and in a shorter training time.

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Original article

Effects of acute exposure to high altitude in acclimatized and non-acclimatized professional soccer players

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Received: 12.09.2017
Accepted: 22.09.2017

Summary

Objective: To evaluate the cardiopulmonary response, gases and acid base balance in a cardiorespiratory maximal test applied to professional football players of first division of Bolivia living at low altitude, during the first six hours after arrival to the high altitude of 3,600 meters.

Methods: Eleven Bolivian players living at an altitude of 150 m (lowlanders, LL) and ten highlanders (HL), living at an altitude of 3,600 m, performed the Yo-Yo endurance test with ergospirometry. Base excess (BE), pH, blood gases and capillary blood lactate were determined at 150 m and at 3,600 m seven days later.

Results: VO_2max ($L•min^{-1}$) decreased at 3,600 m in both groups, without differences in slopes or interaction between the factors residence and altitude. In LL (p <.001), 3.52±0.46 *vs* 2.92±0.38. In HL (p <.001), 4.02±0.5 *vs* 3.41±0.45. The distance covered in the test was lower at 3,600 m in both groups: 1358.2±210.6 *vs* 1903.64±202.55 m in LL (p <.001) and 1605.0±281.17 *vs* 2096.0±272.4 m in HL (p <.001). Pre-exercise at 3600 m, LL had a higher pCO_2 (38.3 ± 3.0 *vs* 30.69 ± 1.78 mmHg; p <.001) and a lower $satO_2$ (83.1± 2.7 *vs* 88.1 ± 1.1%; p <.01). Exercise performed at high altitude produced in LL a higher decrement in pH (-0.258 ± 0.06 *vs* -0.206 ± 0.03; p <.05) and in BE (-18.73±2.83 *vs* -12.62±2.13) with no differences in blood lactate (10.8 ± 2.09 *vs* 9.43 ± 2.1 mmol/L for LL and HL, respectively).

Conclusion: During the first six hours at 3,600 m, aerobic performance decrease is similar in LL and HL, although a lower ventilatory response and resting oxygenation of the LL group is found. LL group also showed a greater metabolic acidosis in both altitudes during exercise.

Key words:
Acid-base equilibrium. Physical performance. Hypobaric hypoxia. Soccer players. Acute mountain sickness.

Efectos de la exposición aguda a gran altitud en jugadores profesionales de fútbol aclimatados y no aclimatados

Resumen

Objetivo: Evaluar la respuesta cardiopulmonar, equilibrio ácido base y gases en una prueba cardiopulmonar máxima en futbolistas profesionales de primera división de Bolivia residentes de altitudes bajas, medidos durante las primeras seis horas de llegada a la gran altura de 3.600 m.

Métodos: A once futbolistas bolivianos residentes a 150 m (lowlanders, LL) y diez residentes a 3.600 m (highlanders, HL) se les realizó el Yo-Yo endurance test con ergoespirometría, determinación de pH, exceso de bases (EB), gases y lactato en sangre capilar a 150 m y a 3.600 m una semana después.

Resultados: El VO_2max ($L*min^{-1}$) disminuyó a 3.600 m en ambos grupos estudiados, sin diferencia entre el lugar de residencia y altitud. En LL (p <0,001), 3,52±0,46 *vs* 2,92±0,38. En HL (p <0,001), 4,02±0,5 *vs* 3,41±0,45. La distancia máxima recorrida (metros) fue menor en altura (3.600 m) en ambos grupos, 1.903,64±202,55 *vs* 1.358,2±210,6 (p <0,001) en LL, y 2.096,0±272,4 *vs* 1.605,0±281,17 (p <0,001) en HL. Pre-ejercicio a 3.600 m, los LL tuvieron mayor pCO_2 (38,3±3,0 *vs* 30,69±1,78 mmHg; p <0,001) y menor $satO_2$ (83,1± 2,7 *vs* 88,1 ± 1,1%; p <0,01). El ejercicio en altura generó en LL mayores decrementos de pH (-0,258±0,06 *vs* -0,206±0,03; p <0,05) y de EB (-18,73±2,83 *vs* -12,62±2,13) sin diferencias en lactato sérico (10,8 ± 2,09 *vs* 9,43 ± 2,1 mmol/L para LL y HL respectivamente).

Conclusión: En las primeras seis horas a 3.600 m, la caída del rendimiento aeróbico es similar en LL y HL, a pesar de una menor respuesta ventilatoria y oxigenación en reposo del grupo LL, además en ejercicio se genera una mayor acidosis metabólica en LL en ambas alturas.

Palabras clave:
Equilibrio ácido-base. Rendimiento físico. Hipoxia hipobárica. Jugadores de fútbol. Mal agudo de montaña.

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Introduction

Playing soccer (football) at high altitudes is an interesting scientific, sports and logistics challenge for sea-level teams. Thus, consideration has been given both to health risks and impaired physical performance and to the root causes of the disadvantage of competing in these conditions[1-4]. Despite this, the FIFA (Fédération Internationale de Football Association) has raised the point that there is still insufficient information on this matter, particularly for altitudes of more than 3,000 m[5-7].

In 2000, Brutsaert *et al*[8] studied the cardiopulmonary and metabolic response to exercise of altitude acclimatized professional players (or highlanders; HL) and non-altitude acclimatized players from near sea level (or *lowlanders*; LL) measured after a 48-hour stay at 3,600 m. At the end of the cardiopulmonary effort, both teams showed increased oxygen ventilatory equivalents (VE/VO_2), high concentrations of blood lactate and low oxygen arterial saturation levels (SaO_2), with no differences between LL and HL. Moreover, both groups had lower VO_2max values in relation to measurements taken at 430 m, with a greater effect observed in the LL, indicating that this group is at a physiological disadvantage with regard to the acclimatized players[8]. Recently, similar results were reported for non-altitude acclimatized young soccer players[2,9].

Regardless of the acclimatization strategy, the lower atmospheric pressure causes a reduction in the alveolar (PAO_2) and arterial (PaO_2) oxygen pressures and also in the arterial oxygen content (CaO_2), thereby reducing aerobic performance in relation to sea level[10]. Therefore, hypobaric hypoxia increases the ventilatory response regulating PaO_2, while the CaO_2 is determined by the displacement of the haemoglobin dissociation curve[11] and particularly by the concentration of haemoglobin. Consequently, changes in the blood volume and in the erythropoietic response will directly affect the CaO_2[12,13]. For its part, the hyperventilation characteristic of hypoxia reduces the CO_2 arterial pressure ($PaCO_2$), which subsequently involves the restoration of the acid-base balance (ABB) through the renal excretion of bicarbonate[14-17]. The mentioned changes form part of altitude acclimatization and require approximately 2 to 3 weeks to adapt[18,19], thereby creating considerable logistics problems for their implementation in sports competitions. In view of this problem, many teams choose to arrive, play and return on the same day as the high altitude match, a strategy termed *"fly-in, fly-out"* [1] or playing in "immediate acute hypoxia" (IAH). The main justification for the use of this strategy is to avoid the symptoms of "acute mountain sickness" which appear from 6 hours onwards, with a peak between 24 and 48 hours, in view of the associated performance impairment[15,19,20]. Taking an empirical approach, a number of clubs and national teams in South America have used this strategy. However, there is no scientific information on this subject with regard to professional soccer players. Therefore, the aim of this study is to ascertain the effects of exposure to IAH at a high altitude (3,600 m) on the maximal cardiopulmonary response, the ABB and the capillary blood gases in high altitude acclimatized and non-acclimatized professional soccer players.

Material and method

Subjects

21 professional soccer players from two Bolivian first division teams took part in the study. One team came from a low altitude and was non-altitude acclimatized (n = 11, Trinidad, Bolivia, 150 m), named *lowlanders* (LL) while the other team comprised altitude acclimatized subjects, having remained for at least six months at a high altitude (n =10, La Paz, Bolivia, 3,600 m) named *highlanders* (HL). None of the subjects of the HL group were native to the highlands, however all had been permanent residents at high altitude for a minimum acclimatization period of 6 months. All the subjects taking part in the study were professional players and were also members of their respective teams, with daily training sessions and soccer matches over the weekends. All the subjects involved had at least 5 years of systematic training. Table 1 summarises the characteristics of the sample. All the subjects were informed of the tests to be made and gave their written consent to voluntarily take part in the study. The study protocols were designed following the guidelines of the Declaration of Helsinki.

Protocol

The assessments were conducted during the first division national championship of Bolivia. Initially both teams were assessed at low altitude (150 m). One day after this measurement, the HL team returned to a high altitude, to be measured six days later in this condition. The LL team travelled to the high altitude one week after the first measurement and, after a 60 minute journey by plane, they went immediately to the Hernando Siles soccer stadium (3,600 m). Less than 6 hours (3 to 5 hours of IAH) elapsed between the players' exposure to high altitude and the assessment. Figure 1 shows the implementation of the measurements.

Procedure

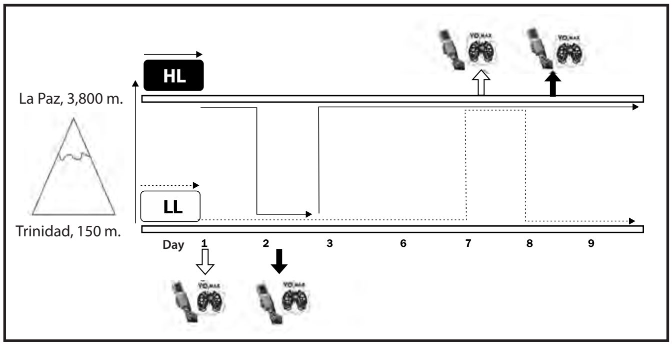
On the day of the assessments, early in the morning, the *Yo-Yo Endurance Test* (YYET)[21] was conducted. This maximum effort field test was used to make the cardiopulmonary assessment. Each player performed the test wearing an ergospirometric device to record the cardiopulmonary changes. At rest (pre-exercise), and at the end of the

Table 1. Anthropometric data, age and time spent at altitude.

	***Lowlanders* (n=11)**	***Highlanders* (n=10)**
Age (years)	21.8±3.4	25.2±3.2*
Height (cm)	172.7±0.07	174.6±0.05
Body mass (kg)	68.6±9.7	72.2±6.3
BMI kg/m²	22.9±2.1	23.7±1.6
Time spent at altitude (months)	0	24.9±32.6*

The data are presented as means ± SD. (*) p<0.05.

Figure 1. Description of the experiment.



The lines represent the travel between 150 and 3,600 m during the experiment. Dotted line for LL and a solid line for HL. The arrows show the measurement times, white for LL and black for HL. Lowlanders (LL), highlanders (HL)

test, during the first 30s of recovery (post-exercise), a capillary blood sample was taken and then used to make the ABB and gas measurements.

YYET field test

The YYET endurance level 1 was used[21-23], with the direct and simultaneous determination of the cardiopulmonary function. The test was conducted on a natural turf soccer field, and with soccer boots. The test is a continuous progressive test, starting at low speeds and with running speed increments of 0.5 km/h per minute in order to achieve the maximal cardiopulmonary effort. The physical performance of each subject was obtained as the maximum distance achieved in the YYET.

The players did not perform any demanding exercise during the 48 hours prior to the YYET test. Before starting the test, they performed a 10 minute warm-up, jogging at 6-8 km/h, as well as joint flexibility and mobility exercises.

Measurement of the cardiorespiratory parameters

To rate the maximal cardiopulmonary response, a portable Metamax 3B (Cortex, Germany) unit was used. This was calibrated before each measurement using factory gases and ambient air for the analysers and a 3 litre certified syringe for the calibration of the flow meter. Likewise, the barometric pressure was recorded.

The achievement of a VO_2max plateau was taken as the criterion for maximal cardiopulmonary effort. In the event of no plateau, then the test was considered valid when 2 of the following criteria were met: 1) an RER ≥1.15; 2) reach at least 95% of the maximal theoretical HR (220 – age); 3) blood lactate concentration of more than 8 mmol/L[24]. The subjects were motivated to achieve the maximal cardiopulmonary effort. At the final stage of the YYET, the maximal uptake of oxygen (VO_2max), maximal pulmonary ventilation (VEmax) and the maximal ventilatory equivalent for oxygen (VE/VO_2max) were obtained. These cardiopulmonary parameters were obtained breath by breath and were subsequently exported to an Excel worksheet at 15 second intervals. The maximum values were determined as those pertaining to the interval in which VO_2max was obtained

Measurement of capillary blood gases and ABB

The ABB and gases were measured in rest conditions (5 minutes sitting down) before starting the warm-up (pre-exercise) and in the 30 seconds following the end of the maximal cardiopulmonary effort (post-exercise). Measurements were made of the pH and the pCO_2 and calculations were made of the HCO_3-, base excess (BE) and SaO_2 in 100 µL of arterialized capillary blood obtained by ear lobe puncture. The samples were analysed with an I-Stat (Abbot, USA) portable unit using specific cartridges (CG4)[25,26]. The concentration of lactate in the blood was determined by a 5 µL blood sample also drawn from the same ear lobe and using a portable analyser (Lactate Pro1, Arkray, Japan).

Statistical analysis

The normality of the distributions was evaluated with the Saphiro-Wilk Test while the homogeneity of variance was determined with the Levene test. As a hypothesis contrast test, a factorial ANOVA was used, considering the principal factors to be the permanent place of residence of the athletes (*Lowlanders* or *Highlanders*) and the place of measurement (altitude of 150 or 3,600 metres). Whenever any significant differences were found in any of the principal factors, the Bonferroni post-hoc test was used. The correlations were analysed through the Pearson test. For all the tests described, a p value of less than 0.05 was used as the cut-off for significance. All the data are presented as mean and standard deviation.

The analysis was performed using the GraphPad Prism 6.0 statistical program.

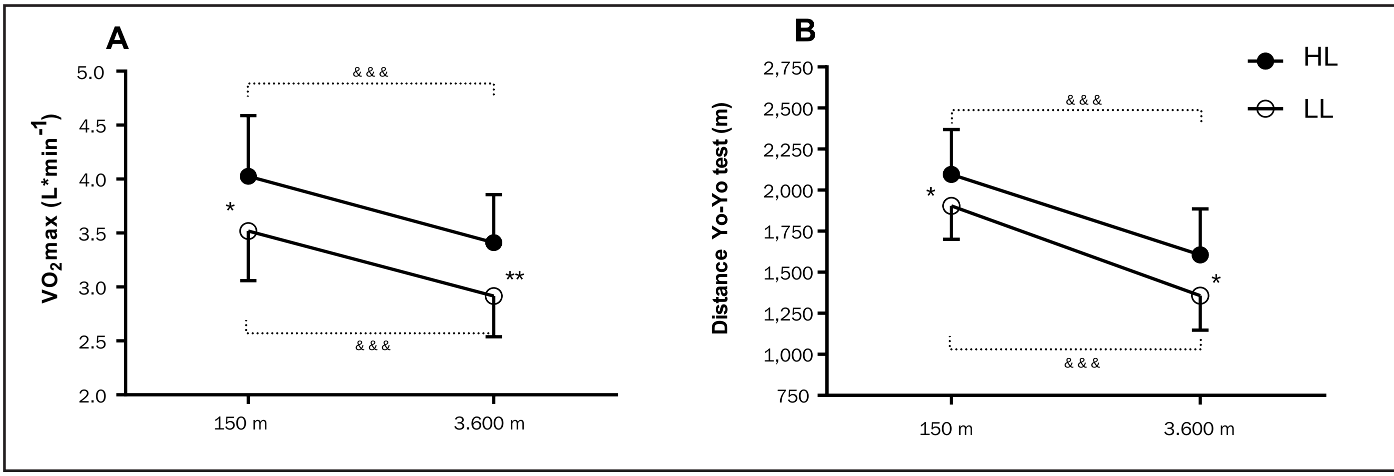
Results

Physical performance

With regard to the physical performance, a reduction in absolute VO_2max ($L*min^{-1}$) was observed at altitude for both groups. For LL this parameter decreased from 3.52 ± 0.46 to 2.92 ± 0.38 $L*min^{-1}$ ($p < 0.001$) while for HL it decreased from 4.02 ± 0.5 to 3.41 ± 0.45 $L*min^{-1}$ ($p < 0.001$) (Figure 2A). Likewise, for the LL, the relative VO_2max ($ml*min^{-1}*Kg^{-1}$) decreased with altitude from 51.48 ± 3.92 to 42.77 ± 3.67 ($p < 0.001$) while, for HL, it decreased from 55.65 ± 4.47 to 47.76 ± 3.53 ($p < 0.001$). For the distance travelled (meters) in the YYET, a decrease in measurements at altitude was also observed, from 1,903.64±202.55 to1,358.2±210.6 m ($p < 0.001$) in the LL group and from 2,096.0±272.4 to 1,605.0±281.17 m ($p < 0.001$) in the HL group (Figure 2B). For both parameters, the LL group showed lower values than the HL group, at 150 m and 3,600 m alike.

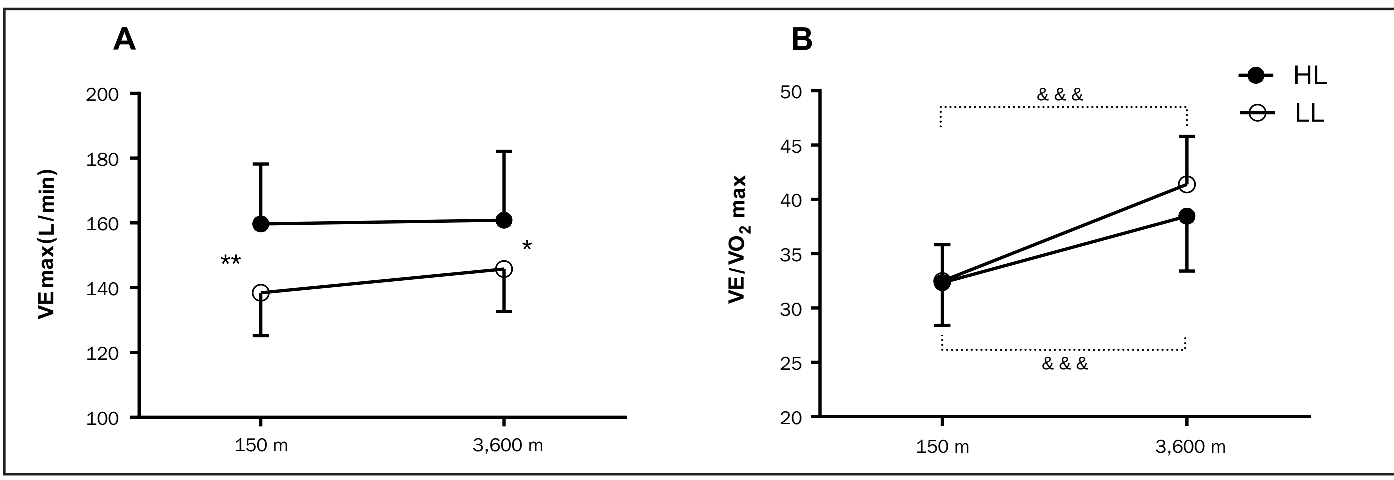
VEmax (L/min) showed no variation ($p = 0.42$) due to altitude change for either group (138.44 ± 13.23 *vs.* 145.83 ± 13.08 for LL and 159.72 ± 18.51 *vs*. 160.84 ± 21.32 for HL) (Figure 3A). The HL group showed higher values for VE both at 150 m ($p < 0.01$) and at 3,600 m ($p < 0.05$). With regard to VE/VO_2max (Figure 3B), this increased from 32.49 ± 3.34 to 41.39 ± 4.41 ($p < 0.001$) for LL, and from 32.35 ± 3.95 to 38.47 ± 5.03

Figure 2. Absolute VO_2max (A) and maximum distance Yo-Yo Test (B) measured at 150 m and 3,600 m in soccer players, *lowlanders* (LL) and *highlanders* (HL). The values are presented as means ± SD.



*Differences between groups at the same altitude: *p <0.05; **p <0.01. (&) Differences between 3,600 m and 150 m: (&&&) p <0.001.

Figure 3. Maximal ventilation (VE max) (A) and maximal ventilatory equivalent of oxygen (VE/VO_2max) (B) measured at 150 m and 3,600 m in soccer players: *lowlanders* (LL) and *highlanders* (HL). The points represent the means ± SD.



*Differences between groups at the same altitude: *p<0.05; **p<0.01. (&) Differences between 3,600 m and 150 m: (&&&) p <0.001.

(p <0.001) for HL, when comparing 150 m with 3,600 m respectively. No differences were found between groups at the same altitude (p = 0.25).

Pre-exercise ABB

Table 2 shows the data for the ABB and gases. With regard to the pre-exercise ABB, the pH did not change for the LL group, however it did increase for the HL group at 3,600 m (p< 0.01). HCO_3-did not change in either group at 3,600 m (p = 0.76) but higher values were found for LL subjects at both 150 m (p <0.001) and at 3,600 m (p <0.001). The pCO_2 (Figure 4A) decreased in altitude for the HL group (p <0.001) with lower values for the HL team at both 150 m (p <0.001) and 3,600 m (p <0.001). The BE (Table 2) did not change with altitude for either team (p = 0.44). However, the HL group showed the lowest values compared to LL, at both 150 m (p <0.001) and 3,600 m (p <0.001). Lactate increased at 3,600 m for LL (p <0.01) and HL (p <0.05), finding higher lactate at 3,600 m for LL compared to HL (p <0.05). Finally, with regard to SaO_2 (Figure 4B) altitude had a different effect on the LL and HL groups. Thus, at 150 m, there is no difference between the groups, decreasing in altitude for both cases (p <0.001) yet with a greater value for the HL group (88.1 ± 1.1 *vs*. 83.1± 2.7; p <0.01).

Post-exercise ABB

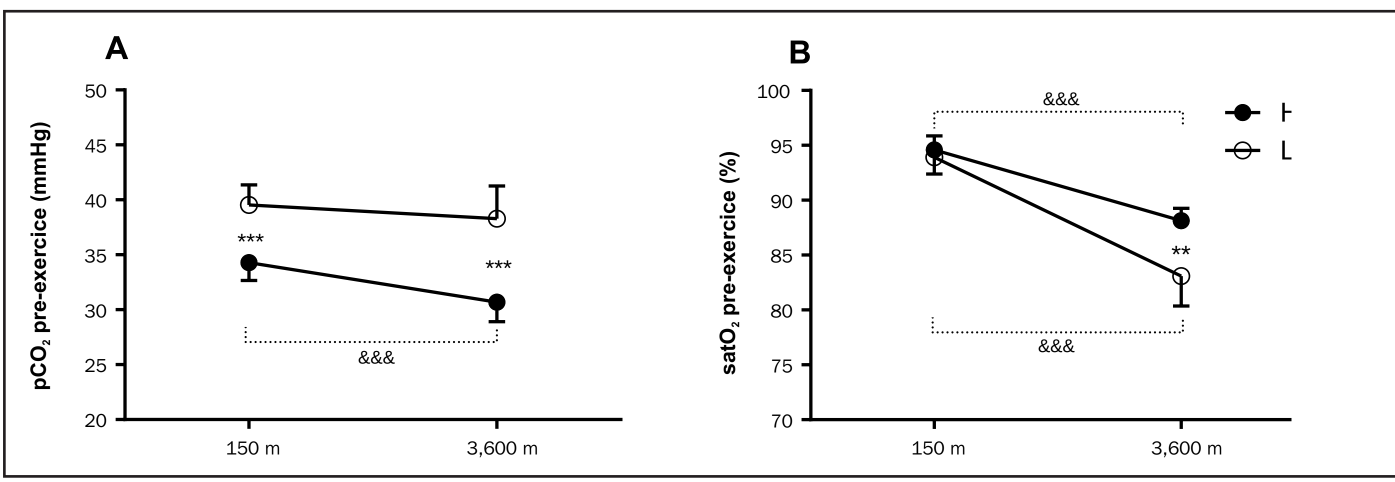
With regard to the post-exercise ABB parameters, it was found that the pH did not change at 3,600 m in either group, with the HL group showing higher values at both 150 m (p <0.05) and 3,600 m (p <0.01).

Table 2. Acid-base balance and capillary blood gases pre and post maximal exercise, in professional soccer players, measured at altitudes of 150 m and 3,600 m.

	Lowlanders (n=11)		Highlanders (n=10)	
	150 m	3,600 m	150 m	3,600 m
pH pre	7.425±0.02	7.440±0.03	7.416±0.01	7.454±0.02b
pH post	7.192±0.05	7.182±0.05	7.230±0.04*	7.248±0.04**
ΔpH -0.234±0.05	-0.258±0.06	-0.185±0.04*	-0.206±0.03*	
HCO3- pre (mmol/L)	25.93±0.74	26.07±2.25	22.01±0.97***	21.59±1.49***
HCO3- post (mmol/L)	14.05±1.80	11.53±1.92[b]	13.95±1.87	12.15±1.38
Δ HCO3- (mmol/L)	-11.93±2.25	-14.55±2.15[b]	-8.1±1.73***	-9.44±1.78***
pCO2 pre (mmHg)	39.5±1.83	38.3±3.0	34.3±1.62***	30.69±1.78 [***,c]
pCO2 post (mmHg)	36.6±4.5	30.5±2.8[b]	33.1±2.25*	27.65±2.64 [*,c]
Δ pCO2 (mmHg)	-2.9±4.7	-7.8±2.4[b]	-1.2±2.38	-3.0±2.57***
BE pre (mmol/L)	1.64±0.92	2.09±2.47	-2.60±1.17***	-2.25±1.39***
BE post (mmol/L)	-14.10±2.33	-16.64±2.77[a]	-13.5±2.64	-14.88±2.42
Δ BE (mmol/L)	-15.8±2.86	-18.73±2.83[b]	-10.9±2.38***	-12.62±2.13***
Lactate pre (mmol/L)	1.89±0.48	2.87±0.81[b]	1.64±0.53	2.1±0.46[*,a]
Lactate post (mmol/L)	11.7±1.93	13.72±2.40[b]	10.7±1.85	11.53±2.12*
Δ Lactate (mmol/L)	9.76±1.82	10.8±2.09	9.06±1.88	9.43±2.1

The absolute changes (Δ) were calculated as the post-pre exercise values. The values are presented as a mean ± SD.
(*)Differences between groups at the same altitude: (*) p (a, b and c). Differences between 3,600 m and 150 m: (a) p<0.05; (b) p<0.01; (c) p<0.001.

Figure 4. pCO_2 (A) and SaO_2 (B) pre-exercise, measured at 150 m and 3600 m in soccer players: *lowlanders* (LL) and *highlanders* (HL). The points represent the mean ± SD.



*Differences between groups at the same altitude: **p<0.01; ***p<0.001. (&) Differences between 3,600 m and 150 m: (&&&) p <0.001.

With regard to post-exercise HCO_3- a lower concentration was found at 3,600 m for both the LL subjects (p<0.01) and for the HL subjects (p <0.05) with no differences between both groups (p = 0.66). The post-exercise pCO_2 also decreased at 3,600 m for the LL group (p <0.01) and HL group (p <0.001) with lower values for the HL group at both altitudes (p <0.05). The post-exercise BE only decreased significantly for the LL subjects at 3,600 m (p <0.05) with no changes found in the HL group (p = 0.16). Finally, the post-exercise lactate only increased in the LL subjects at 3,600 m (p <0.01) while lower values were found for the HL group at altitude (p <0.05).

Absolute changes in ABB per exercise

As can be observed in Table 2, the decreases in the pH, HCO3-, BE and pCO_2 after exercise were greater for the LL group at both altitudes. The increase in Lactate showed no differences within the groups, or comparing one group with another.

Correlations and regression analysis

At rest, we found a negative correlation (r = -0.85 p <0.001) between SaO_2 and pCO_2 for LL and HL measured at 3,600 m (Figure 5). For LL, we

Figure 5. Ratio between the absolute values of SaO_2 (%) and pCO_2 (mmHg) in capillary blood, pre-exercise in soccer players: *lowlanders* (LL, n=11) and *highlanders* (HL, n=8) measured at La Paz (Bolivia) at 3,600 m.

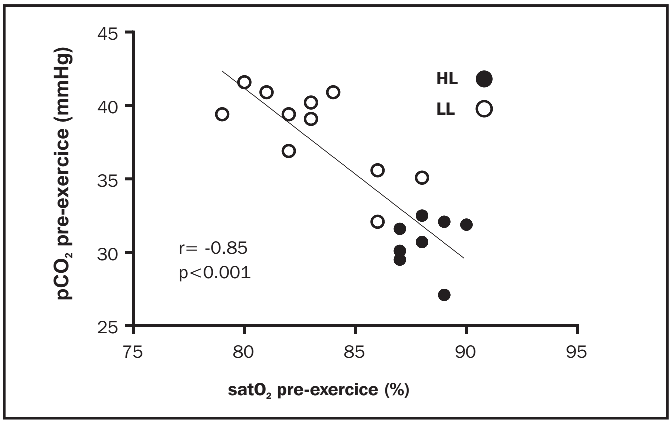
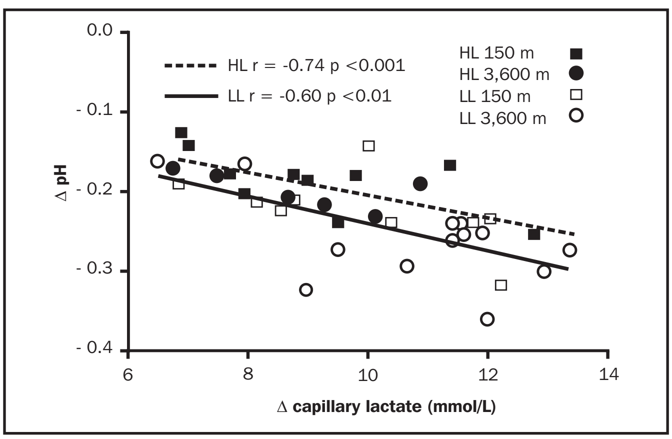


Figure 6. Ratio between the absolute changes in lactate and pH in capillary blood (Δ = post – pre exercise) in soccer players: lowlanders (LL) and highlanders (HL). The dotted line corresponds to the HL (n=11) and the solid line to the LL (n=8).



found a greater pCO_2 and lower SaO_2, while the HL subjects showed a lower pCO_2 and greater SaO_2.

Finally, Figure 6 shows two different straight lines for LL (r =-0.60 p <0.01) and HL (r = -0.74 p <0.001) when relating the lactate increases with the pH increases.

Discussion

Physical performance

As far as we are aware, this work is the first assessment to be made on the effect of IAH on professional soccer players. The most important finding in the study was the reduction of VO_2max at altitude and the reduction in the maximum distance for YYET for HL and LL subjects alike. This suggests that the effect of exposure under an IAH condition would equally affect the physical and cardiopulmonary performance of altitude acclimatised and non-altitude acclimatised subjects alike.

The results of Brutsaert[8], obtained at La Paz with professional soccer players after 48 hours of exposure, are in keeping with our own results, in that both groups show a reduction in VO_2max. However, in Brutsaert's study, the reduction is greater in LL subjects than HL ones (-20% and -13% respectively). In our results, this reduction in VO_2max is similar (-17% and -15% respectively), which is certainly due to the duration of exposure and allows us to affirm that acute exposure to hypoxia in the first 6 hours equally affects the performance of LL and HL. However, when this exposure is extended to 48 hours, it affects the LL subjects to a greater extent.

Our study shows an increase in VE/VO_2max at altitude with no apparent differential effect of this medium on either group, which is in line with other studies[8,27]. The greater VE/VO_2max at altitude is rather the result of the reduction in VO_2max, as no changes were found in the VEmax between 150 m and 3,600 m for either group.

Pre-exercise ABB and $satO_2$

The reduction in pCO_2 at rest in the HL group at 3,600 m (Figure 4A) suggests a greater ventilatory response which is related to greater SaO_2 at altitude, as shown in Figure 5. One possible explanation is that the LL group takes longer to adequately activate the hyperventilation mechanism that is characteristic of hypobaric hypoxia[15,28]. Hyperventilation offers the advantage of increasing the availability of oxygen, in accordance with the alveolar gas equation, but it also has the disadvantage of causing respiratory alkalosis[28] with contradictory effects on performance[28,29]. For its part, alkalosis causes a displacement of the haemoglobin dissociation curve to the left (the opposite to the Bhor effect), increasing the affinity of haemoglobin for O_2[14,28] and is associated with "acute mountain sickness"[19,30,31]. This situation has previously been reported for soccer players acutely exposed to altitude (a stay of 2 to 3 days) producing general discomfort and dyspnoea, affecting performance[32].

The results of ABB at rest, summarised in Table 2, indicate that there are no changes in the pH and HCO_3- for group LL at 3,600 m. Similar findings have been found for young non-professional players also exposed to IAH[20]. For their part, the changes observed in the HL players (Table 2) suggest a respiratory alkalosis compensated by the renal excretion of HCO_3-, a situation that is characteristic of subjects acclimatised to altitude[14,15,17]. Therefore, HL subjects achieve a greater hyperventilation at rest with greater SaO_2 and with a slight alteration of the pH, in contrast to the LL subjects who, probably due to the limited time of exposure to hypoxia, do not change their ABB, achieving a lower ventilatory response and lower SaO_2.

Post-exercise maximal ABB

In relation to physical exercise, the absolute changes in pH are greater for the LL group at both altitudes, implying greater metabolic acidosis or else a lower buffer capacity in this group (Table 2). The same behaviour is observed for HL players at both altitudes, yet less intense.

The acute exposure time to the new altitude conditions makes it impossible to completely compensate the ABB for both groups. Therefore, the acute modifications per exercise are similar to those found in their normal native environment (Figure 6).

The lactate at rest is greater at a high altitude for both groups, with the greatest change experienced by the LL subjects (Table 2). The post-exercise lactate is greater for the LL subjects at 3,600 m. However, when comparing the absolute changes for lactate, no differences were found. Although the correct interpretation of lactate is complex in these conditions[33], this response is consistent with the modifications observed in the pH as shown in Figure 6, where it appears that acclimatization generates less acidosis per exercise for the same change of lactate.

We know that a condition of metabolic acidosis makes it possible to increase the availability of tissue-level oxygen during exercise, due to the Bhor effect, in both normoxia and hypoxia[34,35], although this situation has recently been questioned with high intensity exercise in hypoxia[36]. On the other hand, there is evidence that, under normoxia conditions, metabolic alkalosis (by oral administration of bicarbonate) causes a reduction in VO_2max and physical performance[37]. In this present study, under IAH conditions, the LL players would achieve greater post-exercise metabolic acidosis, which could favour a greater availability of oxygen at the muscle level, which could compensate for the considerable decrease in PAO_2 due to hypoxia.

In conclusion, the present findings make it possible to consider exposure to IAH as a reasonable physiological strategy to address high altitudes in sports such as soccer (which do not allow for long acclimatization periods) given the fact that the decrease in aerobic performance is similar in LL and HL, therefore creating no disadvantages for players coming from lower altitudes.

Acknowledgements

To the Bolivian Football Federation and, in particular, to Ivo Eterovic, the doctor for the Bolivian Football Team, who undertook to coordinate the respective teams and their technical staff.

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Original article

Relationship between anthropometric and metabolic parameters in schoolchildren at state primary schools in Extremadura

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Received: 27.06.2017
Accepted: 16.10.2017

Summary

Currently, obesity is one of the main problems in our society. It is a considerable origin of cardiovascular disseises. It is important to treat this problem from childhood with the aim to prevent higher problems in the future. Therefore, the present study aimed to analyse the overweight and obesity in schoolchildren from Extremadura and describe their anthropometric and metabolic characteristics by gender. 233 participants (between 9 and 12 years old) took part in this study. They were schoolchildren from public schools in Extremadura (Spain). They were classified by their body mass index (normal weight, overweight and obesity). Anthropometric parameters and blood metabolic parameters were obtained. The 18% of the subjects participating in the study were classified as overweight and obese. Boys and girls with overweight and obesity presented higher levels of body fat, although no statistically significant differences were found in blood parameters. The prevalence of overweight and obesity was lower than in previous studies with similar population and carried out in Spain. The school children with overweight and obesity have higher levels of body fat, although the blood parameters analysed (glucose, triglycerides and cholesterol) are within a normal range, which would indicate that during childhood those blood parameters could be influenced by other factors do not associated to the obesity and BMI.

Key words:
Obesity. Cholesterol. Glucose. Triglycerides. Adipose tissue.

Relación entre parámetros antropométricos y metabólicos en estudiantes de colegios públicos extremeños

Resumen

La obesidad continúa siendo una de las principales preocupaciones en la actualidad, suponiendo un importante desencadenante de enfermedades cardiovasculares. Es importante abordar este problema desde la infancia con el fin de evitar problemas futuros mayores. Es por ello que en el presente estudio se ha pretendido analizar el sobrepeso y la obesidad en escolares extremeños y describir sus características antropométricas y metabólicas por sexo. Participaron 233 sujetos (9 - 12 años) pertenecientes a centros de primaria de Extremadura (España). Se clasificaron en función del índice de masa corporal (normopeso, sobrepeso y obesidad). Se obtuvieron medidas antropométricas y parámetros metabólicos en sangre. El 18% de los sujetos participantes en el estudio fueron clasificados como escolares con sobrepeso y obesidad. Los niños y niñas con sobrepeso y obesidad presentaron mayores niveles de grasa corporal, aunque no se encontraron diferencias estadísticamente significativas en los parámetros sanguíneos. La prevalencia de sobrepeso y obesidad fue menor a la de estudios previos con poblaciones similares llevados a cabo en España. Los niños y niñas cuyo IMC denota sobrepeso y obesidad presentan mayores niveles de grasa corporal, aunque sus parámetros sanguíneos analizados (glucosa, triglicéridos y colesterol) se encuentran dentro de un rango normal, lo que indicaría que durante la infancia dichos parámetros sanguíneos podrían estar influenciados por otros factores no asociados a la obesidad y al IMC.

Palabras clave:
Obesidad. Colesterol. Glucosa. Triglicéridos. Grasa corporal.

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Introduction

Over the last few decades, obesity has become a major epidemic and is currently a serious public health issue with a tendency to worsen, in children and adults alike[1-5]. This epidemic causes a reduction in the quality of life of the population and leads to a wide range of health problems[6,7], affecting the well-being of individuals, causing disorders such as high blood pressure, diabetes mellitus type 2[8,9] and heart diseases that could put their lives at risk. Obesity is considered to be a metabolic syndrome risk factor[10], contributing to a reduction in average life expectancy[11], and to a decline in the physical ability to perform motor tasks[12].

Obesity is the fifth most common risk factor for death in the world[13] and its prevalence has rapidly increased in the last few years, causing alarm amongst public health agencies, general practitioners, healthcare investigators and the public in general[14,15]. According to a study by Sánchez-Cruz[16], 45% of Spanish schoolchildren between 8 and 13 years old are overweight. Studies conducted at a European level report the existence of 21.2% of overweight-obesity in Spanish children under 10 years of age, observing 18.7% in boys compared to 23.9% in girls, and with one of the top positions of the obesity ranking in Europe[17]. A recent investigation compared Spanish children to Swedish children, observing greater overweight-obesity prevalence in the former compared to the Scandinavian ones[18]. In this respect, a number of studies have been conducted in Spanish schools in order to analyse the prevalence of childhood and youth obesity, showing that close on 30% of Spanish pre-teens are overweight-obese[19].

Of the overweight and obesity-related metabolic disorders present in childhood, particular mention should be made of the high levels of fasting glucose and alterations in the lipid profile[20,21]. In a study conducted on 1,275 children from four provinces in Spain, it was observed that a high percentage of children exceeded the recommended concentrations of total cholesterol and low density lipoprotein cholesterol[22]. These metabolic disorders during childhood could contribute to the development of coronary disease during adult life[23-25]. However, it is not very clear when this association between obesity and risk factors (glucose and lipid profile) is exactly established, or the influence of age[26].

For these reasons, a national multifactorial (nutrition, physical activity and obesity prevention) strategy was implemented in Spain, in which children and their families are the main stakeholders[27]. On the one hand, with regard to physical exercise, a connection between a high level of sedentary behaviour and a high cardiovascular risk factor was observed in Spanish teenagers[28], recommending vigorous physical activity as opposed to low-intensity physical activity for these young people[29]. On the other hand, with regard to food intake, of particular relevance was the contribution by the enKid study[30] which looked at the eating habits of a large sample of Spanish youths. Once the situation in Spain as a whole has been examined, primarily focussing on the school stage, this study had two objectives: (1) To determine the prevalence of overweight and obesity and (2) to determine the anthropometric and metabolic characteristics in a sample of schoolchildren from Extremadura.

Material and method

Participants

The study was conducted on a population of schoolchildren with ages ranging from 9 to 12 years. This population came from five state Primary Schools, selected according to their location, seeking the greatest representativeness of the sample through a purposive sampling approach, both for rural communities (<10,000 inhabitants) and town and cities (>10,000 inhabitants) in the autonomous community. At each participating school, the sample was randomly selected by clusters (school years). Thus, surveys were conducted at schools located in the south, east, centre and north of Extremadura, achieving a sample of 233 subjects (116 boys and 117 girls).

Participation in the study included all those children whose parents had authorised the survey. The parents and their children were previously informed of the purpose of the study and the nature of the tests to be made, through a written document, and they were given the opportunity to ask any appropriate questions. The investigation was conducted in accordance with the provisions of the Helsinki Declaration and respecting at all times the human rights of the participants in the study. The investigation was approved by the bioethics committee of the University of Extremadura.

Procedure

Each boy and girl was individually measured in a suitable room at the school. All the measurements were made with calibrated equipment, by investigators previously trained at the laboratory. The training process consisted in performing a total of 3 sessions of anthropometric measurements in different population groups, in which they achieved Cohen's Kappa intra-observer values of more than 0.81.

The following data were collected: personal (age, sex and date of birth), anthropometric (weight, height, waist and hip measurements, body fat amount and fat percentage), and haematological (concentration of glucose, cholesterol and triglycerides).

Classification based on the body mass index

The participants were classified according to their BMI, based on the growth tables provided by the Institute for research into growth and development of the Faustino Orbegozo Foundation[31], establishing a distinct BMI according to age and gender. This BMI was then used to determine which individuals were overweight or obese. In this way, the sample was divided into normal weight, overweight or obese, based on the BMI calculated. For the male gender, the BMI threshold, by age, for overweight and obese individuals is as follows: 9 years (20 and 21.8 kg/m^2), 10 years (21 and 22.6 kg/m^2), 11 years (21.7 and 23.6 kg/m^2) and 12 years (22.4 and 24.4 kg/m^2). For the female gender, the BMI threshold, by age, for overweight and obese persons, respectively, is as follows: 9 years (21 and 23 kg/m^2), 10 years (21.8 and 24 kg/m^2), 11 years (22.4 and 24.6 kg/m^2) and 12 years (22.9 and 25 kg/m^2).

Evaluation

The participants went to their school on an empty stomach. The evaluations were made at the school in the early morning. For the exploratory and descriptive analysis of the sample, the following measurements were taken:

– Anthropometric measurements, based on the international standards for the anthropometric assessment of the ISAK[32]:
– *Height and weight* (SECA 214 Measuring Rod). These values were used to calculate the body mass index (BMI) and the weight/height ratio^2 (Kg/m^2).
– *Waist/hip ratio*. To measure the waist to hip ratio (WHR), the participants were told to stand upright and relaxed, with both feet together on a flat surface. The waist perimeter, measured with a tape measure (Seca 201 tape measure) was defined as the smallest horizontal circumference between the rib cage and the iliac crests at the end of a normal exhalation. The hip circumference was measured at the gluteal prominence. The mean value of the two measurements was obtained. However, whenever there was a difference of more than 1 cm between the two measurements, a third measurement was taken and the average of the closest two measurements was calculated. The WHR was calculated as the coefficient between the waist circumference and the hip circumference.
– *Body composition*. The body mass, the body fat and the % of body fat were determined by electrical bioimpedance (Tanita, BC-1500, Amsterdam, Holland). The electrical bioimpedance method has been shown to be reliable and valid to assess the body composition in a paediatric population[33]. The equipment used 8 electrodes and a single frequency of 50 kHz, with the sensitivity to detect weight gains of 0.1 kg and fat weight gains of 0.1%. This measurement was taken observing the rules defined in the consensus document of the Spanish group of Kinanthropometry[34].

Metabolic parameters

A small prick was made on the fingertip by healthcare personnel using single-use disposable sterile lancets (HTL-Strefa, MenaLancetPro, Leczyca, Poland). A portable reflectance photometric analyser (Roche Diagnostics, AccutrendPlus, Mannheim, Germany) with proven scientific validity[35] was used to determine, by specific reactive strips, the blood values of glucose, triglycerides and cholesterol. A drop of fresh capillary blood (10-40 µl) was deposited on the reactive strip, which was subsequently inserted in the portable analyser.

Statistical analysis

In order to perform a correct statistical analysis of the data, an exploratory data analysis was made. In order to assess the normality of the data, the Shapiro-Wilk test was used to check the normality of the data distribution while Levene's test determined data uniformity.

A descriptive analysis was made of the data, to indicate the percentage of obesity among the schoolchildren analysed.

In order to establish comparisons between the various groups, a single factor ANOVA test was run with a Tukey Post-hoc analysis.

The level of significance for all the tests implemented was 5% ($p < 0.05$). The data were presented as a mean (95% CI). The statistical software used to analyse all the data was the SPSS v.20 (IBM Corp., Armonk, NY, USA).

Results

A total of 233 participants were recruited, of which 116 were boys (49.79%) and 117 were girls (50.21%) (Table 1).

77.6% of the boys were put in the normal weight group, while 11.2% were classified as overweight and another 11.2% as obese. For the girls, 86.4% had a normal weight, 5.1% were overweight and 8.5% obese. The total percentage of participants who were either overweight or obese was 18% (Table 2).

The WHR was in a range between 0.81 and 0.90 cm, being at 0.87 cm for the obese group compared to 0.83 and 0.82 cm for the overweight and normal weight groups respectively (Table 3).

The overweight and obese groups had higher body fat levels than the normal weight group (11.37 and 17.46 kg respectively). The fat percentages for the overweight and obese groups were higher than those for the normal weight group, 8.6% and 13.52% respectively. Statistically significant differences were found in both comparisons ($p < 0.05$). The participants with the highest fat percentage were obese girls, while the boys in the normal weight group exhibited the lowest body fat percentage.

The glucose levels shown by the different groups were between 65.14 and 69.70 mg/dl, with no statistically significant differences between the groups or between the sub-groups (divided by gender).

For triglyceride blood levels, there were no statistically significant differences between the groups, ranging from 79.36 to 89.67 mg/dl. The obese group had the highest level of triglycerides in the blood with a mean level of 84.45±9.42 mg/dl.

Table 1. Characteristics of participants.

Gender	Height (m)	Age (years)	BMI (kg/m^2)	Weight (kg)
Male (n=116)	1.45±0.08	10.59±1.02	18.73±3.31	39.89±9.74
Female (n=117)	1.48±0.09	10.60±0.93	18.69±3.04	41.14±9.47
Total (n=233)	1.46±0.13	1 0.53±1.68	18.66±4.89	40.12±16.03

Table 2. Percentage of boys/girls and total classified according to body mass index.

Gender	Normal weight (%)	Overweight (%)	Obese (%)
Male (n=116)	77.6	11.2	11.2
Female (n=117)	86.4	5.1	8.5
Total (n=233)	82.0	8.1	9.9

Table 3. Anthropometric measurements related to the BMI of the subjects.

Factor	Normal weight (n=191)			Overweight (n=19)			Obese (n=23)		
Gender	M	F	Total	M	F	Total	M	F	Total
BMI (kg/m^2)	17.37±2.04[a,b] (16.9 - 17.8)	17.82±2.17[a,b] (17.4 - 18.3)	17.61±2.11[a,b] (17.3 - 17.9)	21.30±0.74 (20.8 - 21.8)	22.52±0.72 (21.8 - 23.3)	21.68±0.92 (21-2 - 22.1)	25.52±1.65 (24.5 - 26.5)	25.12±1.55 (24.0 - 26.2)	25.34±1.58 (24.7 - 26.0)
WHR (cm)	0.83±0.64[b] (0.82 - 0.84)	0.81±0.05 (0.80 - 0.83)	0.82±0.06[b] (0.81 - 0.83)	0.84±0.49 (0.82 - 0.88)	0.81±0.05 (0.76 - 0.88)	0.83±0.05 (0.81 - 0.86)	0.90±0.04 (0.87 - 0.93)	0.83±0.10 (0.76 - 0.91)	0.87±0.08 (0.84 - 0.91)
Height(m)	1.44±0.08 (1.43 - 1.46)	1.47±0.08 (1.45 - 1.49)	1.46±0.08 (1.45 - 1.47)	1.42±0.07 (1.38 - 1.47)	1.51±0.11 (1.40 - 1.63)	1.45±0.09 (1.41 - 1.50)	1.50±0.04 (1.48 - 1.53)	1.49±0.09 (1.43 - 1.57)	1.50±0.07 (1.47 - 1.53)
Weight (kg)	36.80±7.46[a,b] (35.2 - 38.4)	38.93±7.53[a,b] (37.5 - 40.4)	37.93±7.55[a,b] (36.9 - 39.0)	43.21±4.76 (40.3 - 46.1)	52.30±8.91 (42.9 - 61.7)	46.08±7.48 (42.5 - 50.0)	57.97±5.92 (54.4 - 61.6)	56.20±8.72 (50.4 - 62.9)	57.37±7.12 (54.3 - 60.5)
Fat mass(kg)	5.17±2.73[a,b] (4.6 - 5.7)	6.97±3.30[a,b] (6.3 - 7.6)	6.13±3.17[a,b] (5.7 - 6.6)	9.53±1.71 (8.5 - 10.6)	15.36±4.65 (10.5 - 20.3)	11.37±3.96 (9.5 - 13.3)	16.4±3.93 (14.1 - 18.9)	18.75±4.12 (15.8 - 21.7)	17.46±4.08 (15.7 - 19.2)
% fat (%)	13.49±5.66[a,b] (12.3 - 14.7)	18.23±9.59[a,b] (16.3 - 20.1)	16.01±8.32[a,b] (14.8 - 17.2)	22.64±2.90 (20.9 - 24.4)	28.88±4.20 (24.5 - 33.3)	24.61±4.40 (22.5 - 26.7)	26.95±5.60 (23.6 - 30.3)	32.89±2.69 (31.0 - 34.8)	29.53±5.39 (27.2 - 31.9)

WHR: Waist-hip ratio; M: Male; F: Female.
[a]Statistically significant differences ($p < 0.05$) between normal weight and overweight. Results expressed as mean ± SD (95%CI).
[b]Statistically significant differences ($p < 0.05$) between normal weight and overweight. Results expressed as mean ± SD (95%CI).

Table 4. Metabolic parameters in relation to the BMI of the subjects.

Factor	Normal weight (n=191)			Overweight (n=19)			Obese (n=23)		
Gender	M	F	Total	M	F	Total	M	F	Total
Glucose (mg/dl)	67.81±17.34 (64.2 - 71.4)	65.14±14.04 (62.4 - 67.9)	66.41±15.71 (64.2 - 68.7)	69.23±6.00 (65.6 - 72.9)	69.00±14.71 (53.6 - 84.4)	69.16±9.17 (64.7 - 73.6)	67.54±17.17 (57.2 - 77.9)	69.70±14.17 (59.6 - 79.8)	68.48±15.63 (61.7 - 75.2)
Triglycerides (mg/dl)	80.68±14.20 (77.70-83.65)	79.36±12.36 (76.91 – 81.80)	79.98 ±13.24 (78.09-81.87)	81.85±9.48 (76.11 – 87.58)	88.50±7.79 (80.32–96.68)	83.95±9.32 (79.45- 88.44)	89.67±13.17 (81.29– 98.04)	84.40±9.99 (77.25 – 91.55)	84.45±9.42 (80.28 – 88.63)
Cholesterol (mg/dl)	157.92±31.65 (151.3 - 164.5)	165.12±32.47 (158.7 - 171.5)	161.73±32.20 (157.1 - 166.3)	145.38±36.32 (123.5 - 167.3)	148.67±32.29 (114.8 - 182.6)	146.42±34.16 (130.0 - 162.9)	172.69±41.20 (147.8 - 197.6)	151.30±28.34 (131.0 - 171.6)	163.39±37.04 (147.4 - 179.4)

M: Male; F: Female.

Although the obese group had the highest level of cholesterol in the blood with 163.39 mg/dl, there were no statistically significant differences between the groups (Table 4).

Discussion

The population studied had lower overweight and obesity levels than those established for similar populations in other studies conducted in Spain[16]. In any case, the proportion in the prevalence of overweight and obesity is likely to be greater in boys than girls, as shown by other studies such as Enkid[36]. In the Aladino study conducted in Spain during 2015-2016 by the Spanish Agency for Food Safety and Nutrition 37 on surveillance of nutrition, physical activity, child development and obesity, in which data were collected from 10,899 boys and girls aged from 6 to 9 years at 165 schools in all the autonomous communities, it was found that 23.2% of schoolchildren were overweight and 18.1% were obese. More specifically, at the level of the autonomous community of Extremadura, the PERSEO study[38], which used the Obergozo tables[31] as a reference, concluded that 18.4% of boys and 14% of girls aged between 6 and 10 years were obese. In any case, the results obtained in this study show that, despite the fact that the overweight and obesity levels are high, it appears that they have started to stabilise.

With regard to the anthropometric characteristics, the BMI is a good indicator of the total body fat and is widely used[39]. It was therefore the criterion used in this study to divide the subjects into groups in order to compare the different variables. However, one limitation to this indicator is that it does not reflect the anatomical distribution of the excess weight. In this respect, the concentration of abdominal fat is more representative of a future cardiovascular event and, therefore, other indices such as the WHR are also used[40]. Some investigations have shown that, for boys aged 6-11 years, the body circumferences show the level of global adiposity[41]. In this study, it was observed that overweight and/or obese individuals had higher WHR levels than those with a normal weight, both for the total values and the values referring to the male gender. This would indicate a higher concentration of abdominal fat, as has been observed in recent studies[42]. These increased WHR values in boys compared to girls could be explained by over-feeding, lack of physical activity and a sedentary lifestyle of these boys in this age group[43]. Likewise, those overweight and/or obese individuals also exhibit higher levels of fat mass and percent body fat mass. This is a cause for concern given the fact that, during childhood, weight gain should be associated with maturational and physical changes, and not with increases in fat mass[44].

With regard to the metabolic parameters, obesity is a serious nutritional problem related to disorders such as high blood pressure, type II diabetes and the development of cerebral or vascular thrombosis and which are associated with the serum level of cholesterol, glucose and triglycerides[20,21,45]. These authors demonstrated an association between artery distensibility and cholesterol levels, in a study on a population of apparently healthy children aged between 9 and 11 years. They found that the children had high LDL-C serum levels, lower distensibility of the brachial artery, which supports the possibility that the cholesterol level during childhood could be significant for the development of vascular disease. In relation to the data obtained, despite the fact that the obese group showed a tendency to higher values, it was observed that the levels of the study participants were within a normal range. However, it should be borne in mind that normal concentrations of total cholesterol can give a false sense of not having a cardiovascular risk, as this could conceal low levels of HDL-cholesterol which, together with high levels of triglycerides, could lead to a diabetic dyslipidemia[46]. In this respect, it has already been demonstrated that greater physical activity by boys and girls produces a lower quantity of triglycerides[47]. However, Garces *et al.*[26] concluded that the BMI of a group of 1,048 Spanish children did not show a high association with the blood glucose values and total cholesterol, assuming that other factors such as age, maturational level and hormonal status of the schoolchildren could have a decisive impact on the association between obesity and risk factors. Likewise, in a recent study conducted on Chinese children, it was observed that the BMI showed a slight correlation with the metabolic parameters indicating a potential cardiovascular risk[48]. Similar results were obtained in another investigation in which it was concluded that the body mass index charts were useful in predicting cardiovascular risk factors in Australian and North American children. However their use was questioned in European and Asian children[49]. Finally, we need to refer to some limitations of our study. As the calorie intake was not assessed, it was not possible to check the actual intake of saturated fats and sugar in the diet. Neither was a questionnaire used on the practice of physical exercise.

Conclusions

Approximately one in five schoolchildren assessed were overweight or obese, with greater prevalence amongst boys than girls. Those boys and girls with a BMI indicating overweight or obesity had higher levels of body fat, although their blood parameters analysed (glucose, triglycerides and cholesterol) were within the normal range. This would indicate that, during childhood, these blood parameters could be influenced by other factors not associated with obesity and BMI. Furthermore, other long-term longitudinal studies should be conducted in order to define how and when obesity starts to be related to possible metabolic disorders.

Financing

This study was financed by the Regional Government of Extremadura (File number: GR15020) and the European Union with the framework of the RITECA II project (Cross-Border Research Network of Extremadura, Centre, Alentejo).

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Original article

Psychophysiological response of fighter aircraft pilots in normobaric hypoxia training

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Received: 15.09.2017
Accepted: 18.10.2017

Summary

Hypoxia remains the most important hazard in high altitude flights as it is a rare condition presenting itself without consistent symptoms that prevent aircrew from warning in advance. An acute ventilatory response is the mechanism that works to get back oxygen concentration homeostasis, causing hypocapnia and a respiratory alkalosis, which causes breathing muscles fatigue. Some authors have identified previous training on hypoxia contexts as essential to avoid accidents but it is still poor know the effect of hypoxia exposition in the psychophysiological and cognitive functions. We proposed the present study with the aims of to study the effect of hypoxia training in cortical arousal, autonomic modulation and muscle strength. We analysed 3 male fight pilots of the Spanish Army before and after normobaric hypoxia training. The following variables were reported: subjective perceived stress (SPS), rated perceived exertion (RPE), cortical arousal (Critical Flicker Fusion Threshold (CFFT)), isometric handgrip strength, blood oxygen saturation (SaO_2), heart rate (HR) and spirometry values (forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), peak expiratory flow (PEF)). The effect size (ES) was tested by Cohen's D. No variable presented significant differences between tests. SPS, RPE, handgrip strength, heart rate and FVC increased after training. FEV_1, PEF, CFFT and SaO_2 decreased during the training. These results agreed with previous research in military population. Normobaric hypoxia training produces a decreased tendency in cortical arousal and an increase in perceived effort, stress, and increased tendency in muscular strength. These results can help to find specific training for better prepare fight pilots for hypoxic threats.

Key words:
Hypoxia. Pilots.
Cortical arousal.
Fatigue.

Respuesta psicofisiológica de pilotos de caza en entrenamiento de hipoxia normobárica

Resumen

La hipoxia es el peligro más importante en los vuelos a gran altitud, debido a que es un estado poco frecuente y se presenta sin síntomas consistentes que impiden una alerta temprana. Una respuesta ventilatoria aguda es el mecanismo que trabaja para recuperar la homeostasis de la concentración de oxígeno, causando hipocapnia y una alcalosis respiratoria, provocando fatiga en los músculos respiratorios. Algunos autores han identificado que el entrenamiento previo en contextos de hipoxia es esencial para evitar accidentes pero todavía es pobre el conocimiento existente sobre el efecto de la exposición a hipoxia en las funciones psicofisiológicas y cognitivas. El objetivo de esta investigación fue estudiar el efecto del entrenamiento en hipoxia en la activación cortical, la modulación autonómica y la fuerza muscular. Analizamos 3 pilotos de caza del Ejército del Aire antes y después del entrenamiento de hipoxia normobárica. Se registraron las siguientes variables: estrés subjetivo percibido (RPE), esfuerzo percibido (RPE), excitación cortical (Critical Flicker Fusion Threshold (CFFT)), fuerza isométrica de agarre, saturación de oxígeno en sangre (SaO_2), frecuencia cardíaca (FC) y espirometría (capacidad vital forzada (CVF), volumen espiratorio forzado en 1 segundo (FEV_1), flujo espiratorio máximo (PEF)). El efecto de muestra fue analizado mediante la D de Cohen. Ninguna variable presentó diferencias significativas entre los tests. SPS, RPE, fuerza isométrica, frecuencia cardiaca y FVC aumentaron con el entrenamiento. FEV_1, PEF, CFFT y SaO_2 disminuyeron con el entrenamiento. Estos resultados coincidieron con investigaciones previas en población militar. El entrenamiento de hipoxia normobárica produce una tendencia disminuida en la excitación cortical y un aumento en el esfuerzo percibido, el estrés y la tendencia creciente en la fuerza muscular. Estos resultados pueden ayudar a encontrar entrenamiento específico para preparar mejor a los pilotos de caza ante la hipoxia.

Palabras clave:
Hipoxia. Pilotos.
Activación cortical.
Fatiga.

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Introduction

The effect of altitude exposition in human body systems have been traditionally studied as they represent a source of stress for human beings[1,2]. Mechanical, psychological and physiological risks have been reported and studied although hypoxia remains the most important hazard in high altitude flights[3]. Moreover, hypoxia is a rare condition presenting itself without consistent symptoms that prevents aircrew from warning in advance, fact that can lead to fatal aviation incidents[4].

Hypobaric hypoxia (resulting from the air pressure reduction with increasing altitude) produces a lower alveolar oxygen partial pressure, reducing oxygen partial pressure in the arterial blood. An acute ventilatory response is the mechanism that works to get back oxygen concentration homeostasis, causing hypocapnia and a respiratory alkalosis[3], which causes breathing muscles fatigue[5]. The individual tolerance of low blood oxygen concentrations defines the symptoms experienced, most of them caused by cerebral oxygen delivery. These symptoms include: psychomotor impairment, impairment of cognitive function, visual impairment, psychological stress and anxiety, shortness of breath, paraesthesia, headache, dizziness, nausea, light-headness and tachycardia[4].

Some authors have identified previous training on hypoxia contexts as essential to avoid accidents facing cabin depressurization incidents[6,7]. Psychomotor impairment is one of the acute hypobaric hypoxia symptoms, as it affects aircrew postural control, increasing the postural sway as altitude augments[8]. Memory impairment has been reported, both in short-term[9] and working memory capacity[9,10], especially above 25000 feet altitude, where aircrew unawareness of their inability to maintain performance was underlined. Other parameters as cortical arousal seems to be impaired during hypoxia; perceptual ability (measured by the flicker fusion threshold) suffers an exertion and causes fatigue in pilots during hypoxia exposition[11]; and logic reasoning that was impaired in altitude, as well as the increased number of math test errors in hypoxic conditions[12,13]. Also, the autonomic modulation has been studied by some authors: although hypoxia clearly affects autonomous system, there is still some controversy on the opposite psychological symptoms (anxiety, depression or euphoria). Heart Rate Variability (HRV) tends to be the preferred instrument to measure this variable, as it is a non-invasive method. HRV has been reported to increase in aircrew population under hypoxic conditions, showing sympathetic nervous system prevalence[14-16]. To highlight the importance of hypoxia in altitude, autonomic modulation acts in reverse at 4574 m with hyperoxic conditions, showing parasympathetic nervous system prevalence as reported in one of these studies with aircrew[17].

All of these facts are factors that can affect pilots in high altitude, but is still poor know the effect of hypoxia exposition in the psychophysiological and cognitive functions. We proposed the present study with the aims of to study the effect of hypoxia training in cortical arousal, autonomic modulation and muscle strength.

Material and method

Participants

We analysed 3 male pilots of the Spanish Army that belonged to Group I (pilots of any type of aircraft) and with a qualification of "fit" according to the periodic medical examination as recorded in the ministerial order 23/2011. In addition, during the research they were carrying out the periodic aeromedical training included in the ministerial order 23/2011 and the STANAG 3114 "Aeromedical Training of Flight Personnel" (NATO regulations). Soldiers were equipped with standard uniforms, boots, and flying operative helmet and mask. Before starting the research, the experimental procedures were explained to all the participants, who gave their voluntary written informed consent. The procedures conducted in the present research were designed following the Declaration of Helsinki and approved by the Medical Service of the Aerospace Medicine Instruction Centre of Spanish Air Force.

Instrumentation and study variables

Before and after the hypoxia training, the following parameters were analysed in this order:

- Subjective perceived stress was assessed using a 0-100 scale.
- Rated Perceived Exertion was analysed through the Borg scale (values ranged from 6 to 20).
- Cortical arousal was measured through the Critical Flicker Fusion Threshold (CFFT) in a viewing chamber (Lafayette Instrument Flicker Fusion Control Unit Model 12,021) following the procedures conducted in previous studies[18].
- Isometric handgrip strength by a grip dynamometer (Takei Kiki Koyo, Japan).
- Blood oxygen saturation (BOS) and heart rate (HR) were measured with a normobaric hypoxia training system with these characteristics:
  - Simulated altitude levels: 0-27000 feet.
  - Hypoxic and hyperoxic air generation. Oxygen margins: 6.5%-40.0%
  - Membrane system for the separation of hypoxic and hyperoxic air.
  - Flexible system for configuration of flight profiles.
  - Cognitive battery to configure and record the evolution of cognitive performance depending on the state of hypoxia.
  - Continuous recording of physiological variables including BOS and HR.
- Spirometry values of forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1) and peak expiratory flow (PEF) were measured using a spirometer QM-SP100 (Quirumed, Spain) performing a maximum inhale-exhale-inhale cycle as previous research[19].

Procedure

The pilots performed the hypoxia training seating in front of a touch screen computer while completing cognitive tests that were repeated with different instances of the same test in a 2 minute interval basis.

Altitude changes were defined for three intervals depending of the simulated altitude. The characteristics of each period were: i) 3 minutes at 0 feet (0 metres); ii) 8 minutes at 16300 feet (5000 metres); iii) 10 minutes at 24700 feet (7500 metres).

The training was supervised by the Medical Service and the Training Flight Instructor of the Aerospace Medicine Instruction Centre. The end of the training could occur if one of these facts happened: i) Medical

Service noticed health risk; ii) Soldier noticed health risk; iii) Sudden HR raise detected by the training system; iv) Blood oxygen saturation below 60% detected by the training system.

Statistical analysis

The SPSS statistical package (version 21.0; SPSS, Inc. Chicago, Illinois) was used to analyse the data. Normality and homoscedasticity assumptions were checked with a Shapiro-Wilk test. Differences between pre and post samples were analysed using a non-parametric Wilcoxon test because the low sample analysed. Spearman test was used to analyse correlation between variables. The effect size (ES) was tested by Cohen's D [ES = (Post-test mean-Pre-test mean)/Pre-test SD]. The level of significance for all the comparisons was set at $P < .05$.

Results

The results are reported as mean±SD. In Table 1 are shown the pre-post results of the physiological and psychological variables studied in both pre and post tests.

No variable presented significant differences between tests. A large effect size was reported for Subjective Stress Perception and Rated Perceived Effort, which augmented during the training. Handgrip Strength and HR, also increased but presented a small effect size. The last reported raised variable was the FVC, which had a moderate effect size. FEV_1, PEF, CFFT and SaO_2 decreased during the training. A large effect size was found for SaO_2. A small effect size was found for CFFT. Finally, a trivial effect size was reported for FEV_1 and PEF.

Discussion

The aim of this research was to study the effect of hypoxia training in cortical arousal, autonomic modulation and muscle strength in fight pilots. The results showed a tendency towards the decrease of cortical arousal and rise in perceived effort and stress. They also reported a trend to increased upper body strength as an autonomic response facing hypoxic stress.

Oxygen saturation decreased and mean SaO_2 after hypoxia was similar to some studies[11,14,16], but higher than in other mild hypoxia research[13]. These differences could be explained taking into account the goal of each study: in mild hypoxia training the maximum altitude rarely surpass a maximum altitude of 4000 m. A decreased SaO_2 usually has a negative effect on the cortex performance. The analysis of cortical arousal was previously analysed in pilots, reporting a significant decreased value of CFFT after hypoxia training in hypobaric chamber[11]. Taking into account the effect size, these results are similar to ours and suggest that normobaric hypoxia training could also fatigue the Central Nervous System (CNS) and affect cortical arousal in aircrew[20]. It could be related with the lower oxygen availability in these situations, fact that produces a decrease in cortical arousal because of the lower access to oxygen of CNS cells[21]. The decrease in cortical arousal after the third series has also been evaluated by Clemente *et al*., (2010) after performing a RSA (repeated sprint ability) maximum speed test[22], and after performing a cycling test to exhaustion in triathletes[23]. In contrast, during a maximal oxygen uptake cycling test[24], an incremental maximum cycling test[25], a 30 min maximum cycling test[26], a 70% maximal oxygen uptake cycling trial[27] and a 1RM squat test[28] cortical arousal increased.

Heart rate has been previously monitored in aircrew hypoxia training researches, reporting increased in cardiovascular response after the hypoxia exposition[11,14-16] as a physiological adaptation to lack of oxygen[3]. The small effect size of our sample suggest that normobaric hypoxia training could decrease the HR augmentation as there are no significant differences comparing with signification found in previous hypobaric chamber studies[11,14,16]. The increased HR after training was also lower than in a study of automatic parachute, what suggest that the reminiscence of the sympathetic activation during the training is higher when aircrafts are used to practice. Future studies with a higher number of participants have to confirm these findings. RPE and Subjective Stress Perception increases during training can be related to CNS fatigue and autonomic modulation. These results agree with previous research conducted in both normobaric[11] and hypobaric hypoxia[14,16] and reinforce the assumption of hypoxia-induced changes in CNS functions.

Handgrip strength slightly improved after hypoxia training, which seems to partially exert during hypoxic conditions as an adaptation in

Table 1. Results of study variables.

Variable	Units	Pre	Post	Z	P	Cohen's D
SSP	0-100 rank	6.7±5.8	33.3±28.9	-1.414	.157	4.59
RPE	6-20 rank	7.7±1.5	12.7±1.5	-1.604	.109	3.27
HG Strength	kg	44.0±2.0	45.3±4.5	-.816	.414	0.67
FVC	l	4.9±0.4	5.5±0.3	-1.604	.109	1.23
FEV 1	l	4.0±0.3	3.9±0.9	.000	1.000	-0.41
PEF	l	8.6±2.1	7.7±2.6	-1.069	.285	-0.46
SaO_2	0-100%	97.0±1.0	77.7±3.8	-1.604	.109	-19.33
HR	bpm	78.3±13.0	85.7±8.0	-1.069	.285	0.56
CFFT	Hz	34.5±2.2	34.3±2.1	-.535	.593	-0.84

SSP: Subjective Stress Perception; RPE: Rated Perceived Exertion; HG: Handgrip; FVC: Forced Vital Capacity; FEV_1: Forced Expiratory Volume in 1 second; PEF: Peak Expiratory Flow; SaO_2: Oxygen Saturation; HR: Heart Rate; CFFT: Critical Flicker Fusion Threshold.

which the sympathetic nervous system is activated and prepares the body for any hazardous situation[29]. This uncertainty makes the sympathetic system to foster muscle activation which can cause an increase in muscle strength, as shown in previous research[30].

Something similar happened in terms of breath muscles strength: FVC slightly improved as a result of an activation of breath muscles after an external threat was perceived. As a result, the autonomic nervous system releases catecholamine into blood stream that produces an increase in strength, as shown in previous research with soldiers[31]. But explosive-related variables (FEV_1 and PEF) slightly decreased, probably because of fatigue after hypoxic conditions, as previously reported at altitude[5].

Study limitations and future research

The main limitation found in this study is the small sample size and the difficulties to access fighter pilots, as they belong to an elite group among military forces. Secondly, due to resource availability, there were no measurements of stress hormones (as cortisol, adrenaline, etc.), autonomic modulation and electroencephalography. Future studies should take into account these variables as they could help to better understand psychophysiological response to hypoxia.

Practical application

These results can help to find specific training for better prepare fight pilots for hypoxic threats. The data collected in the present work is of vital importance in order to define specific training systems as well as operational protocols for flight personnel in the development of their different tasks in their job, both in military and civil aviation. Training should be specific, individualized, prevent injuries and directed by qualified personnel. While many of the research agree on the need to be trained to withstand the stress of flight crews, many of the recommendations still lack adequate specificity as there is a need to take into account the actual needs of the pilot population.

Conclusion

Normobaric hypoxia training produces a decreased tendency in cortical arousal and an increase in perceived effort, stress, and increased tendency in muscular strength.

Acknowledgment

We would like to acknowledge the contribution of the Aerospace Medicine Instruction Centre of Spanish Air Forces (Centro de Instrucción de Medicina Aeroespacial, CIMA), including the colonel, the military instructors and the medical service personnel for their excellent work and collaborative spirit towards the present research.

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Sports injuries management update

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Summary

This paper takes a look at how sport injuries are managed considering factors such as: affected population, yielded benefits and costs generated by their practice. The analysis included below focuses on three specific sectors: Public healthcare administration, professional sport and recreational sport.

The aim of this paper is to show how sports injuries are currently managed as part of a healthy life style in Spanish society, so that the social system which takes care of the population's health becomes aware of the practice of a matter which has shown to have ever-increasing importance in today's society: physical activity and sport. We must asses whether the framework in which health care was established 20 years ago – and which is currently still applied- is an appropriate one under today's social conditions when it comes to dealing with all those deep changes-take for instance, the percentage of population which has decided to take up a regular practice of physical activity (and it's 10% increase in the last five years) and what this change means in terms of social expenses.

As well as mentioning economic concepts which may be considered as social costs as a direct result of recreational sports practice, I discuss which institutions are to cover such costs, the kind of situations which are considered secondary sick leaves from a labour point of view, how insurance companies and mutual insurance companies establish criteria when dealing with these events; I also deliberate on how each of these institutions' actions overlap with our public healthcare system when it comes to coping with them and finally, I analyse current preventive measures.

In summary, I have addressed the impact sports practice has on today's society and I have also assessed the costs and possible alternative economic, regulatory, assistance, insurance and legislative conditions for it.

Received: 15.09.2017
Accepted: 04.10.2017

Key words:
Management. Injuries sports. Insurance.

Actualización de la gestión de las lesiones deportivas

Resumen

En este artículo se realiza una reflexión sobre cómo gestionar la lesión deportiva teniendo en cuenta factores como: a qué población afecta; qué beneficios reporta y qué costes tiene la práctica deportiva. Es un análisis enfocado a tres ámbitos; como son la gestión desde la Administración Pública, el deporte profesional y el deporte amateur o de ocio.

El objetivo del presente trabajo de revisión es reflejar el estado actual de la gestión las lesiones deportivas dentro del sistema de prácticas saludables de la población española, con el fin de concienciar al sistema social que vela por la salud de la población de un tema, con un peso cada vez más importante como es el de la práctica deportiva. Debemos valorar si el marco en el que se movía el sistema hacer 20 años es el adecuado hoy día, para hacer frente al cambio tan drástico que se ha producido en este ámbito.

El porcentaje de población que practica deporte se ha incrementado en los últimos cinco años un 10% y habrá que analizar cómo hacer frente al aumento asociado de gasto económico social que este hecho supone.

Se analizan medidas preventivas así como cuál es la entidad que se hará cargo de los costos económicos, bajas laborales secundarias… que plantea la lesión deportiva, a través de compañías de seguros, el sistema nacional de salud, las mutuas de seguro…

En resumen, se ha explicado la repercusión que en la sociedad actual tiene la práctica deportiva. Se ha valorado el coste, las posibilidades o no de variar las actuales condiciones económicas, reguladoras, asistenciales aseguradoras y legislativas en relación a la cobertura de dichos costes y al tratamiento de los mismos.

Palabras clave:
Gestión. Lesión deportiva. Seguros.

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Introduction

When it comes to discussing sports injury management, clearly we should first define what we understand by management, as in today's society this term is often linked to numbers, accounts, results, benefits, expenses, etc. It is however true that in recent times the concept of management has changed considerably, and we use the term to refer to planning, strategy, targets, etc. This is why when focusing on an issue such as sports injury management, we are going to study and analyse it thoroughly within a more conceptual sphere as opposed to using figures.

We will therefore deal with this issue from a strategic and rational perspective. Given that sports injury is such a wide field, we will start by introducing the definition of a sports injury, then we will perform a potential market analysis, and finally we will study the possible management focuses that we could have. In this study the following angles will be presented: from the perspectives of Public Administrations; of professional sports; and of amateur level or leisure sports.

Sports injury can be considered as "damage that is produced in the human body as a result of practicing sport" [1,2], but it is true that society evolves, and particularly so in recent years. Therefore, this concept is becoming limited and exiguous, making it more thorough to state that a sports injury is "any damage, whether physical or psychological, that the body may suffer whilst performing a sporting activity, on both an amateur and professional level, and which produces incapacity to train or compete" [3].

Potential market analysis

In terms of market analysis, to see what we are talking about and to establish the number of people that practice sport in Spain4, we can say that there were 3.5 million federated athletes in Spain in 2015, of which 78.5% were males and the rest were females. The top federation or sport in terms of federated members was still football, with around 900,000 federates, followed by basketball, hunting and golf.

In terms of leisure athletes, the increase in recent years has been spectacular; in fact, in 2015, in a population aged over 14 years, some 53.5% practiced sport at least twice a week, whilst in 2010 this percentage was just 43%[4]. Consequently this equates as an increase of 10 percentage points in five years. It is also true that practicing certain sports is becoming a form of social status marker; as such, the cult of the body, of being healthy, seems to be an increasingly important factor in society.

In terms of the most practiced leisure sports, the gym is the outstanding leader, a trend that has grown considerably since 2010, followed by running, cycling and swimming.

If we take the case study that was carried out regarding injuries as a base study[5], of 1616 injuries that occurred whilst practicing sport, the demographic under 35 years suffered approximately 70% of the injuries, whilst those over 35 years sustained the remaining injuries, with considerably more males than females suffering injuries[6]. The most injured parts of the body were the lower limbs, followed by the upper limbs. Furthermore, according to statistical and percentage data, these are practically identical in both men and women. In terms of the sport that produces the most injuries, football is at the top, followed by running, indoor football and basketball. In football, predominantly males acquired injuries, whilst more women obtained injuries whilst running. Yet the rate of football injuries is still the highest. It is also true that most of the demographic studied practiced football. In terms of the causes of the injuries according to this study, coinciding with what the general public usually perceives, the most frequent type are muscular injuries, followed by strains, tendon injuries and joint injuries.

In terms of what this represents from a healthcare point of view, football is at the head, because 66% of those injured require medical attention, and 22% cause working leave. Of these injuries, in this study some 63% of football injuries required rehabilitation, and the weight in terms of healthcare was as follows: first football, second indoor football, and third tennis.

Management focuses. Public Administration

Once the population subject to suffering a possible sports injury has been established, either from practicing federated, semi-professional or even professional sports or leisure sports, we are going to examine the angle that we could take from a public administration perspective. In a Public Administration study, we observed that in 2015 sport generated some 184,600 job positions in Spain, which equates as 1% of the working population. It also drives a total of 31,000 companies, also representing 1% of all Spanish companies[4]. In terms of public expenditure linked to sport, the statistics are not very recent. In 2010 this expenditure was around 3700 million euros, which fell to around 3,200 in 2011, and this figure has reduced gradually as a result of the financial crisis. However, sport also attracts a large number of tourists; in fact estimates position this figure at around 475 million euros of sport-related travel costs.

From the point of view of a public administration manager, in terms of the advantages that can sport can offer, we find that as a physical exercise, it is a fundamental part of the development and correct functioning of our organism, both physically and mentally. What are the benefits of the population doing sport?[1] It helps prevent pathologies such as obesity, diabetes, hypertension, and protects our locomotive system. It also helps in the everyday struggle against insomnia, stress, depression and low self-esteem. What are the disadvantages? Sports injury and its cost. In 1990 an act was created about healthcare received for sports injuries[7], later developed by Royal Decree 849/93[8], establishing the minimum conditions of compulsory sports insurance. It is true that this act – establishing that all federated athletes should have insurance that should be paid by the corresponding federation on a local, autonomic and state level – also covers a series of conditions that all federated athletes should know, and that in my point of view I believe very few people are aware of. These include having to provide a personal insurance certificate, stating the insurance company chosen, the cover that this policy provides, and the items that are excluded from this insurance. I feel that this is a grey area, which is vastly unclear for the demographic involved, and one that has not been transparent, which is why this issue requires improvement. Act 19/2007 was also developed (against violence, racism, xenophobia and intolerance in sport)[9], which established that sport was an ideal vehicle for transmitting culture and team spirit, and for avoiding gender-based violence, racism and xenophobia.

What actions do I believe should be performed from the perspective of a Public Administration manager? Clearly controlling federate insurance is a priority. We are talking about 3 and a half million potentially injury-prone federated athletes, and there should be a way of clarifying or controlling that these 3.5 million people have insurance. We believe that it is fundamental to control sporting events and the physical condition of athletes, because every weekend in Spain thousands of sporting events take place, whether running, ball sports such as football, basketball, paddle, etc. and there are no kinds of controls in these competitions. Anyone can run a marathon and the only requisite is to sign up and to receive a number. There are no previous sporting medical examinations, echocardiograms or minimum physical condition requirements.

Then we have the issue regarding the follow-up of health costs accumulated through all the staff and the healthcare systems that look after people with sports-based injuries. If an injured federated athlete, who should theoretically be covered by an insurance broker, goes to the public healthcare system, this causes a healthcare cost. The problem is that no one makes sure that this expense can be covered by an insurance broker, which is why the public healthcare system ends up increasing the healthcare material and personnel expenditure created by caring for this injured athlete, when a third party insurer could cover it. It is essential to educate the population in this issue. I believe that the system would run much smoother if everyone were educated in the costs entailed, and it would be essential to carry out prevention work with anyone practicing any kind of sport.

Management approaches. Professional sport

From the perspective of professional sport management, when it comes to treating an injury, it seems obvious that in professional sport it would be essential to become an expert in preventing possible injuries that athletes can acquire, but this will always depend on the individual resources of each athlete.

It is also true that the best treatment option should be carefully considered, but again, the individual is not always the best candidate to choose the optimum treatment option because we depend on the necessary resources to get the best medical team, the best reference centre or the best diagnostic image centre, etc.

On a sporting level we could classify as elite footballers, it seems obvious that with an athlete that may cost 10 million or 20 million euros each year, no expense will be spared in carrying out any kind of test as quickly as possible and by the very best professional available. In these cases it is obvious that the cost is not greater than the return of the investment, but this is neither standard nor usual. The problem arises when the cost is greater than the return of the investment. What should be done in these cases? This athlete must wait for longer than an athlete with higher income. We must also discuss recovery from the injury, which is where we encounter the same problem. Where will this athlete recover? At the best centre? Where he/she can afford? What can my income stretch to? Perhaps we should think that all of these issues should be linked to specific insurance covers, so that all athletes can always receive the optimum treatment. Yet once again, unfortunately, we find that insurance is pricy and if there is not enough money to cover it, we will have the recurring issue of funding to consider.

How is leave dealt with in professional sport? What happens when the leave occurs during a transfer to a national selection? Who covers this leave? Who pays for this leave? Efforts are always made to keep a kind of reference to make it clear who covers these leaves, but in reality selections do not usually have many resources, meaning they cannot easily pay for them. They do not usually want to designate resources to hiring insurance to cover these contingencies; it is an on-going debate. There are discussions, for example, in the world of football with the UEFA or with FIFA, because the cover that is usually taken on is very low for athletes that are transferred. We return to the fact that there should be specific insurance covers for this case, for these case studies, because they are insurance covers with costs that practically no federation can stretch to. It is also true that there are conditioning injuries, such as those of any athlete that is going to attend an important event (such as a European, World or Olympic event), in which case priority is usually given, in the case of a possible medal, to pouring more resources into recovery from an injury. However, we return to the inequality that occurs in the treatment of athletes because if a medal is not likely, the athlete will not be designated the same resources.

When discussing who covers a leave, I would firstly like to refer to the leave resulting from your working or mercantile relationship with the federation, team or whoever corresponds, and to establish who will cover it or not. In many cases, these leaves are not covered or paid for… the social system covers the minimum in the case of self-employed athletes, whilst in the case of athletes with a working relationship, this depends on the agreement with each club or federate member, which is an issue that we should take lengths to define.

Management approaches. Amateur level/leisure

In terms of leisure sport, we find that in 2015, in Spain the national household expenditure linked to sport is 4,200 million euros, entailing an average cost per inhabitant of 92 euros[4], which is a more than respectable figure. It is becoming a symptom of social status: nowadays when you go running, more care is taken regarding the choice of footwear and the calorie-heart rate control device used because it appears that you are being observed by society.

Leisure sports are performed an average of twice a week, and this is where we find ourselves before an economic term, perhaps applicable to this case study, which is usefulness. How can we measure the usefulness reported by a person that practices sport when this depends on the satisfaction that this sporting practice brings to each individual? This depends on each moment and on each person, which is why it is impossible to measure.

It is quite complicated and difficult to debate why people partake in so much leisure sport. In some cases even medically acceptable and beneficial limits are exceeded, almost constituting an illness or an obsession. But of course, what problems do we find in leisure sport? It would seem that no one wants to talk about this. Who covers the leaves of leisure athletes? This demographic constitutes 20 million potentially injury-prone people. A large percentage of these people work, and if an injury occurs during leisure sport, work leave is taken, meaning that the company covers part and the state system the other part. We are talking about an enormous amount of money that no one wants to face or touch, because there are too many people practicing sport. In this issue measures must be taken, I am not sure whether this would entail certain additional insurance covers for this kind of athlete, but the population should be made aware that this has a very high economic cost and that someone or some system will have to pay for it.

Conclusions

To conclude, we consider that, on an institutional level, social expenditure and insurance covers should be controlled, regardless of whether the federated individual is insured or not. We believe that it is key to educate, raise awareness and prepare the population for this issue. Equally vital is a drive to prevent all kinds of injuries whenever possible.

In professional sport the ideal solution would be to insist upon athlete injury prevention. This is not always equitable or fair, but we will evidently have to aim to minimise the expense and the corresponding leave: the shorter, the better.

In terms of leisure sport we strongly feel that measures should be applied to prevent the appearance of injuries and to educate the population in terms of the entailing cost of them. Training and education are the sturdiest cornerstones of an advanced and progressive civil society.

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Running economy and performance. High and low intensity efforts during training and warm-up. A bibliographic review

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Received: 23.06.2017
Accepted: 04.10.2017

Summary

Interest in relation to running economy has increased such as determinant of running performance in scientific literature in trained long and middle distance runners and recreational runners. Trained runners are more efficient than untrained runners, meaning it is a "trainable" parameter. A key factor during endurance training is the intensity of corresponding effort, characterized by two endurance training methods such as interval and continuous training. In recreational runners, there is some controversy about which intensities are optimal in order to improve running economy, thus, periodized endurance training with a logical relationship between high and low-intensity training is recommended. We recommend the inclusion of 2-3 session per week of interval training, compensated with continuous training. Regarding to trained runners, interval training (at intensities close to VO_2max) will be more important because of the need to be more economical at competitive intensities. Very high training intensities would not lead improvements in running economy due to it is not posible to accumulate enough training volumen during the training period. Conversely, the high-intensity efforts prior to competition (intensities above anaerobic threshold), during a warm-up protocol, increase the energy cost (reduce the running economy) and therefore, it is recommended a long transient phase (9-20 min) before to competition so as not to disturb the subsequent performance. An increase of scientific studies regarding the effects of high-intensity efforts during a warm-up protocol is needed in order to know the optimal intensities, flat or uphill ground, or the adequate recovery to improve the subsequent performance.

Key words:
Endurance training.
Energy cost. Runner.
High intensity.

Economía de carrera y rendimiento. Esfuerzos de alta y baja intensidad en el entrenamiento y calentamiento. Revisión bibliográfica

Resumen

La economía de carrera ha crecido en importancia en la literatura científica como factor de rendimiento en corredores de fondo y medio fondo tanto de alto nivel como recreacional. Los atletas entrenados son más económicos que aquellos no entrenados, mostrando que es una variable que se mejora con el entrenamiento. Un factor clave en la selección del entrenamiento de resistencia es la intensidad del esfuerzo a realizar, principalmente caracterizado por dos métodos de entrenamientos como son el interválico y el continuo. En corredores de nivel recreacional, existe cierta controversia en relación a qué intensidades son las óptimas para mejorar la economía de carrera, recomendándose la realización de entrenamiento periodizado y exista una lógica relación entre entrenamiento de alta y baja intensidad. Recomendamos la inclusión de 2-3 sesiones semanales de entrenamiento interválico, compensado con entrenamiento continuo. En cuanto a los corredores entrenados de más nivel, el entrenamiento interválico cobra mayor importancia (intensidades cercanas al VO_2max) dado que la realización de esfuerzos de mayor intensidad provocará que sean más económicos a intensidades de competición. Intensidades de entrenamiento muy altas no conllevarán mejoras en la economía de carrera debido a que no es posible acumular suficiente volumen de entrenamiento. Por otro lado, los esfuerzos de alta intensidad previos a la competición (intensidades superiores al umbral anaeróbico), es decir, durante el calentamiento, aumentan el coste de energía (reducción de la economía de carrera) y, por lo tanto, se recomienda una amplia fase de transición entre tales esfuerzos y la competición (entre 9-20 min), para que el rendimiento no se vea perturbado. Se recomienda un aumento en el aporte científico en relación a los efectos de esfuerzos de alta intensidad durante el calentamiento, con el fin de conocer qué intensidades son más óptimas, el terreno a utilizar (llano o pendiente), o la recuperación necesaria para mejorar el rendimiento.

Palabras clave:
Entrenamiento de resistencia.
Coste de energía. Corredor.
Alta intensidad.

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Introduction

Endurance sports call for a certain amount of exertion over a long period of time. Hill and Lupton[1] were already discussing Maximal Oxygen Uptake (VO_2max) and its importance to sports performance in scientific publications back in the 1920s. Their view has come to be accepted over the years and in more recent times further physiological factors which may affect performance in endurance sports have been advanced. In addition to VO_2max, both the anaerobic threshold (AT)[2,3] and running economy (RE)[4,5] have been documented and incorporated as determinants of performance in endurance sports, especially long- and middle-distance running[6]. Although differences in VO_2max can be observed between distinct populations and sports, such differences cannot be identified so well when focusing on elite runners. Daniels[7] was puzzled to find athletes with comparatively low VO_2max values achieving better times and performing better in competitions than others with higher VO_2max values. This could be explained by RE. Athletes with poor RE values tend to have higher VO_2max values (inverse relationship), it being possible to improve RE and see VO_2max negatively impacted[8,9]. In highly trained athletes, a weak-to-moderate relationship was found between RE and VO_2max[10]. While such variables as VO_2max have been widely studied as a determining factor in runners, RE was ignored until a few decades ago, but has gradually grown in importance in the scientific literature since the 1970s[11].

RE is the result of the complex interplay of multiple factors. Of these, we could single out biomechanical variables[12], neuromuscular variables such as leg stiffness, exposure to periods of training at altitude and anthropometric variables[6]. In this review, we will explain what running economy is and the ways in which it is measured, and will centre on endurance training through the use of two training methods, continuous and interval training, and consequently high- and low-intensity exercise, and their relationship with RE. High-intensity work (interval method) shall be understood as intensities over the anaerobic threshold, i.e. over 85-90% of vVO_2max and maximum HR. Low-intensity work, consequently, shall be understood as intensities below these limits. Finally, we will discuss the impact of high- and low-intensity exercise in warm-ups prior to competitions or performance testing, and the relationship with RE.

Running economy. Definition and evaluation methods

Running economy (RE) is generally used to refer to the steady-state consumption of oxygen at a certain running speed[4,13,14] and expresses the energy expenditure required to perform at this intensity. The economy of effort is a variable which has been used to evaluate endurance sports in the scientific literature[15]. There are currently several ways to measure RE. The main, most commonly used method in articles is oxygen cost. Given that it is necessary to ascertain the subject's oxygen consumption (VO_2) during the exercise in order to measure RE, oxygen cost is the easiest way to find out his/her RE. Since steady-state VO_2 is needed to quantify RE, the intensities selected should be below the lactate threshold[4,16] and the blood lactate concentration should be similar to basal levels[17]. A respiratory exchange ratio of less than 1 at the selected running speeds is another easy way to know that the subject has attained steady state[4]. This respiratory exchange ratio is the relationship between the consumption of CO_2 and O_2, and can be used to determine energy use, energy production and the energy cost of an activity. Measuring RE as oxygen cost, however, does not take into account changes in the energy substrate used at the running speed. For this reason, Fletcher *et al.*[18] compared two ways of measuring RE, as oxygen cost and as energy cost, and concluded that the latter was more sensitive to changes in intensity and, therefore, more correct. The running speed most used to measure RE in the literature is 16 km h^{-1}, although a range between 12 and 21 km h^{-1} has been used in different studies depending on the level of the sample used[4,6,19]. In a recent review, Barnes and Kilding[20] established a range of speeds at which to measure RE depending on the level of the sample based on VO_2max values: for recreational athletes (54.2-62.2 $ml \cdot kg^{-1} \cdot min^{-1}$), the speed would be 10-14 $km \cdot h^{-1}$; for moderately trained runners (62.2-70.8 $ml \cdot kg^{-1} \cdot min^{-1}$), 12-16 $km \cdot h^{-1}$; for highly trained runners (70.8-75.4 $ml \cdot kg^{-1} \cdot min^{-1}$), 12-20 $km \cdot h^{-1}$ and for elite runners (> 75.4 $ml \cdot kg^{-1} \cdot min^{-1}$), 14-20 $km \cdot h^{-1}$.

Running economy and its relationship with performance

The scientific literature has documented the relationship between RE and performance in long- and middle-distance runners quite well. Recently, Hoogkamer *et al.*[21] reached the conclusion that changes in RE led directly to changes in performance. These authors registered changes in RE and performance with increasingly heavy sports footwear. They concluded that increments of 100 g. in footwear weight worsened RE by 1.1% and this reduced performance by 0.78% in a 3,000 m. run. This means that any change which affects RE may also affect the end result of a competition. For example, Kenyan runners have small gastrocnemius muscles compared to European athletes and have less weight away from the axis of movement of their legs. As a result, they have a lower moment of inertia and require less muscular effort to move their legs[22], as could happen with the heavier footwear. Previously, Pollock[19] observed differences in RE between elite runners (runners with times of less than 30 minutes in a 6-mile test, according to the author's definition) and good runners, establishing the categories by performance level, proving more economical those who performed the best. Subsequently, Conley and Kranhenbuhl[4] established RE as a good predictor of performance over 10 km., those athletes with better performance proving to be the most economical (r = 0.83). Later, di Prampero *et al.*[23] found that an improvement of 5% in RE meant an improvement of 3.8% in performance. Meanwhile, focusing on the changes produced over a prolonged period of training, Svedenhag and Sjodin[24] observed improvements in RE (-1.0 ± 0.3 $ml \cdot kg^{-1} \cdot min^{-1}$ per year) after a long period of training (approximately 22 months) and, at the same time, improvements in performance over 5,000 m. without observing changes in VO_2max. This tells us that, in trained runners, a situation can arise in which no changes in VO_2max are observed, but changes in performance are. One of the causes of this could be the improvements in RE and the speed at which VO_2max (vVO_2max) is achieved, as Morgan *et al.*[16] observed, RE and vVO_2max serving as reliable predictors of performance over 10 km.

A clear example of the relationship between RE and performance is the progression of the athlete Paula Radcliffe, the holder of the marathon world record (2h15:25). Jones[25] studied her physiological changes over more than 10 years. He saw that her RE improved by 15% (from 205 $ml \cdot kg^{1} \cdot km^{-1}$ in 1992 to 175 $ml \cdot kg^{-1} \cdot km^{-1}$ in 2003) during this time, improving all her times from 5,000 m to marathon. Similarly, the American athlete Steve Scott, who held the world record for the mile, improved his RE by 5% over a period of training[26]. There exists consensus in the scientific literature regarding the importance of RE as a performance factor and that improving it is key to improving the performance of runners. As we can see, RE is a variable which changes according to a runner's training, but it is essential to know what type of training is the most suitable for improvement and why. Tables 1 and 2 describe several studies which have observed improvements in RE accompanied by improvements in the performance tests used in each case, showing a relationship between RE and improvement in performance.

Endurance training and running economy

We know how endurance training affects the body. Improvements have been noted in the cardiorespiratory system and skeletal muscle oxidative capacity[27,28]. At the same time, the improvement in oxidative capacity is associated with an improved mitochondrial function[6,29] and this entails a reduction in the oxygen use needed to work at submaximal intensity[30], thus improving RE. There are also changes in the skeletal muscle buffering capacity[31] and at blood level[32]. Although the mechanisms involved in the relationship between buffering capacity and improvements in mechanical efficiency are not clear, these processes have been observed following training at altitude. It may be due to a more marked use of carbohydrate oxidation compared to fat oxidation[31]. Haematologically, increases in the mass of red blood cells and a relationship with improvements in RE have been observed[32]. Regarding endurance training and its effects on RE, it has been well established in the scientific literature that trained athletes are more economical than those less trained[33].

Two endurance training methods are commonly used today by coaches and athletes all over the world: interval training and continuous training. Interval training (INT) was first used in the 1920s by the Finnish athlete Paavo Nurmi[34]. He won numerous long- and middle-distance medals at the 1920, 1924 and 1928 Olympic Games. But it was not until a few years later, in the 1930s, that a coach and a doctor (Gerschler and Reindell), both German, introduced the term "interval training" and it started to become better known in other parts of the world[34]. This method can be defined as a series of repeated bouts of exercise lasting a short to moderate period of time (between 10 seconds and 5 minutes) completed at an intensity higher than the anaerobic threshold[35,36]. The peculiarity of this method is that there exist a multitude of variants depending on the length of the stimulus, the length of recovery following the stimulus and the number of repetitions and series of the stimulus carried out. A total of nine variables can be altered in this method to change its effects[37]. The intensity and duration of the intervals are key factors, while the number of intervals and the number of series they comprise, the recovery between intervals and series, and the type of exercise all influence the final outcome. Hetlelid and Seiler[38] studied 6x4 min. at the maximum intensity possible for the session and task in which the only difference was the length of recovery between repetitions (1, 2 and 4 min), which modified the running intensity. Switching from a recovery time of 1 min. to one of 2 min. led to an increase in intensity, but changing from 2 to 4 min. did not. VO_2 worked more with 2 min. of recovery, but the blood lactate concentration did not change. Surprisingly, when they let the subjects choose the recovery time between repetitions, they chose something close to 2 min. (118 ± 23s). This is a clear indication of how complex manipulating the variables which affect the INT training method is.

The continuous training method (CON), on the other hand, is characterised by lower-intensity work without pause, i.e. continuous work at an intensity beneath the anaerobic threshold. The main difference, therefore, between the two methods is the intensity of effort during training and this may be the key to the modifications and improvements which take place in the body.

Regarding altering the volume and intensity of training, there is no evidence yet of a relationship between more training (chiefly using the CON method as a large percentage of training) and better RE. What intensities, therefore, are optimal for improvement and what combination of intensities and, consequently, training methods is the most suitable?

The scientific literature tells us that intensities near the speed at which maximal oxygen uptake is achieved have commonly been employed in endurance training using the INT method. INT training with recreational athletes (Table 1) at intensities between 93% and 106% of VO_2max[39], and between 90% and 95% of maximum heart rate[40,41] (HRmax) has registered RE improvements of 1 to 9%. Other authors, however, have not found improvements in RE after INT training. Gliemann *et al.*[42] found no changes in RE after 8 weeks with two sessions/week of INT training (alternating 10-20-30s at intensities of 30%, 60% and 90-100% of maximum running speed). González-Mohíno *et al.*[9] did not observe RE improvements after INT training at 95-110% of vVO_2max.

Turning to CON training, a single low-intensity training session produces no change in RE[43,44], meaning that a long training period is needed to produce changes. Zaton and Michalik[45] noted significant improvements in RE (17%) following 3-4 sessions of CON a week (voluntary

Table 1. Effects of interval and continuous training on the running economy and performance of recreational athletes. Participants, design and results.

Study	Participants	Research design			Results	
	Description	Interval training (n)	Continuous training (n)	Duration (sessions/week)	RE	Performance
Franch *et al.*(1988)	n = 36 M; 30,4 y.o.; 54,8 ml·kg^{-1}·min^{-1}; Recreational athletes	Long (12) 4x4 min. with 2 min. recovery, Short (12) 30-40x 15 sec. with 15 sec. recovery	20-30 min. at 15km/h	2-3 days/week for 6 weeks	↑ 3.1% CON;↑ 3.0% LONG; ↑ 0.9% SHORT	T-Lim at 87% vVO_2max: ↑ 94% CON; ↑ 67% LONG; ↑ 65% SHORT
Sproule (1998)	n= 15 M; 23 y.o.; 56 ml·kg^{-1}·min^{-1}; PE students		Acute effect of 40-60 min. sessions at 70% VO_2max. G1 40 min. at 80%; G2 60 min. at 70%; G3 60 min. at 80%	3x40-60 min. at 80% VO_2max.	↓4.4% (G1); 6.6% (G2); 9.5% (G3)	
Beneke y Hutler (2005)	n=16 M; 24.8 y.o.; n/a ml·kg^{-1}·min^{-1}; Recreational athletes		CON training for 20-30 min. for first 4 weeks (intensity 50% HR reserve) increased to 45-60 min. in weeks 5-8 (60-75% reserve HR).	8 weeks: 3 sessions in week 1, 4 in weeks 2-6 and 5 in weeks 7 & 8.	↑ 10% CON	↑ 56% CON
Helgerud *et al.* (2007)	n = 40 M; 24.6 y.o.; 57.8 ml·kg^{-1}·min^{-1}; Students	Long (10) 4x4 min. at 90-95% HRmax with 3min. rec. at 70% HRmax, Short (10) 47x15s at 95% HRmax with 15 sec. rec. at 70% HRmax	Slow pace (10) 45 min. at 70% HRmax, anaerobic threshold pace (10) 25 min. at 85% HRmax	3 days/week for 8 weeks	No diff. between groups: ↑7,5-11,7%	
Quinn y Manley (2012)	n = 15 M 35.3 y.o.; 63.6 ml·kg^{-1}·min^{-1}; Healthy participants		Effect of long continuous training (26 km.).	Acute effect 1 session	No changes in subsequent days.	
Zaton y Michalik (2015)	n = 17 (11M, 6W); 34 y.o.; 50.7 ml·kg^{-1}·min^{-1}; Recreational athletes	G1 did 2 sessions of 4x20-30 sec. at max. intensity to complete 90-200 m. with active recovery (ratio 2:1) plus one continuous training session per week	G2: 3-4 sessions of continuous training per week without specifying intensity.	8 weeks	↑17% significant in relative VO_2max% in G2	↑2,5% in G1 ↑1,3% in G2 in Cooper Test
Gliemann *et al.* (2015)	n = 160 (73M, 84W); 47y.o.; 52,3 ml·kg^{-1}·min^{-1}; Recreational athletes	2 sessions of 3-4 x 5 min. alternating 10-20-30 sec. with 2 min. rec. Intensity of 30%, 60%, 90-100% maximal speed + 1 CON session (75-85% HRmax).	3 sessions per week at intensity 75-85% HRmax	8 weeks	↓2,85% INT, ↓ 1,95% CON	~
González-Mohíno *et al.* (2016)	n = 11 H; 33,1 y.o.; 56,7 ml·kg^{-1}·min^{-1}; Recreational athletes	3 sessions/week of repetitions of 1, 2 and 3 min. at 110%, 100% and 95% vVO_2max	3 sessions/week at 70% and 75% vVO_2max	6 weeks	↑ 17.8 and 8.5% CON sig. at 60% and 90% vVO_2max	vVO_2max ↑ 7,9% INT
Hoydal y Hareide (2016)	n = 22 (8M, 14W); 27,7 y.o.; 51,7 ml·kg^{-1}·min^{-1}; Healthy participants	4x4 min. (11) at 90-95% HRmax, 3 min. active recovery at 70%	75 min. (11) at 75% HRmax	3 days/week for 8 weeks	↑ 6% INT; 9% CON	3000 m: ↑ 3,06 min and 1,59 min (INT, CON)

Symbols: ↑ increase or improvement; ↓ decrease or deterioration; ~ no change.
Abbreviations: M: Men; W: Women; y.o.: Years old; n: Number of participants; PE: Physical Education; G: Group; HRmax: Maximum heart rate; CON: Continuous method; INT: Interval method; VO_2max: Maximal oxygen uptake; vVO_2max: Speed at maximal oxygen uptake intensity; T-Lim: Time to exhaustion; n/a: Not available.

intensity dictated by the subject). Intensities of 50% to 75% HR reserve[46], 70-85% maximum HR[40,41] and 70-75% of vVO_2max[9] have also produced RE improvements, although some authors have failed to observe changes at intensities of 75% to 80% maximum HR[42]. However, sessions of 40 to 60 min. at intensities between 70% and 80% of VO_2max evaluated as acute effect led to a reduction in RE in Physical Education students[44], showing that it is not advisable to evaluate RE after training sessions.

RE improvements in recreational runners could be due to biomechanical changes which make them more economical at the same running speed[47]. Hence the need to include biomechanical variables in the evaluations of recreational athletes when studying changes in RE.

Table 1 shows the studies of recreational athletes analysed in this section. Note the wide range of protocols used and results obtained in the different studies.

In trained athletes, INT training intensities of 100% vVO_2max[48,49] have obtained improvements of between 1 and 6.7%. Other high-intensity exercises, such as maximum sprints lasting 30 seconds[50], have revealed improvements of 6-7.2% and intensities of vΔ50[51-53] (intensity corresponding to 50% between speed at lactate threshold (vLT) and vVO_2max) have shown RE improvements of 3.6 to 5.4%. High-intensity training can also be carried out on terrain with different gradients. Intensities of 80% to 120% VO_2max[54] (4-18% gradient) have shown improvements in RE.

Billat *et al*.[55], on the other hand, investigated the effect of increasing the number of INT training sessions at 100% vVO_2max from 1 to 3, combined with 5 and 3 CON sessions, respectively, and its influence on RE. These authors noted an increase of 6% in RE with a single session of INT training, compared to a 2.7% increase when the sessions were raised to 3 per week and the CON training was reduced. This means that the relationship between high-intensity (INT) and low-intensity (CON) sessions is essential when it comes to improving the RE of trained runners. Enoksen *et al.*[56] conducted a study in which an INT training group did 33% of all its training using the INT method (3 sessions/week) at 82-92% HRmax and used the CON method at 65-82% HRmax for the rest. The CON training group did 13% of all its training with the INT method (1 session/week) and used the CON method at 65-82% HRmax for the rest. Both groups' RE improved: between 2.5% and 5% in the INT group, and between 1.5% and 4.8% in the CON group. Finally, it is important to note that very high training intensities (132% vVO_2max) do not lead to improvements in RE[39], possibly because they seriously limit the volume of training achievable. INT training and its acute effect on RE has also been studied. Collins *et al*.[57] evaluated the effect of three sessions of 10x400 with different recovery times (1, 2 and 3 min.). In all the sessions, RE suffered from 2 to 5%, indicating that RE should not be evaluated after training sessions, because high-intensity sessions increase the subsequent energy cost in the runner.

With the CON training method, training at vOBLA intensity[58,59] (intensity at which 4 mmol/L is produced in the body) has registered RE improvements of 2.8%. Table 2 shows the studies of trained athletes analysed in this section, describing the protocols used and results obtained in each study.

As can be seen, the RE improvements are proportionally higher in recreational athletes compared to trained athletes, reflecting the complexity of improving athletic performance through training at high levels. We can also see that, at high levels of performance, small improvements in any performance factor can be decisive to the final outcome.

Finally, it is important to note that athletes are normally more economical at the intensities at which they train[60], so it would be interesting to include intensities similar to competition intensities. Changes in RE depend on the intensity of training. In a comparative study of middle-distance and marathon runners by Daniels and Daniels[61], the results showed that the athletes were more economical at the intensities at which they compete (1,500 m or marathon). Therefore, these competition intensities, which will be high intensity, would lean us towards INT training to work at those paces and be more efficient.

While it is very important to know the effects of the two training methods on RE, discerning the best combination of the two will be key to future research and this calls for longitudinal studies capable of addressing the issue[62].

Warm-up intensity, running economy and performance

The effort involved in the warm-up prior to competition and its influence on RE can determine final performance, but this has not been studied very much to date. Warming up, of course, is an accepted practice in all sports prior to high-intensity exertion, be it later on in training or in a competition[63]. Given its specificity, the active warm-up is the method most widely used by runners[63]. High-intensity exercise (80% of the lactate threshold or vΔ50) prior to a performance test can alter the VO_2 response in the test, increase the magnitude of the main component of VO_2 and reduce the slow component[64,65]. Any intervention resulting in a rapid VO_2 dynamic (acceleration of VO_2 with respect to the baseline by increasing the absolute magnitude of VO_2) tends to result in an improvement in performance[66].

In the little research linking high-intensity exertion, RE and performance, some authors have found increases in energy cost (reduction of running economy) of 3% to7% after intense exercise[57,67-71] above the anaerobic threshold. A recent study by Barnes and Kilding[72], however, observed an improvement in performance after a warm-up with a series of 10-second sprints with a weighted vest at an intensity similar to competition intensity in the 1,500 metres. In this case, RE improved by 6% after the warm-up and the authors associated the improvement in performance with the improvement in RE and leg stiffness (neuromuscular variable). To date, studies suggest that high-intensity work prior to a performance test or competition increases energy cost (worsening RE), so it is essential that we investigate how long the recovery time between the high-intensity work and the competition should be for the physiological variables involved to return to basal levels so as not to hinder later performance.

Table 2. Effects of interval and continuous training on the running economy and performance of trained athletes. Participants, design and results.

Study	Participants	Research design		Results		
	Description	Interval training (n)	Continuous training (n)	Duration (sessions/week)	RE	Performance
Sjödin y Svedenhag (1982)	n = 8 M; 19.8 y.o.; 68.7 ml·kg^{-1}·min^{-1}; Middle- and long-distance runners		20 min. at vOBLA	1 day/week for 14	↑ 2.8%	
Yoshida *et al*. (1990)	n = 6 W; 19 y.o.; 51.8 ml·kg^{-1}·min^{-1}; Trained athletes		6x vOBLA (20 min.) + normal training (120 min. at threshold speed)	6 days/week for 8 weeks	↑2.8%	↑3,000 m test
Billat *et al.* (1999)	n = 8 M; 24 y.o.; 71.2 ml·kg^{-1}·min^{-1}; Well-trained athletes	Comparative study of 1 and 3 sessions/week of INT training at vVO-2max intensity, with 5 and 3 sessions CON training, resp.		4 weeks: 1 session/ week and another 4 weeks: 3 sessions/week	↑ 6.1% with 1 ses-sion/week and 2.7% switching from 1 to 3 sessions/week	↑ 2.9% in vVO$_2$max with 1 session/week, and 1.9% with 3 sessions/week
Collins *et al.* (2000)	n = 7 M; 25.4 y.o.; 72 ml·kg^{-1}·min^{-1}; Highly trained athletes	Three sessions of 10x400 with variation in recovery (1, 2, 3 min.)		Acute effect (3 random sessions)	↓ 4.6% y ↓1.8% at 3.33 and 4.47 m.·s^{-1}	
Demarle *et al.* (2001)	n = 6 M; 27 y.o.; 61.2 ml·kg^{-1}·min^{-1}; Trained athletes	2 INT sessions (50% at intensity vΔ50) in usual training. The number of repetitions was increased over the week.		2x interval + 3x continuous training sessions for 8 weeks	↑3.6%	↑10.24 and 10.1% in vVO2max in only 3 subjects
Slawinski *et al.* (2001)	n = 6 M; 27 y.o.; 61.2 ml·kg^{-1}·min^{-1}; Trained athletes	2 sessions of severe (vΔ50) and moderate (50%vVO-2max) INT training per week + 3 CON training sessions at 60%vVO$_2$max.		2xINT+ 3xCON, 8 weeks	↑3.6%	T-Lim at 17km/h. ↑17% not sig T-Lim at 17km/h. ↑17% not sig
Smith *et al*. (2001)	n = 27 M; 25.2 y.o.; 61.4 ml·kg^{-1}·min^{-1}; Well-trained athletes	6x2 min. vVO$_2$max + 1 x continuous at 60% and 5x 2.5 min. at vVO$_2$max + 1 x continuous at 70% vVO$_2$max			↑3.3% in 60% group and 0.8% in 70% group. Not sig.	↑ 6% T-Lim vVO$_2$max in 60% group.
Laffite *et al.* (2003)	n = 7 M; 24 y.o.; 61.1 ml·kg^{-1}·min^{-1}; Trained athletes	2x Δ50 INT; 3xCON		3xINT, 2xCON, 8 weeks	↑5.4%	Incremental test without changes
Denadai *et al.* (2006)	n = 17 M; 27.4 y.o.; 59.5 ml·kg^{-1}·min^{-1}; Trained athletes	2 x INT at 95 and 100% vVO$_2$max + 1 CON session vOBLA + 3 CON training sessions at 60-70%VO$_2$max		2 days/week INT + 4 days CON for 4 weeks	↑2.6 in 95% group; ↑6.7% in 100% vVO$_2$max group	↑2% in 1,500 m. and 1.4% in 5,000 in 100% vVO$_2$max group
Iaia *et al.* (2009)	n = 17 M; 33.9 y.o.; 55.5 ml·kg^{-1}·min^{-1}; Trained athletes	(9) Replaced training with 8-12x30" with 3' rec. Intensity of 93% per 30" maximum sprint	(8) Usual training + moderate-intensity training	3-5 days/week for 4 weeks	↑ 6-7.2% INT	~ 10k test
Enoksen *et al*. (2011)	n = 26 M; 19.9 y.o.; 70.3 ml·kg^{-1}·min^{-1}; Well-trained athletes	33% of training at 82-92% HRmax; the rest at 65-82% HRmax (G1). 3 INT sessions/week	13% of training at 82-92% HRmax, and the rest at 65-82% (G2). 1 INT session/week		↑2.5-5% in G1; ↑1.5-4.8% in G2	~ T-Lim at vVO$_2$max
Barnes *et al.* (2013)	n = 20 M; 21 y.o.; 63.9 ml·kg^{-1}·min^{-1}; Trained long-distance runners	At gradient: (G1) 12-24 x 8-12 sec. at 120%vVO$_2$max; (G2) 8-16 x 30-45 sec. at 110%vVO$_2$max; (G3) 5-9 x 2-2.5 min. at 100%vVO$_2$max; (G4) 4-7 x 4-5 min. at 90%vVO2max; (G5) 1-3 x 10-25 min. at 80% vVO$_2$max. *In addi-tion to usual training		2 days/week for 6 weeks	↑ 2.4% (G1); ↑ 0.6 (G2); ↓ 1.2 (G3); ↓ 2.4 (G4); ↓ 3.2 (G5)	↑ 2.15% T-Lim without differences between groups

Symbols: ↑ increase or improvement; ↓ decrease or deterioration; ~ no change.
Abbreviations: M: Men; W: Women; y.o.: Years old; n: Number of participants: PE Physical Education; G: Group; HRmax: Maximum heart rate; CON: Continuous method; INT: Interval method; VO$_2$max: Maximal oxygen uptake; vVO$_2$max: Speed at maximal oxygen uptake intensity; T-Lim: Time to exhaustion; vOBLA: speed as of 4mmol/L; vΔ50: 50% intensity between lactate threshold speed (vLT) and vVO$_2$max; n/a: Not available.

Regarding the effect of the intensity of the warm-up on subsequent performance, Zourdos *et al*[73] recently came to the conclusion that a warm-up at submaximal intensity (45-65% VO_2max) had little effect on performance compared to no warm-up at all. Van den Tillar *et al.*[74] compared two warm-up protocols and assessed their effects on subsequent performance. The first protocol was longer (general part plus specific high-intensity part) and the shorter one only consisted of the specific part (8x60 m. sprint). They found no differences in performance between the warm-up protocols and came to the conclusion that, because it represents a more efficient use of time, the shorter option may be a good alternative. Ingham *et al.*[75] used competition intensity (800 m.) to quantify the impact of the prior warm-up on their performance test. They came to the conclusion that sustained high-intensity exertion (2x50 m. + 200 m. at competition intensity) improved performance compared to less sustained effort (6x50 m.) at the same intensity. As can be seen, recent research[74,75] shows that the inclusion of high-intensity exercise in warm-up sessions improves later performance more than low-intensity exercise[71], although high-intensity exercise may worsen RE[57,67-71] and this should be taken into account, especially regarding the amount of time between the high-intensity work and the competition or performance test.

Conclusions

As we have seen, RE is a basic variable which, due to its direct relationship with performance, needs to be evaluated to establish how much runners improve. Endurance training modifies this variable and the intensity of training is crucial when it comes to achieving this.

With recreational runners, disparate results are obtained when INT and CON training are compared. For this group of athletes, controlled training organised into periods should lead to improvements in RE over time. INT training (2-3 sessions per week) should be included gradually and always in combination with a lot of CON training[42], because a greater proportion of INT compared to low-intensity training (CON) does not lead to any improvement in RE[45]. Besides biomechanical changes[47], the increase in the volume of training could be the chief reason for improvements in RE. With trained athletes, the relationship between high-intensity (INT) and low-intensity (CON) sessions is essential when it comes to improving RE[55]. Intensities near vVO_2max are recommended to improve RE and the speed associated with VO_2max[51], but when these are too high (132% VO_2max), they do not lead to improvements in RE, possibly because it is not possible to do enough high-intensity training[39]. With long-distance runners, CON training at vOBLA[58] produces RE improvements approaching 3%. Given the great variety of methodologies used in the studies reviewed, it is difficult to pinpoint an optimal intensity for RE improvement. We recommend that trained runners train at intensities near 100% vVO_2max to improve RE and intensities close to competition intensity to enhance the efficiency of this work.

Finally, regarding the effect of race intensity during the warm-up on RE, high-intensity exercise[57,67-71] reduces RE by 3-7%. This means that there should be a generous transition and recovery stage between such exercise and a competition. This transitional period could be between 9 min.[67] and 20 min.[2]. The incorporation of high intensity exercise[74,75] improves final performance when compared with low-intensity exercise[73].

In conclusion, and on a practical note, we recommend that coaches and athletes include high-intensity training (INT) in their programmes, bearing in mind that it should be accompanied by low-intensity training (CON) so that the training loads can be assumed. For trained athletes, a ratio of 80:20 is usually recommended, giving priority to low-intensity training and only working at high intensity, above the anaerobic threshold, in the remaining 20%[76]. The inclusion of intensities similar to competition intensity could also be recommendable for both recreational and trained athletes.

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XVII CONGRESO INTERNACIONAL DE LA SOCIEDAD ESPAÑOLA DE MEDICINA DEL DEPORTE

FUERZAS ARMADAS – SOCIEDAD
Una alianza a través de la actividad física y el deporte

Toledo - Hotel Beatriz Toledo Auditórium
29-30 de noviembre y 1 de diciembre de 2018

Sociedad Española de Medicina del Deporte

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	Ángel Sánchez Ramos
	José Luis Terreros Blanco

PROGRAMA PRELIMINAR

JUEVES, día 29

SESIÓN PLENARIA: El pasado y el presente de la traumatología del deporte.

José María Vilarrubias Guillamet
Mikel Sánchez Álvarez

PONENCIA OFICIAL: Patología del pie en el deporte.
Moderador: **Ángel González de la Rubia Heredia**

Valoración de la morfología, rigidez y función del arco del pie en el corredor.
Luis Enrique Roche Seruendo

Talalgias en el deportista. Abordaje clínico.
Alfonso Martínez Franco.

Dolor aquileo: las lesiones del tendón más poderoso.
Sergio Tejero García

PONENCIA OFICIAL de la Agencia Española de Protección de la Salud en el Deporte (AEPSAD): El Pasaporte Biológico del Deportista (PBD), presente y futuro.
Moderador: **José L. Terreros Blanco**

El PBD como herramienta en el control de dopaje.
Jesús A. Muñoz Revilla

El PBD, una visión desde la Medicina del Deporte.
Pedro Manonelles Marqueta

El PBD, una visión jurídica.
Agustín González González

PONENCIA OFICIAL: Probióticos y deporte.

SIMPOSIO: Alimentación en situaciones extremas

La alimentación del ejército en operaciones de campaña.
Juan Manuel Ballesteros Arribas

La alimentación en la travesía del Atlántico a remo.
Jorge Pena Mariño

La alimentación en altitud extrema.

TALLER: Taller de interpretación del electrocardiograma en el deportista.

Emilio Luengo Fernández

VIERNES, día 30

SESIÓN PLENARIA: El futuro del alto rendimiento deportivo/ *The future of high sports performance.*
Moderador: **José Naranjo Orellana**

El maratón en menos de dos horas:
The Sub2 Marathon Project: Galileo contra Goliat.
The Sub2 Marathon Project: Galileo versus Goliath.
Yannis Pitsiladis

Algoritmos de predicción de récords deportivos.
Sports record prediction algorithms.
John H. J. Einmahl

PONENCIA OFICIAL: El entrenamiento de la fuerza y la fatiga.
Moderador: **Fernando Alacid Cárceles**

Entrenamiento de fuerza y fatiga.
José Manuel García García

Entrenamiento adecuado para soportar la fatiga en colectivos especiales.
Nuria Mendoza Laiz

Alimentación adecuada para soportar la fatiga.
Antonio López Farré

PONENCIA OFICIAL: Actualización en deporte adaptado.

Principales adaptaciones de los servicios médicos a la inclusión deportiva en el deporte federado.
Josep Oriol Martínez Ferrer

Baloncesto en silla de ruedas en España: aplicaciones inclusivas y de investigación.
Javier Pérez Tejero

Deporte terapéutico en lesionados medulares.
Ana Esclarín de Ruz

PONENCIA OFICIAL: Ejercicio físico en el ámbito militar.
Moderador: **Juan Ramón Godoy López**

Ejercicio físico en condiciones extremas en militares de operaciones especiales.
Claudio Nieto Jiménez

Hacia un nuevo modelo de preparación física militar.
José Francisco García Marco Reclamado

Entrenamiento físico del personal de vuelo.
Carlos Velasco Díaz.

SIMPOSIO: Terapias no invasivas en la tendinopatía calcificante del hombro.
Moderador: **Miguel Del Valle Soto**

Electroterapia.
Juan Nápoles Carreras

Ejercicio.
Fernando Ramos Gómez

Ondas de choque.
Óscar Sanjuán Reguera

TALLER: Taller de interpretación de la prueba de esfuerzo.
José Naranjo Orellana

SÁBADO, día 1

SESIÓN PLENARIA: ¿Hacia dónde se dirige la nutrición en el deporte y en la actividad física?

La alimentación en el deporte y el ejercicio / *Nutrition for sports and exercise*
Ron Maughan

El futuro de la nutrición en la actividad física.
Luis Moreno Aznar

PRESENTACIONES

Documento de consenso de la Sociedad Española de Medicina del Deporte (SEMED-FEMEDE) sobre contraindicaciones para la práctica deportiva.

Documento de Consenso de la Sociedad Española de Medicina del Deporte (SEMED-FEMEDE) sobre lesiones y accidentes deportivos.

Documento de Consenso de la Sociedad Española de Medicina del Deporte (SEMED-FEMEDE) sobre ayudas ergogénicas.

REMISIÓN DE COMUNICACIONES CIENTÍFICAS

El Comité Científico invita a todos los participantes a remitir comunicaciones científicas (comunicaciones orales y póster-presentación interactiva) al XVII Congreso Nacional de la Sociedad Española de Medicina del Deporte.

Temas para presentación de Comunicaciones Científicas en el Congreso:

- Medicina del deporte.
- Entrenamiento y mejora del rendimiento.
- Biomecánica.
- Cardiología del deporte.
- Fisiología del esfuerzo.
- Nutrición y ayudas ergogénicas.
- Cineantropometría.
- Lesiones deportivas: diagnóstico, prevención y tratamiento.
- Actividad física y salud.

Las Comunicaciones Orales se distribuirán en sesiones de los temas del Congreso. Por favor, escoja uno de los temas del listado como propuesta para realizar su presentación. El Comité Científico podrá reasignar el abstract en otro tema del Congreso.

Los trabajos deberán ser originales y no se habrán presentado en congresos anteriores o reuniones similares.

Las comunicaciones científicas admitidas, comunicaciones orales y pósters (presentación interactiva), serán publicadas en la revista Archivos de Medicina del Deporte.

Normas de remisión de abstracts

Por favor, preste atención a las siguientes normas de preparación del abstract de su comunicación científica (comunicación oral o póster: presentación interactiva), porque son de obligado cumplimiento:

- La fecha límite para la remisión de los trabajos científicos será el día **14 de septiembre de 2018**.
- Se remitirá la Comunicación Científica a la atención del presidente del Comité Científico, con el formulario debidamente cumplimentado, a la siguiente dirección de correo electrónico: **congresos@femede.es**.
- El abstract tiene que tener una clara relación con los contenidos del XVII Congreso Nacional de la Sociedad Española de Medicina del Deporte y, en definitiva, con la Medicina y Ciencias del Deporte.
- El Comité Científico podrá destinar el trabajo presentado a la forma de presentación (comunicación oral o póster: presentación interactiva) que considere más adecuada al tipo y contenido del mismo.
- El Comité Científico se reserva el derecho de rechazar los trabajos que no cumplan los requisitos indicados anteriormente por la calidad y temática que el evento científico requiere.

Forma de preparación del abstract

- Sólo se aceptarán las comunicaciones científicas presentadas en el formato electrónico que se encuentra en la página web del Congreso: http://www.femede.es/congresotoledo2018/ "Formato de comunicación científica".
- **Título:** El título deberá ser breve (máximo de 15 palabras) y específico. Debe reflejar el contenido de la presentación. No use abreviaturas en el título. Se escribirá en letras mayúsculas, usando el tamaño 12 del tipo de letra Arial.
- **Autores:** Se escribirá, en minúsculas, el apellido seguido, sin coma, de la inicial del nombre de cada autor, separados por comas.
- **Centro:** Indicar el centro de trabajo de los autores. Si son varios, indicar con un número superíndice.
- **Preferencia de presentación:** Seleccionar con un asterisco el tipo de presentación a la presenta la comunicación científica.
- **Texto:** La extensión máxima del texto es de 300 palabras o 3.000 caracteres. Se escribirá en minúsculas,

usando el tamaño 10 de la letra Arial. Se evitarán abreviaturas no explicadas. Se escribirá el contenido del resumen científico sin repetir el título de la Comunicación y ajustándose al siguiente esquema: introducción, material y métodos, resultados y conclusiones.

- Respetando la extensión máxima del texto se pueden incluir tablas, gráficos o imágenes.
- Es obligatorio indicar un máximo de **tres palabras clave**.
- Los abstracts deben incluir **información específica** sobre los resultados y las conclusiones de la investigación. No se aceptarán abstracts que establezcan que "se discutirán los resultados".

Notificación de la recepción de la comunicación científica

En el plazo de 15 días, Vd. recibirá la confirmación de recepción de la comunicación por parte de la Secretaría del Congreso. Si no la recibiera, no vuelva a remitir la comunicación y envíe un mensaje electrónico: congresos@femede.es.

Inscripción del responsable de la comunicación científica

- Cada persona puede presentar dos comunicaciones científicas como máximo (comunicación oral o póster: presentación interactiva). En caso de ser aceptadas ambas, sólo una de ellas podrá ser presentada como comunicación oral.
- Los autores (CADA UNO PUEDE PRESENTAR DOS TRABAJOS) que presenten una comunicación científica (comunicación oral o póster-presentación interactiva) y ésta haya sido aceptada, deben haberse registrado y **haber pagado los derechos de inscripción del Congreso antes del 25 de octubre de 2018**. En caso contrario su comunicación científica (comunicación oral o póster-presentación interactiva) será eliminada del programa y del libro de abstracts.
- Cada autor puede FIRMAR todos los trabajos que quiera.
- No hay limitación en el número de comunicaciones que puede aparecer una misma persona.

Presentación de la comunicación oral

- Las Comunicaciones Orales tendrán un **tiempo de presentación de 8 minutos.** Al final de cada sesión habrá un turno de preguntas.
- Todas las exposiciones orales se harán en **formato Powerpoint**, debiendo estar en posesión del responsable de las Comunicaciones de la organización el día anterior a la presentación de la misma.
- Se limita a un **máximo de 12 el número de diapositivas** de la presentación de powerpoint.

Póster (presentación interactiva)

Si su abstract se acepta, pero no se puede ajustar a una presentación en forma de Comunicación Oral, se le propondrá presentarlo en forma de póster-presentación interactiva, dándole un tiempo para su preparación.

Presentación del póster (presentación interactiva)

Para la elaboración del póster (presentación interactiva) debe seguir las siguientes instrucciones que son de obligado cumplimiento:

- Formato **Microsoft Powerpoint**.
- Hasta 12 diapositivas, de las cuales:
  - La primera: debe contener **título, autores, centro de trabajo**.
  - La última: debe contener **título** y la palabra **FIN** o expresión similar que indique que la presentación ha concluido.
  - La penúltima o las dos penúltimas deben contener las **conclusiones**.
- Fondo de diapositivas: color neutro y uniforme.
- Texto de diapositivas: color que **contraste** con el fondo.

- En lo posible evitar incluir vídeos en las diapositivas, si se hiciera debería ser en formato **.wmv** y se deberá incluir en un subdirectorio/carpeta que enlace automáticamente con la presentación remitida. Si el video no enlazara con la presentación, no se editará por parte de la organización para corregir el error.
- La organización se reserva el derecho de ocultar diapositivas que incluyan contenidos inapropiados o inadecuadamente referenciados.
- El uso de cualquier imagen que no sea de la autoría del/de los firmante/firmantes de la presentación deberá contener referencia a (y eventualmente permiso de) su autor en la misma presentación o bien podrá ser retirada de la misma y en todo caso la organización no se hará responsable en ningún caso de las consecuencias del uso inapropiado de aquellas.
- Se cuidará de igual manera de incluir las referencias bibliográficas oportunas en pequeño tamaño de letra, pero que sea legible.
- El abstract debe remitirse preparado tal como se indica anteriormente **(Forma de preparación del abstract)**.
- Una vez que se le confirme que su comunicación científica ha sido aceptada para ser presentada en forma de póster (presentación interactiva) debe enviar el documento electrónico **(.Ppt)**:
  - Trabajos destinados por el autor directamente a póster (presentación interactiva): **antes del 14 de septiembre de 2018**.
  - Trabajos destinados por el autor a Comunicación Oral y que el Comité Científico destina a póster (presentación interactiva): **antes del 20 de septiembre de 2018**.
- El documento electrónico **(.Ppt)**: debe enviarse a la dirección electrónica del Congreso: congresos@femede.es.

Certificaciones

Tras la presentación de la comunicación oral o la defensa del póster en el modo en que se indique se entregará un **único certificado** al responsable de la comunicación científica.

Publicación de los trabajos científicos

Los abstracts de los trabajos científicos (comunicaciones orales y póster) **aceptados y presentados** en el XVII Congreso Nacional de la Sociedad Española de Medicina del Deporte serán publicados en la revista ***Archivos de Medicina del Deporte***, publicación científica de esta especialidad y revista oficial de la Sociedad Española de Medicina del Deporte, que tiene una periodicidad de publicación bi-mensual.

PREMIOS

Los inscritos en el Congreso que presenten comunicaciones podrán optar al Premio a la **Mejor Comunicación oral** del Congreso.

Para optar al premio **SE DEBE HACER CONSTAR EXPLÍCITAMENTE QUE SE OPTA A PREMIO** en carta dirigida al presidente del Comité Científico y adjuntar al Resumen remitido. En este caso, además de enviar el Formato del Resumen de Comunicación Científica, se debe de mandar el trabajo completo en el plazo de presentación de las Comunicaciones Científicas, presentado según las normas de publicación de la revista Archivos de Medicina del Deporte.

Los trabajos que se presentan en formato de póster (presentación interactiva) no optan a premio.

El trabajo que obtenga la segunda mejor puntuación, y supere en nivel de calidad exigible, será dotado con un accésit a la Mejor Comunicación del Congreso.

Dotación de los premios

Premio a la Mejor Comunicación Oral del Congreso:

- Dotación económica: 1.500 euros.
- Certificado acreditativo.
- Publicación en la revista Archivos de Medicina del Deporte con indicación del premio obtenido.

Accésit a la Mejor Comunicación Oral del Congreso:

- Dotación económica: 1.000 euros.
- Certificado acreditativo.
- Publicación en la revista Archivos de Medicina del Deporte con indicación del premio obtenido.

Los trabajos premiados serán publicados en la revista Archivos de Medicina del Deporte y se aceptará la revisión efectuada por el Comité Científico.

Los premios podrán ser declarados desiertos si no alcanzan el nivel de calidad exigible.

INFORMACIÓN GENERAL

Fecha
29-30 de noviembre y 1 de diciembre de 2018

Lugar
Hotel Beatriz Toledo Auditorium
C/ Concilios de Toledo, s/n. 45005 Toledo
Teléfono: +34 925 26 91 00
Página web: http://www.beatrizhoteles.com/es/beatriz-toledo.html

Secretaría Científica
Sociedad Española de Medicina del Deporte
Apartado de correos 1207. 31080 Pamplona
Teléfono: +34 948 26 77 06 – Fax: +34 948 17 14 31
Correo electrónico: congresos@femede.es
Página web: http://www.femede.es/congresotoledo2018/

Secretaría Técnica
Viajes El Corte Inglés S.A.
División Eventos Deportivos
C/ Tarifa, nº 8. 41002 Sevilla
Teléfono: + 34 954 50 66 23
Correo electrónico: areaeventos@viajeseci.es
Personas de contacto: Marisa Sirodey y Silvia Herreros

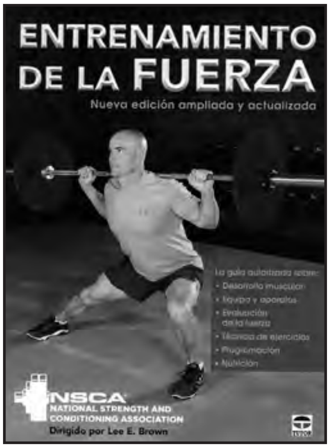
Idioma oficial
El lenguaje oficial del Congreso es el español.
Traducción simultánea de sesiones plenarias y ponencias.

DERECHOS DE INSCRIPCIÓN

	Antes del 31/8/2018	Del 1/8/2018 al 8/11/2018	Desde el 9/11/2018 y en Congreso
Cuota general	350 euros	450 euros	500 euros
SEMED-FEMEDE	300 euros	400 euros	450 euros
Médicos MIR, doctorandos y becarios de investigación*	300 euros	400 euros	450 euros
Médicos MIR, doctorandos y becarios de investigación* que presenten comunicación científica	250 euros	200 euros	450 euros
Dietistas/Nutricionistas**	300 euros	400 euros	450 euros
AEF***	300 euros	400 euros	450 euros

*Es necesaria acreditación. Sin certificación se cobrará la cuota general.
**Dietistas-nutricionistas de asociaciones o colegios autonómicos de todo el territorio español. Es necesaria acreditación. Sin certificación se cobrará la cuota general.
***AEF: Asociación Española de Fisioterapeutas. Es necesaria acreditación. Sin certificación se cobrará la cuota general.

Cuota general, SEMED-FEMEDE, MIR, Dietistas/Nutricionistas, AEF. Incluye la asistencia a todas las sesiones científicas, la documentación del congresista, los cafés, las comidas de trabajo y la exposición comercial.

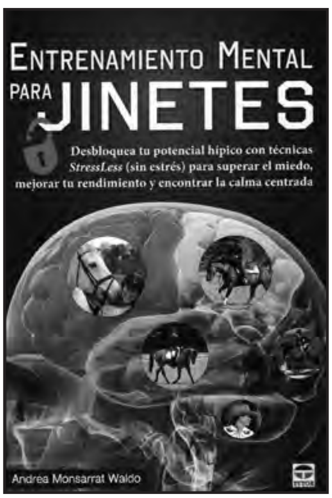


Entrenamiento de la fuerza. Nueva edición ampliada y actualizada

Por: NSCA
Edita: Ediciones Tutor-Editorial El Drac.
Impresores 20. P.E. Prado del Espino. 28660 Boadilla del Monte. Madrid.
Telf. 915 599 832 - Fax. 915 410 235
E-mail: info@edicionestutor.com Web: www.edicionestutor.com
Madrid 2017, 400 páginas, P.V.P: 49,95 euros

En una época en la que estamos rodeados de información, el reto es encontrar una ciencia segura y eficaz que se base en datos objetivos. Pues bien, eso es justo lo que nos ofrece la NSCA, la autoridad mundial en el campo de la fuerza y el acondicionamiento. La primera edición de "Entrenamiento de la fuerza" redefinió las reglas del ejercicio físico con una ciencia sensata y clara. Ahora, esta nueva edición ampliada y actualizada pone el listón aún más alto.

Escrito por un equipo de expertos seleccionados por la NSCA, esta obra combina la información más valiosa con las mejores indicaciones para obtener unos resultados demostrados a la hora de: evaluar la fuerza para personalizar los programas; incorporar nuevos ejercicios y aparatos para una mayor variedad; aumentar la masa muscular, así como la fuerza, la potencia y la resistencia de los músculos; prevenir lesiones y mejorar el rendimiento.



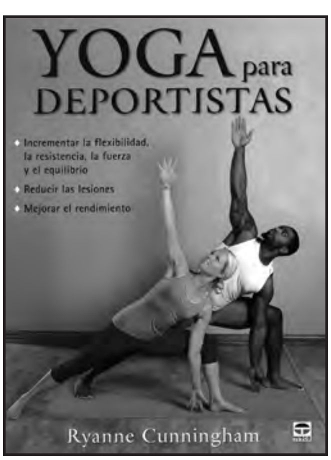
ENTRENAMIENTO MENTAL PARA JINETES

Por: Andrea Monsarrat Waldo
Edita: Ediciones Tutor-Editorial El Drac.
Impresores 20. P.E. Prado del Espino. 28660 Boadilla del Monte. Madrid.
Telf. 915 599 832 - Fax. 915 410 235
E-mail: info@edicionestutor.com Web: www.edicionestutor.com
Madrid 2017, 224 páginas, P.V.P: 19,95 euros

¿Sabía el lector que existe una zona de su cerebro conocida como "Cerebro Reptiliano" que piensa solo en el momento inmediato y cómo sobrevivir? Sí, en determinadas circunstancias, nuestro "Cerebro Racional" puede dejar de funcionar y quedarnos a merced de un reptil… la boca seca, sudamos, temblamos, siendo incapaces de pensar con claridad… aunque sepamos que no deberíamos hacerle caso.

¿Cuándo toma las riendas el cerebro reptiliano? Puede suceder en cualquier situación poco familiar, incómoda, desafiante o estresante, con caballos o sin ellos. Pero aquí viene lo bueno: con el entrenamiento correcto, se puede aprender a controlar el reptil que llevamos dentro, lo que conduce a una mayor confianza con los caballos, un mejor rendimiento ecuestre y, en definitiva, a un entorno feliz en la cuadra, en las competiciones y en cualquier otro punto entre medias.

Esta obra ayudará al lector a lidiar con emociones incómodas y perfeccionar el juego mental



YOGA PARA DEPORTISTAS

Por: Ryanne Cunningham
Edita: Ediciones Tutor-Editorial El Drac.
Impresores 20. P.E. Prado del Espino. 28660 Boadilla del Monte. Madrid.
Telf. 915 599 832 - Fax. 915 410 235
E-mail: info@edicionestutor.com Web: www.edicionestutor.com
Madrid 2018, 256 páginas, P.V.P: 29,95 euros

Desde el campo de fútbol hasta la pista de tenis, los mejores atletas conocen hoy los beneficios del yoga. Por eso, tantos lo han convertido en un componente esencial de sus programas de entrenamiento y acondicionamiento. La autora, ha trabajado con algunos de los nombres más destacados del deporte. Ha ayudado a mantener en el campo a algunos de los jugadores más duros de la NFL, y a correr durante más tiempo y con mayor potencia a atletas de resistencia sobresalientes.

Esta obra está pensada para todos los deportistas, desde aficionados de fin de semana hasta profesionales, de deportes tales como: tenis, fútbol, golf, running, natación, baloncesto, ciclismo, etc. Utilizando demostraciones de las posturas físicas, respiración y visualización mental guiada, se busca mejorar el rendimiento, reducir el riesgo de lesión y potenciar al máximo los resultados del entrenamiento.

2018		
14º Congreso Internacional de Ciencias del Deporte y la Salud	3-5 Mayo Pontevedra	web: www.sportis.es/congresos
Congreso Internacional de Fisioterapia	4-5 Mayo Barcelona	web: http://ftp18.cat/en/
18th ESSKA Congress	9-12 Mayo Glasgow (Reino Unido)	web: http://esska-congress.org/
III Congreso Internacional y IV Nacional de Hidratación	13 Mayo Bilbao	web: http://hydration2018.cieah.ulpgc.es/programa.asp
56 Congreso SERMEF	16-19 Mayo Gijón-Asturias	web: www.sermef.es
7thWorld Conference on Women and Sport	17-20 Mayo Gaborone (Bostwana)	web: www.icsspe.org/sites/default/files/e8_7TH%20 IWG%20Conference%20docx.pdf
ICAS 2018: 20th Int. Conference on Adoleslescent Sports	24-25 Mayo Montreal (Canadá)	web: https://www.waset.org/conference/2018/05 /montreal/ICAS
XXII Curso Asoc. Española Med. del Futbol	25-26 Mayo Málaga	web: http://www.aemef.org/es/
Jornada GREC: "Bioimpedancia eléctrica y composición corporal"	26 Mayo Málaga	E-mail: femede@femede.es web: www.femede.es
World Congress on Exercise is Medicine (ACSM)	29 Mayo-2 Junio Minneapolis (EEUU)	web: /www.acsmannualmeeting.org/attend/registration/
19th EFORT Congress	30 Mayo-1 Junio Barcelona	web: https://www.efort.org/barcelona2018/
XXVII Isokinetic Medical Group conference:"Football medicine outcomes. Are we winning?"	2-4 Junio Barcelona	E-mail: conference@isokinetik.com web: www.footballmedicinestrategies.com
5th International Congress of Exercise and Sport Sciences	5-10 Junio Netanya (Israel)	web: https://events.eventact.com/EventsList/ 5sportsceince2017/General-Information
20th Int. Conference on Women and Sport	6-7 Junio San Francisco (EEUU)	web: www.waset.org/conference/2018/06/ san-francisco/ICWS
Women in Sport and Exercise Conference 2018	13-14 Junio Staffordshire (Reino Unido)	web: www.staffs.ac.uk/events/womeninsport/
Curso nacional de rehabilitación en deformidades del raquis	14-15 Junio Barcelona	web: www.aulavhebron.net/aula/ index.php?go=info_cursos&curso=110&idioma=es
Juegos Mundiales de la Medicina y Simposio Internacional de Medicina Deportiva	16-23 Junio Malta	web: www.medigames.com/?page_id=6408&lang=es ç
XVII Congreso de la Sociedad Española de Nutrición	27-29 Junio Barcelona	web: http://www.sen2018barcelona.com/index.asp
XXIX Jornadas AEMB	28-30 Junio Barcelona	web: https://aemeb.es/barcelona2018/

European Congress of Adapted Physical Activity (EUCAPA)	3-5 Julio Worcester (Reino Unido)	Andrea Faull. E-mail: a.faull@worc.ac.uk Ken Black. E-mail: k.black@worc.ac.uk
23rd Annual Congress of the European College of Sport Science	4-7 Julio Dublín (Irlanda)	web: www.ecss-congress.eu/2018/
World Congress of Biomechanics	8-12 Julio Dublín (Irlanda)	web: http://wcb2018.com/
12th World Congress of the International Society of Physical and Rehabilitation Medicine (ISPRM)	8-12 Julio París (Francia)	web: http://isprm2018.com/
21st World Congress on Nutrition & Food Sciences	9-10 Julio Sydney (Australia)	web: https://nutritioncongress.nutritionalconference.com
The Annual World Congress of Orthopaedics	25-27 Julio Milán (Italia)	web: http://www.bitcongress.com/wcort2018 / http://www.bitcongress.com/wcort2018/programlayout.asp
World Congress of the Association Internationale des Ecoles Supérieures d'Education Physique (AIESEP)	25-28 Julio Edimburgo (Reino Unido)	web: http://aiesep.org/
XXXV Congreso Mundial de Medicina del Deporte	12-15 Septiembre Rio de Janeiro (Brasil)	web: www.fims.org
28º Congress European Society for surgery of the shoulder and the elbow (SECEC-ESSSE)	19-22 Septiembre Ginebra (Suiza)	web: www.secec.org
XI Congress Société Française de Médecine de l'Exercice et du Sport (SFMES)	20-22 Septiembre Le Havre (Francia)	web: www.sfmes.org
55 Congreso SECOT	26-28 Septiembre Valladolid	web: www.secot.es
5th International Scientific Tendinopathy Symposium (ISTS)	27-29 Septiembre Groningen (Países Bajos)	web: http://ists2018.com/
VII Congreso Iberoamericano de Psicología del Deporte	3-5 Octubre Las Condes (Chile)	web: www.postgradounab.cl/actividades/vii-congreso-iberoamericano-de-psicologia-del-deporte/
XXVIII Congreso AMLAR 2018 - Asociación Medica Latinoamericana de Rehabilitación	3-6 Octubre Guayaquil (Ecuador)	web: http://amlar2018.com/
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Congreso Internacional Cubamotricidad 2018	22-26 Octubre La Habana (Cuba)	web: http://cubamotricidad.inder.gob.cu
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2as Jornadas Nacionales SETRADE	8-9 Noviembre Vitoria	web: www.setrade.org

7º Congreso Mundial del Deporte Escolar, Educación Física y Psicomotricidad	8-10 Noviembre A Coruña	web: www.sportis.es/congresos
XVIII Congreso latinoamericano de Nutrición (SLAN) 2018	11-15 Noviembre Guadalajara (México)	web: www.slaninternacional.org
XII World Congress on Mountain Medicine	21-24 Noviembre Kathmandu (Nepal)	web: http://ismm2018.org/
XVII Congreso Nacional de la SEMED-FEMEDE	29 Noviembre-1 Diciembre Toledo	web: www.femede.es
2019		
XVI Congreso Nacional de Psicología de la Act. Física y del Deporte	13-16 Marzo Zaragoza	web: www.psicologiadeporte.org
XXXVI Congresso FMSI: "Età biologica, età anagrafica"	27-29 Marzo Roma (Italia)	web: www.fmsi.it/
2019 AMSSM Annual Meeting	12-17 Abril Houston (EEUU)	web: https://www.amssm.org/
12th Biennial ISAKOS	12-16 Mayo Cancún (México)	web: www.isakos.com
VIII Congreso Iberoamericano de Nutrición	3-5 Julio Pamplona	web: http://www.academianutricionydietetica.org/congreso.php?id=7#
24th Annual Congress of the European College of Sport Science	3-6 Julio Praga (Rep. Checa)	E-mail: office@sport-science.org
13th Congreso Mundial de la International Society of Physical and Rehabilitation Medicine	9-13 Julio Kobe (Japón)	web: http://www.isprm.org
14th International Congress of shoulder and elbow surgery (ICSES)	17-20 Septiembre Buenos Aires (Argentina)	web: www.icses2019.org
5th World Conference on Doping in Sport	5-7 Noviembre Katowice (Polonia)	web: http://www.wada-ama.org/
2020		
25th Annual Congress of the European College of Sport Science	1-4 Julio Sevilla	E-mail: office@sport-science.org
XXXVI Congreso Mundial de Medicina del Deporte	24-27 Septiembre Atenas (Grecia)	web: www.globalevents.gr
2021		
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/

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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 de las prestaciones y rendimiento del deportista, para que cumpla con sus expectativas competitivas y de prolongación de su práctica deportiva, y para que la práctica deportiva minimice las consecuencias que puede tener para su salud, tanto desde el punto de vista médico como lesional.

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Curso "ALIMENTACIÓN Y NUTRICIÓN EN EL DEPORTE"

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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.

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- Traumatismos [11]
- Artrosis [12]
- Intolerantes a los AINE's

Referencias bibliográficas:
1. Klein G, Kullich W. Reducing pain by oral enzyme therapy in rheumatic diseases. Wien Med Wochenschr 1999;149(21-22):577-580.2. Gregory, S, Kelly, ND. Bromelain: A Literature Review and Discussion of its Therapeutic Applications. Alt Med Rev 1996;1(4):243-257. 3. Roep BO, van den Engel NK, van Halteren AGS, Duinkerken G, Martin S. Modulation of autoimmunity to beta-cell antigens by proteases. Diabetologica 2002;45(5):686-692. 4. Klein G, Kullich W, Schnitker J, Schwann H. Effi cacy and tolerance of an oral enzyme combination in painful osteoarthritis of the hip. A double-blind, randomised study comparing oral enzymes with non-steroidal anti-infl ammatory drugs. Clin Exp Rheumatol 2006;24(1):25-30. 5. Ueberall, M. A., Mueller-Schwefe, G. H., Wigand, R., & Essner, U. (2016). Efficacy, tolerability, and safety of anoral enzyme combination vs diclofenac in osteoarthritis of the knee: results of an individual patient-level pooledreanalysis of data from six randomized controlled trials. Journal of pain research, 9, 941.6. Wittenborg A, Bock PR, Hanisch J, Saller R, Schneider B. Comparative_epidemiological_study in patients with rheumatic diseases illustrated in a example of a treatment with non-steroidal anti-inflammatory drugs versus an oral enzyme combination preparation. Arzneimittelforschung._2000;50(8):728-38. 7. May C, Smola M, Ruda C, Scharnagl E. Randomized open controlled clinical study on the efficacy and tolerance of an oral enzyme preparation in lymphadenectonomy patients. International Journal of Immunotherapy. 2001; XVII (2/3/4):149-152. 8. Akhtar N, Naseer R, Farooqi A, Aziz W, Nazir M. Oral enzyme combination versus Diclofenaco in the treatment of osteoarthritis of the knee- a double-blind prospective randomized study. Clinical –rheumatology. 2004;23:410-415. 9. Masson M. Bromelain in blunt injuries of the locomotor system. A study of observedapplications in general practice. Fortschr. Med. 1995;113:303-6. 10. Kerkhoff s GM, Struijs PA, de Wit C, Rahlfs VW, Zwipp H, van Dijk CN. A double blind, randomised, parallel group study on the effi cacy and safety of treating acute lateral ankle sprain with oral hydrolytic enzymes. Br. J. Sports Med.2004;38:431-5. 11. KamenícekV, Holán P, Franêk P. Systemic enzyme therapy in the treatment and prevention of post-traumatic and postoperative swelling. Acta Chir. Orthop.Traumatol. Cech. 2001;68:45-9. 12. Wittenborg A, Bock PR, Hanisch J, Saller R, Schneider B. Comparative epidemiological study in patients with rheumatic diseases illustrated in a example of a treatment with non-steroidal anti- inflammatory drugs versus an oral enzyme combination preparation. Arzneimittelforschung 2000;50:728-38.

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