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Sociedad Española de Medicina del Deporte
C/ Cánovas nº 7, local
50004 Zaragoza (España)
Tel. +34 976 02 45 09
femede@femede.es
www.femede.es

Correspondencia:
C/ Cánovas nº 7, local
50004 Zaragoza (España)
archmeddeporte@semede.es
http://www.archivosdemedicinadeldeporte.com/

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Summary / Sumario

Fewer supplements and more nourishment. More professionals and less professional intrusion

Menos suplementos y más alimentos. Más profesionales y menos intrusistas

Jesús Rodríguez Huertas

Instituto de Nutrición y Tecnología de los Alimentos. Centro de Investigación Biomédica. Departamento de Fisiología. Universidad de Granada.

Sports medicine and related sciences are as old and determinative for athletes as the relationship between nutrition and health has been for the development of the human species. It is a science in continuous development which surprises us with its endless breakthroughs. However, and maybe for this very reason, it is the victim of an unprecedented and intolerable level of professional intrusion.

An interesting article was recently published which revealed that only 3% of British runners receive advice on nutrition from specialists, the rest resorting to the Internet, their coach, non-specialised magazines, friends and so on[1]. This goes to show that, for athletes, both recreational and professional, the need to embrace supplements, functional foods, nutraceuticals, vitamins and so on is of the greatest importance, and, worse still, that the first thing that those starting physical activity in search of quality of life do is to buy all the professional paraphernalia, which, of course, includes a host of ergogenic aids.

It is difficult to know why they do this, but what we do know are the dire consequences in the medium and long term, and so we must continue to insist on the right strategy, which always involves turning to a professional. Nutritional supplements are necessary, but, as the law says, only in specific circumstances after diagnosis from professionals and under their supervision.

We now know that protein supplementation of 1.6 g/kg or less a day is enough to maximise the effects of training and facilitate muscle hypertrophy and recovery[2]. Greater amounts do not increase the benefits, but they do open the door to negative effects in the short and medium term. This amount, 1.6 g/kg a day, is easy to reach by following a balanced diet varied in nutrients. We also know that high-protein diets and/or those involving carnitine supplements mean that carnitine is trimethylated by the intestinal microbiota and that this molecule, once absorbed and oxidised in the liver, promotes atheromatous plaques[3]. This should lead us to wonder whether many sudden deaths could result from supplements of this kind, which are as widespread as they are unnecessary.

The same occurs with supplements containing antioxidants. For years we attributed part of muscle fatigue to the unwelcome effect of oxygen radicals generated as a result of the metabolism when energy needs are increased in conjunction with the mechanical action associated with sarcomeric contraction[4]. Research in this direction justified recommending increased antioxidant intake through supplements. However, we now know that the premise was mistaken and that this solution may even be counterproductive. In the last ten years, several authors have shown that reactive oxygen and nitrogen species (ROS/NOS) *"are required in very low quantities, in physiological quantities, for genes key to the establishment of the phenotype of the healthy, high performance athlete to be expressed and that high doses block such effects"*[5].

A decade ago, M. Ristow[6] was one of the first researchers to demonstrate that oxidative stress induced by exercise improves insulin resistance and induces an adaptive response consisting of improved endogenous antioxidative capacity and that the supplementation of antioxidants, vitamin C (1,000 mg/day), plus vitamin E (400 IU/day) blocks these beneficial effects of exercise[6]. Therefore, diabetics who do specific exercise and take antioxidant supplements may not obtain the expected benefits. In recent years, the vast majority of double-blind intervention studies fail to show any potential health improvements associated with antioxidant supplementation[7].

The current consensus in most laboratories working in this field is as simple as it is forceful: *"Adequate vitamin and mineral intake is recommended through a varied, balanced diet, which is still the best way to maintain an optimal antioxidant status during physical activity"*[8].

The human body is designed to generate adaptive mechanisms that allow us to respond to physical effort more efficiently. Many of these have to do with the endogenous antioxidant machinery itself, which, paradoxically, requires small amounts of ROS[9]. Dr J. Vinas' group[10] blazed a trail in this field with its article *"Exercise as an antioxidant: it up-regulates important enzymes for cell adaptations to exercise"*, in which they demonstrated the adaptive mechanisms through which exercise

Correspondence: Jesús Rodríguez Huertas
E-mail: jhuertas@ugr.es

increases the quantity and activity of antioxidant enzymes. Recently, another antioxidant mechanism by which mitochondria generate less oxidative stress has been revealed. Mixed HIIT/SIT training leads to a greater formation of mitochondrial supercomplexes which are more efficient in generating the proton gradient, but produce less superoxide radical[11]. All these mechanisms, especially the supercomplexes mechanism, are adversely affected by high doses of antioxidants through supplements[12,13].

These are two clear examples of current research marking a trend and reaffirming food rather than supplements in order to minimise errors. The best strategy is to let the body respond and adapt to extreme situations. Supplements, out of context, confuse response mechanisms and incite partial adaptations.

Therefore, the moral is to let the body respond with adaptations and not to interfere unnecessarily. We have to insist and continue to recommend "more nourishment and fewer supplements".

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Original article

Unilateral and bilateral isokinetic knee strength indices in professional soccer players

José E. Velázquez Barrera, Oscar Salas Fraire, Antonino Aguiar Barrera, Alan M. Vázquez Pérez, Juan G. De la Cruz González, Francisco J. Beltrán Zavala

Medicina del Deporte y Rehabilitación. Hospital Universitario "Dr. José Eleuterio González". Monterrey Nuevo León. México.

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Summary

Introduction: The maximum isokinetic torque is one of the most commonly applied methods to assess the muscle strength of the lower extremities in soccer. Knee force indices have been used extensively to identify possible risk factors for injuries such as torn hamstring muscles or rupture of the anterior cruciate ligament.
There are previous studies that describe the isokinetic profile in different populations and there are few in Latin American population. The objective of this study is to describe the isokinetic profile and strength indices in a population of soccer players from a professional Mexican team.
Methodology: This is an observational, retrospective, analytical study. The maximum torque was measured with an angular velocity of 60°/s in 375 professional soccer players from 1st, 2nd and 3rd division from 2010 to 2015 in the Department of Sports Medicine and Rehabilitation of the "Dr. José Eleuterio González" University Hospital, Monterrey Nuevo León, Mexico.
Results: The results obtained were general, clinimetry and isokinetic parameters. The maximum torque was cataloged by group in injured and non-injured players according to the division: 1st (n = 142), 2nd (n = 86) and 3rd (n = 147). From these, the isokinetic strength indices of each of the players were obtained, observing anthropometric differences, in the unilateral and bilateral knee indices, between each category, and even more so in players with injuries.
It is important to have isokinetic parameters and identify at-risk players according to their category as this will provide reference data for future assessments of professional soccer players and they can be used to categorize muscle function as normal or at risk of injury.

Key words:
Dynamometry. Soccer. Sports injury. Torque. knee.

Índices de fuerza isocinética unilateral y bilateral de rodilla en jugadores profesionales de futbol

Resumen

Introducción: El torque máximo isocinético es uno de los métodos más comúnmente aplicados para evaluar la fuerza muscular de las extremidades inferiores en el futbol. Se han empleado índices de fuerza de la rodilla extensivamente para identificar posibles factores de riesgo para lesiones como desgarros de la musculatura isquiotibial o la ruptura del ligamento cruzado anterior.
Hay estudios previos que describen el perfil isocinético en distintas poblaciones y hay pocas en población latinoamericana. El objetivo de este estudio es describir el perfil isocinético y los índices de fuerza en una población de jugadores de soccer de un equipo profesional mexicano.
Metodología: Es un estudio observacional, retrospectivo y analítico. Se midió el torque máximo con una velocidad angular de 60°/s en 375 futbolistas profesionales de 1°, 2° y 3° división del 2010 al 2015 en el Departamento de Medicina del Deporte y Rehabilitación del Hospital Universitario "Dr. José Eleuterio González", Monterrey Nuevo León, México.
Resultados: Los resultados recabados fueron generales, clinimetria y parámetros isocinéticos. Los torques máximos fueron catalogados por grupo en jugadores lesionados y no lesionados de acuerdo a la división: 1°(n=142), 2° (n=86) y 3° (n=147). A partir de estos se obtuvieron los índices de fuerza isocinética de cada uno de los jugadores existiendo diferencias antropométricas, en los índices unilateral y bilateral de rodilla, entre cada categoría, y más aún en jugadores con lesiones.
Es importante tener parámetros isocinéticos e identificar jugadores en riesgo según su categoría ya que esto aportar datos de referencia para futuras valoraciones en los jugadores profesionales de soccer y pueden ser utilizados para categorizar la función muscular como normal o con riesgo de lesión.

Palabras clave:
Dinamometría. Futbol. Lesión deportiva. Torque. Rodilla.

Correspondence: José E. Velázquez Barrera
E-mail: Eduardo_325@hotmail.com

Introduction

Soccer is considered the most popular sport in the world with 270 million people actively involved in the sport[1]. Physiologically, soccer is characterized by a high intensity and intermittent exercise[2–4] where basic motor skills and specific technical abilities of the players must be constantly adapted to the internal and external variables that are modified during the game period[5]. This is why it is essential to identify the aspects that comprise general physical performance and then examine these individually in each game position as well as establish injury prevention measures[6].

Isokinetic strength assessment tests are probably the most frequently used tools for estimating muscle function in the physical-sports field[7]. Assessment of maximum isokinetic torque is a method that is commonly applied to assess lower limb muscle strength in soccer[8,9].

From this, knee force indices have been extensively used in sports medicine to identify possible risk factors for injuries such as hamstring muscle tears[10] or rupture of the anterior cruciate ligament (ACL)[11], as well as to monitor the effectiveness of rehabilitation programs in soccer players and determine if an athlete can safely return to the game[7,12].

Bilateral strength indices have been used more often because of the relationship between maximum strength of the dominant and nondominant leg[13]. It has been found that the bilateral strength index of concentric knee flexion is able to distinguish people with hamstring and/or ACL[14] pathology and healthy individuals[15]. An asymmetry of less than 10% in the bilateral index at an angular velocity of 60°/s was able to identify non-injured players with a probability of 90.1%[16].

The unilateral strength index is calculated as the quotient of the moment or peak maximum force of the flexor muscle and the extensor muscle of the knee measured during concentric contractions.[16] An index less than 0.50-0.60 has been associated with a significant increase of 17-times the probability of suffering lesions of the ACL and hamstring tears[13,17].

There are previous studies that describe the isokinetic profile in different populations and few studies that describe this in Latin American populations. The objective of this study is to describe the isokinetic profile and strength indices in a population of professional Mexican soccer players.

Material and method

Design

The studied population includes a retrospective analysis of 375 isokinetic tests of professional soccer players recognized by the Mexican Football Federation and evaluated annually by a protocol of the Department of Medicine, Sports and Rehabilitation of the UANL University Hospital in Monterrey, Mexico from 2010 to 2015. The study was previously approved by the Ethics in Research Committee of the institution with registration number MD16-00001. Medical files of first, second and third division players, regardless of age, were included. Files that did not have the collected data or studies with a variation coefficient greater than 12% were excluded[18,19].

Test

Isokinetic tests were performed on a Biodex Multijoint System 4 (Shirley NY, Biodex Medical Systems, Inc.) with a maximal concentric stress isokinetic test. The patient was in a sitting position and movement arcs were established individually according to the anatomical characteristics of each player with five repetitions of extension and knee flexion executed at an angular velocity of 60°/s. The players were instructed to work with as much force as possible in both directions of movement, performed bilaterally, to compare the difference in strength between the two legs, starting with the dominant leg, after at least five minutes of warm-up on the static bicycle and some movements on the dynamometer to get used to the dynamics of the test. Trunk flexibility was assessed with the "Sit and Reach" test. The equipment automatically analyzed the torque peaks of the 5 repetitions in both flexion and extension of both knees; gravity corrections were made for the results obtained in the isokinetic tests.

Data collection

The data collected from each record were general (category, age), clinical (weight, height, flexibility) and isokinetic (peak torque of knee flexors and extensors of both legs) at an angular velocity of 60°/s.

The bilateral strength index was calculated as the difference between the peak torque of the knee flexors for both extremities, expressed as a percentage deficit, using the dominant leg or the uninjured leg as a reference.

The unilateral strength index was calculated as the quotient between the peak torque of the flexor muscles and the peak torque of the extensor muscles, expressed as the quotient of each one of the legs.

Players with a prior injury of the ACL or a lesion of the hamstring muscles were included in this work.

Statistical Analysis

Descriptive statistics were performed for all variables. The distribution of the numerical variables was verified with the Kolmogorov-Smirnov normality test finding that all variables followed a parametric distribution, which is why they were reported as means and standard deviation.

Results

A total of 375 medical records were included and classified according to the participant´s clinical characteristics as injured and non-injured. Players with injuries were older in the first and third division. All injured players had a lower weight and height in all three divisions. Flexibility was greater according to division; the higher the division, the greater the flexibility (Table 1).

Regarding isokinetic tests, players without injuries had greater flexor and extensor strength. Flexor strength, which is related to hamstring injuries, was close to 100 N.m for injured players. Second division players had a better flexor and extensor strength profile than first and third division players (Table 2).

Table 1. General, clinical y flexibility characteristics.

Players	Age, years	Weight, kg	Height, cm	Trunk flexibility, cm
1st division				
Non injured, n=114	25.1 ± 3.8	75.5 ± 8.4	178.4 ± 7.4	11.53 ± 6.3
Injured, n=28	28 ± 4.1	70.2 ± 6.9	174.4 ± 6.9	9.8 ± 5.6
2nd division				
Non injured, n=67	18 ± 1.1	69.5 ± 7.0	176.5 ± 6.1	11.26 ± 4.9
Injured, n=19	17.7 ± 1.1	66.3 ± 6.9	174.1 ± 5.0	10.6 ± 5.2
3rd division				
Non injured, n=133	15.7 ± 1.0	66 ± 6.6	176 ± 6.6	9.68 ± 5.8
Injured, n=14	16.3 ± 1.3	62.8 ± 6.6	174 ± 4.5	6.7 ± 7.0

Values are means ± standard deviation.

Table 2. Bilateral peak torque strength of knee flexors and extensors.

Variable	PRET, N•m	PLET, N	PRFT, N•m	PLFT, N•m
1st division				
Non injured, n=114	208.93 ± 40.5	207.9 ± 35.9	123.67 ± 29.6	120.84 ± 26.2
Injured, n=28	196.1 ± 43.2	185.25 ± 39.3	110.22 ± 30	100.17 ± 29.6
2nd division				
Non injured, n=67	219.57 ± 40.2	212.46 ± 34.8	124.91 ± 26.7	119.77 ± 20.6
Injured, n=19	196.3 ± 40.3	201.87 ± 40.7	115.99 ± 30.1	109 ± 25.7
3rd division				
Non injured, n=133	191.15 ± 37.5	190.55 ± 34.3	105.61 ± 22.2	102.54 ± 23.4
Injured, n=14	166.8 ± 27.1	163.48 ± 24.7	98.51 ± 18.9	89.45 ± 17.5

Values are means ± SD (standard deviation).
PRET: Peak right extensor torque; PLET: Peak left extensor torque; PRFT: Peak right flexor torque; PLFT: Peak left flexor torque; N•m: Newton meter.

Table 3. Isokinetic strength indices according to category.

Variable	Bilateral index	Unilateral index right	Unilateral index left
1st division			
Non-injured	11.14 ± 9.89	0.598 ± 0.12	0.585 ± 0.10
Injured	15.65 ± 13.12	0.564 ± 0.10	0.536 ± 0.08
2nd division			
Non-injured	11.46 ± 9.86	0.577 ± 0.11	0.569 ± 0.08
Injured	14.27 ± 10.66	0.538 ± 0.11	0.544 ± 0.10
3rd division			
Non-injured	11.54 ± 8.37	0.558 ± 0.09	0.541 ± 0.09
Injured	12.12 ± 8.14	0.50 ± 0.08	0.541 ± 0.12

Values are means ± SD (standard deviation).

Results of the bilateral isokinetic strength index were less than 12% in non-injured players in the three divisions. In contrast, the bilateral index was increased in first and second division and only slightly above 12% in third division. The best results regarding the left and right unilateral indices (<0.6) were found in the first division (Table 3).

Discussion

General and clinical

The age of the population is similar to the age of other professional soccer team players. The mean height found in both groups was lower than in another Latin population studied, Brazil[20,21], and European populations, such as England[22], Spain[23] and Poland[24]; however, it is similar to population from the Middle East, such as Qatar[25], Saudi Arabia[26], and the United Arab Emirates[27].

The mean weight in both groups was lower than that reported in populations such as Brazil, Poland, and England[9,21,23]. This variation seems to be in agreement with ethnic variants. Mean flexibility was lower than in other populations also measured by the sit and reach test, such as Irish[28] and Chinese population[29].

Isokinetics

In this study, the isokinetic strength of knee extension and flexion was greater in elite players with a more variable pattern in the category of second division. Although there is literature available to compare the differences in strength in the different soccer categories, this is limited, and methodological differences make it difficult to analyze this when they are compared by position[9,30].

The results of this study indicate that in general, the isokinetic profiles of knee extension and flexion strength of the players of the three categories are lower than in other elite football populations and the junior elite of the Belgian league[31]. French elite soccer players and amateurs[32] showed higher absolute maximum torque peak values at 60°/s. There are studies that have reported values that may explain the apparent reduction in absolute strength due to a lower body mass[25].

In the unilateral isokinetic index, significantly lower values were observed when comparing the first against the second and third division. This could be explained by greater experience with better muscle strength parameters. These proportional differences have been demonstrated with age and in the knee flexor-extensor muscle strength in young and adult soccer players with isokinetic torque peaks increased with age and professional level[15,33]. Imbalances of muscle strength in the knee joint, measured by the quadriceps/hamstring ratio, are a predisposing factor for hamstring strain injuries and are related to joint stability[34,35].

The index between the flexor and extensor muscles is an indicator of the functionality of the knee joint. This means that values below 0.50 at an angular velocity of 60°/s indicate a discrepancy between muscle capacity and risk of injury. When the extensor muscles exert a disproportionate force on the flexor muscles, this will cause excessive work of the tibia on the femur during dynamic activities, and the ACL will have excessive tension[21]. Therefore, if the flexor muscles are weak, to neutralize the excessive force, the ACL will have a greater chance of rupture[36–38]. The results show a difference in the unilateral index, the best results, close to 0.60, decrease by soccer category and even more in players with a history of injury, thus, it is a good marker of discrimination.

The imbalance found in the bilateral index shows a pattern consistent with the literature where the highest value of this imbalance in players without an injury does not exceed 12%[39,40]. When the muscle forces of the flexors of the dominant leg against the non-dominant leg are compared, this same index is increased almost 0.4% more in those players with apparent injuries. Compared with other studies, the results showed that the normality point or reference value of 12.5% of bilateral imbalance expressed by the FR/FRCON60 index[41] (sensitivity and specificity, 0.73 and 0.80, respectively), is more important for the detection of a previous injury in the hamstring musculature in soccer players, with this being consistent with the results obtained. Naturally, muscle strength disorders cannot explain all hamstring injuries; persistent disorders in various players do not significantly correlate with the presence of bilateral index imbalances[42].

Intrinsic and extrinsic factors have been described that contribute to the risk of lesions of the ACL and the hamstring muscles. Importance has been given to those that are related to muscular force imbalances. A significant difference between the agonist and antagonist groups of the knee joint entails risk and rapid identification for injury prevention. The most difficult task will be that the agonist and antagonist muscles should be trained correctly because it is complicated to make an accurate assessment of each muscle group. This ironically leads strength training to a muscular imbalance, and this in turn, to sports injuries.

Conflict of interest

The authors do not declare a conflict of interest.

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Original article

Heart rate variability to assess the effect of sleep deprivation in mountain troops of the chilean army: a pilot study

Claudio Nieto-Jiménez[1], **José Naranjo Orellana**[2]

[1]Centro de Lecciones Aprendidas, División Doctrina, Ejército de Chile. [2]Universidad Pablo de Olavide. Sevilla.

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Summary

Background: Our objective was to identify the effect of sleep deprivation on a stress test simulating a military march, via changes in heart rate variability (HRV) in special mountain troops.

Eight subjects from special mountain troops carried out a simulated march test on a treadmill. The incremental march test had 7 stages of 3 minute duration at a constant velocity of 5 km/h and slopes of 1, 3, 5, 7, 8, 9 and 10 %. To assess the HRV, two heartbeat records were taken over 5 minutes in dorsal decubitus position before and after the march test; the first session took place without sleep deprivation, and the following day with sleep deprivation.

Results: The main finding of this study is that the physiological stress imposed by the simulated treadmill march is the same with and without sleep deprivation.

There were no significant differences between pre and post HRV data in any of the situations, but effect size was moderate or large (d=0.2 was considered as the Smallest Worthwhile Change). indicating a highly relevant response. However, after comparing with and without sleep deprivation tests no changes were found (non-significant and non-relevant).

Conclusions: The stress test performed, did not present differences in physical and physiological responses while being deprived of sleep over 24 hours.

A simple test is proposed to evaluate the effect of sleep deprivation as a stressor agent. A treadmill test at a constant speed with increasing slopes would be performed and repeated the following day after 24 hours of sleep deprivation.

Key words:
Heart rate variability.
Sleep deprivation.
Special Mountain Troops.

Variabilidad de la frecuencia cardíaca para evaluar el efecto de la privación del sueño en tropas de montaña del ejército chileno: un estudio piloto

Resumen

Introducción: Nuestro objetivo fue identificar el efecto de la falta de sueño en una prueba de esfuerzo que simula una marcha militar, a través de cambios en la variabilidad de la frecuencia cardiaca (VFC) en tropas especiales de montaña.

Ocho sujetos de tropas especiales de montaña realizaron una prueba de marcha simulada en una cinta de correr. La prueba de marcha incremental tuvo 7 etapas de 3 minutos de duración a una velocidad constante de 5 km/h y pendientes de 1, 3, 5, 7, 8, 9 y 10%. Para evaluar la VFC, se tomaron los registros de latidos latido del corazón durante 5 minutos en posición de decúbito dorsal antes y después de la prueba de marcha; la primera sesión tuvo lugar sin privación de sueño y al día siguiente con privación de sueño.

Resultados: El principal hallazgo de este estudio es que el estrés fisiológico impuesto por la marcha simulada de la cinta rodante es el mismo con y sin privación del sueño.

No hubo diferencias significativas entre los datos de VFC anteriores y posteriores en ninguna de las situaciones, pero el tamaño del efecto fue moderado o grande (d = 0.2 se consideró como umbral de cambio pequeño). Indica una respuesta altamente relevante. Sin embargo, después de comparar con y sin las pruebas de privación de sueño, no se encontraron cambios (no significativos y no relevantes).

Conclusiones: La prueba de esfuerzo realizada no presentó diferencias en las respuestas físicas y fisiológicas al estar privada de sueño durante 24 horas.

Se propone una prueba simple para evaluar el efecto de la falta de sueño como agente estresante. Se realizaría una prueba de la cinta rodante a una velocidad constante con pendientes crecientes y se repetiría al día siguiente después de 24 horas de falta de sueño.

Palabras clave:
Variabilidad de la frecuencia cardiaca.
Privación de sueño.
Tropas Especiales de Montaña.

Correspondence: Claudio Nieto-Jiménez
E-mail: c.nieto@udd.cl

Introduction

The completion of a mission on the battlefield is the result of the sum of multiple factors, in their preparation; soldiers must be conditioned to resist fatigue, fear and doubt, all of which are characteristic of the human condition. This requires highly prepared subjects in good physical conditions to allow for optimum performance under stressful situations.

One of the main components of that plan is to improve the morphological, fitness and physiological profile as well as basic and specific military skills[1].

Sleep deprivation is one of the main stressor agents in the training of soldiers, particularly in mountain special forces of Chilean Army[2]. We know that the lack of sleep affects directly to the physical status and the capacity to perform specific tasks in soldiers[2,3].

It has been observed that a single night of sleep deprivation may affect the resistance performance of a 30 minute treadmill run at an intensity of 60% of the VO_2max and alter cardio-respiratory, thermoregulatory and perceptual responses to exercise[4]. A study undertaken by the Croatian Army[3] for Special Operations, reported the influence of basic training on specific shooting tasks under sleep deprivation conditions. The results showed that basic training had a positive impact on the reduction of the effects of sleep deprivation in shooting related tasks. The data obtained suggests that during basic training (62 days) there was an adaptation to stress as well as an improvement in weapons handling skills, which contributes significantly to improved shooting results in stressful conditions, mainly in terms of sleep deprivation.

Likewise, Tyyskä[5] *et al.* (2010) investigated the links between physical fitness, sleep duration and hormonal responses during military training over 15 days while carrying out offensive maneuvers in a rural area. On average, the subjects slept 6.20 hours per day, but their sleeping patterns were altered due to guard shifts. The study found hormonal changes related to a lack of sleep and low physical fitness.

Ricardo[6] *et al.* (2009) determined that 30 hour of sleep deprivation did not alter leukocyte traffic, neutrophil degranulation or resting S-IGa responses.

But in addition to affecting the general physical state of the subject, sleep deprivation should have some kind of impact on the balance of the sympathetic-parasympathetic system, especially when it is required for some specific task[7].

Heart rate variability (HRV) is a non-invasive tool to analyze changes in the autonomic nervous system (ANS)[8-10] and it is used to assess adaptations to effort in different circumstances[11-14].

A study carried out on soldiers Huovinen[15] *et al*. reported changes in some indicators of HRV with a positive correlation with changes in testosterone and cortisol. However, we have not found any study utilizing HRV to evaluate the effect of sleep deprivation in the execution of military tasks. On the other hand, there is no simple test to evaluate the effect of sleep deprivation on the physical performance in Special Forces troops.

The aim of this pilot study was to identify the effect of sleep deprivation on HRV during a effort test (simulating a military march) in special mountain troops in the Chilean Army; and to propose it as a pilot simple test to evaluate the role of sleep deprivation as a stressor agent in this population.

Material and method

Eight subjects from special mountain troops carried out a simulated march test on a treadmill, in full combat equipment. They spent one night without sleep during a planning exercise in a classroom and returned to carry out the test the following day. The evaluated soldiers belonged to a Special Forces patrol with five years of experience working together in winter and summer mountain training. All were volunteers; they were informed of the procedures and consequently signed a consent form. The study had the approval of the Ethics Committee of Health Sciences of Santiago´s Military Hospital and was carried out in accordance with the dispositions of the Helsinki Declaration[16].

An incremental march test was carried out on a treadmill with 16.5 kg of weight in individual combat equipment. The test had 7 stages of 3 minute durations and slopes of 1, 3, 5, 7, 8, 9 and 10% as well as a constant velocity of 5 km/h. To assess the HRV, a heartbeat record was taken over 5 minutes in dorsal decubitus position prior to the march test (Pre) and another upon completion (Post); the first session took place without sleep deprivation, and the following day, at the same hour (06:00 a.m.), the procedure was repeated after a night of sleep deprivation.

Prior to the tests, the weight was measured with a Tanita weighing machine (Tanita Ironman BC1500, Japan, 2015). All subjects wore a heart rate monitor Polar V800 (Polar, Kempele, Finland). The data from this device were downloaded via USB throw the application Polar FlowSync in order to obtain a time series of the RR intervals (beat by beat). This time series was analyzed with the software Kubios HRV[17] (University of Eastern Finland, Kuopio, Finland).

The general variables obtained from the effort test were: resting heart rate (rHR), prior to the test; theoretical maximum heart rate (HRmax); exercising heart rate (eHR) for each stage of the test; the relative intensity (%) for every step obtained via the Karvonen[18] equation and the total power (Watts) calculated from the velocity, gradient and body mass with equipment.

The use of slopes requires to have into account the vertical component of velocity in the calculation of the work and total power generated on a treadmill. The most common way to take this into account is via the sine of the angle α formed by the treadmill and the horizontal[19] or by substituting the sine α by the percentage of slope of the treadmill, divided by 100[20], given that for very small values of α, the numerical value of sine α is very close to that of the slope expressed in decimals, so the following equation may be used[21]:

$$P = m * g * v * p * 0{,}278$$

Where v is the velocity expressed in km/h; g is the average acceleration of gravity (9,8 m/s2); m is the subject mass in kg and p is the percentage of gradient of the treadmill, divided by 100.

The HRV variables used for the analysis in the time domine[22,23] were: RR; time interval between two R waves (ms); SDNN: standard deviation of the RR; RMSSD: square root of the average of the differences of the sum of the squares between adjacent RR intervals (ms); pNN50: percentage of adjacent RR intervals which differ more than 50 ms (%);

The transversal axis (SD1) and the longitudinal axis (SD2) were determined in the Poincaré´s plot[23] and, in accordance with Naranjo[24] *et al.*, the Stress Score (SS) was calculated as the inverse of the SD2 multiplied by 1000 and the sympathetic-parasympathetic ratio (R-S/Ps) as the ratio between the SS and SD1. For analysis purposes of the autonomic balance, the Napierian logarithm of the SS was used (LnSS) as an indicator of sympathetic activity and the LnRMSSD as an indicator of parasympathetic activity.

Statistical Analysis

A descriptive study was carried out, presenting the data as averages, standard deviations (SD) and variation coefficient (VC).

For hypothesis contrasting, the normality of distributions was tested using the SHAPIRO-WILK test, and the LEVENE test was used to establish the equality of variances.

For the HRV data analysis a multiple comparison ANOVA test was used for the 4 distributions (pre and post without sleep deprivation and pre and post with sleep deprivation) utilizing BONFERRONI´s *post-hoc* test.

For the analysis of general variables of both tests (rHR, HRmax, eHR, intensity and total power) a *t*-Studen test was used for paired samples.

In all cases the significance level was fixed at $p<0,05$.

Given the reduced sample size, significant results were not expected to be achieved with conventional statistical hypothesis contrast; consequently, in order to assess the changes between the different variables the effect size (ES) was calculated throw the Cohen's d[25] using the intervals proposed by Hopkins[26]: <0.2 = trivial, 0.20-0.59 = small; 0.6-1.2 = moderate; ≥1.2 = large.

Results

Table 1 shows the average and standard deviatios (SD) for age, weight (kg), theoretical HRmax, rHR, maximal eHR and maximal intensity of the test. The values of p comparing rHR, eHR and intensity between the situation 1 (no sleep deprivation) and the situation 2 (sleep deprivation) indicate that changes were not statistically significant. The values of d for both situations show that the effect size was trivial or small.

Table 2 shows general data for every stage in the effort test (power, speed and slope) together with average, SD and VC of eHR in both situations: with and without sleep deprivation. No significant differences were observed between both conditions.

Figure 1 shows the evolution of the eHR in relation to the power of each stage in both tests.

Table 3 shows pre and post results of HRV with and without sleep deprivation. The p values for PRE-POST comparisons were all above 0.8; the values of d are shown in the table and we can see that the effect size is medium or large for all the variables.

When the HRV values post-test are compared in both situations, there are no significant differences (p>0,5 in all the cases) and the effect size is small for all the variables (d<0,2).

Figures 2 shows the changes in LnSS (A) and LnRMSSD (B) in both tests as indicators of sympathetic and parasympathetic activity respectively.

Figure 1. Exercising Heart Rate (eHR) data in relation to the power of each stage.

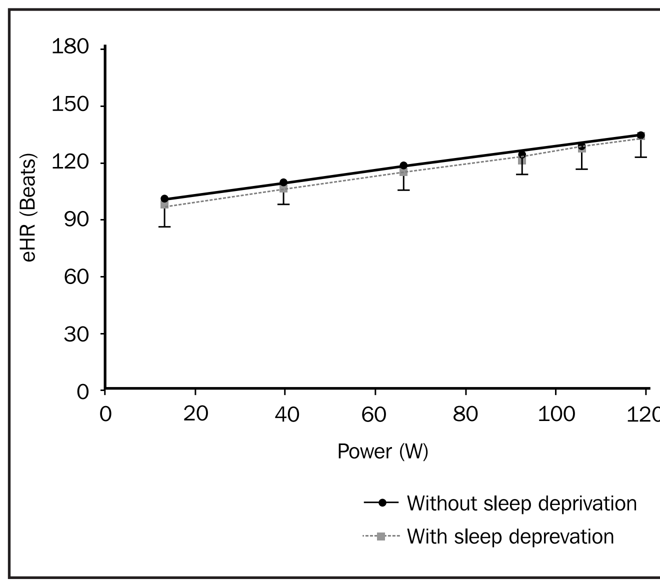


Table 1.

Subject	Age (years)	Weight (kg)	Theoretical HRmax	rHR 1	rHR 2	Maximal eHR 1	Maximal eHR 2	Maximal Intensity 1	Maximal Intensity 2
1	32	80.3	188	48	44	138	133	0.64	0.62
2	33	76.9	187	53	52	150	143	0.72	0.67
3	31	78.1	189	51	52	130	126	0.57	0.54
4	31	80.7	189	40	40	132	128	0.62	0.59
5	27	71.7	193	84	52	140	130	0.51	0.55
6	24	81.2	196	56	52	125	127	0.49	0.52
7	28	83.7	192	64	61	166	162	0.80	0.77
8	22	91.5	198	49	50	145	146	0.64	0.65
Average	28.50	80.51	191.50	55.69	50.45	140.75	136.88	0.63	0.61
SD	3.96	5.70	3.96	13.40	6.36	13.04	12.59	0.10	0.08
				p =0.33		p =0.55		p =0.86	
				d =0.53		d =0.30		d =0.12	

The measurements without sleep deprivation are identified with (1) and the measurements with sleep deprivation with (2). The values p and d correspond to the comparison between scenarios 1 and 2. (d <0.2= trivial, 0.20-0.59= small; 0.6-1.2= moderate; >1.2= large). rHR: Resting HR; eHR: Excercising HR.

Table 2.

				eHR (beats)					
				Without sleep deprivation			With sleep deprivation		
Stage	Power (Watt)	Speed (km/h)	Slope (%)	Average	SD	VC	Average	SD	VC
1	13.21	5	1	100.125	14.623	15%	96.75	11.498	12%
2	39.64	5	3	108.75	10.195	9%	105.25	8.225	8%
3	66.07	5	5	116.5	12.107	10%	114.125	9.833	9%
4	92.49	5	7	122.5	9.827	8%	119.875	7.200	6%
5	105.71	5	8	127.5	11.352	9%	126.25	10.512	8%
6	118.92	5	9	133.75	12.116	9%	133	11.288	8%
7	132.13	5	10	140.75	13.036	9%	136.875	12.586	9%

Exercising heart rate (eHR) data corresponding to the stages of the test. (SD: Standard Deviation; VC: Variation coefficient).

Table 3.

		Without sleep deprivation			With sleep deprivation		
		PRE	POST	d	PRE	POST	d
RR	Average	1124.50	825.00	1.49	1207.59	870.81	1.99
	SD	231.31	172.02		160.03	178.59	
	VC	0.21	0.21		0.13	0.21	
SD NN	Average	88.08	57.15	0.99	109.77	58.75	1,99
	SD	29.51	32.98		25.52	25.71	
	VC	0.34	0.58		0.23	0.44	
RMSSD	Average	80.69	31.86	1.44	92.85	35.73	2.09
	SD	38.20	29.78		25.63	28.93	
	VC	0.47	0.93		0.28	0-81	
LnRMSSD	Average	4.26	3.03	1.48	4.49	3-24	2.02
	SD	0.61	1.05		0.30	0-95	
	VC	0.14	0.34		0.07	0.29	
pNN50	Average	44.38	16.49	1.29	54.36	14.31	2.62
	SD	21.45	21.65		10.24	20.38	
	VC	0.48	1.31		0.19	1.42	
SD1	Average	57.23	25.47	1.18	65.79	25.25	2.09
	SD	27.05	26.66		18.16	20.61	
	VC	0.47	1.05		0.28	0.82	
SD2	Average	109.26	75.71	0.86	139.46	78.48	1.80
	SD	37.77	40.07		35.89	31.78	
	VC	0.35	0,53		0.26	0.40	
SS	Average	10.22	16.33	1.10	7.61	14.46	1.88
	SD	3.63	7.48		2.04	5-26	
	VC	0.36	0.46		0.27	0,36	
LnSS	Average	2.27	2.69	0.99	2.00	2.61	1.90
	SD	0.36	0.50		0.26	0.38	
	VC	0.16	0.18		0.13	0,15	
Ratio	Average	0.28	2.45	1.10	0.13	1.56	1.31
	SD	0.31	3.65		0.06	2.14	
	VC	1.11	1.49		0.43	1.37	

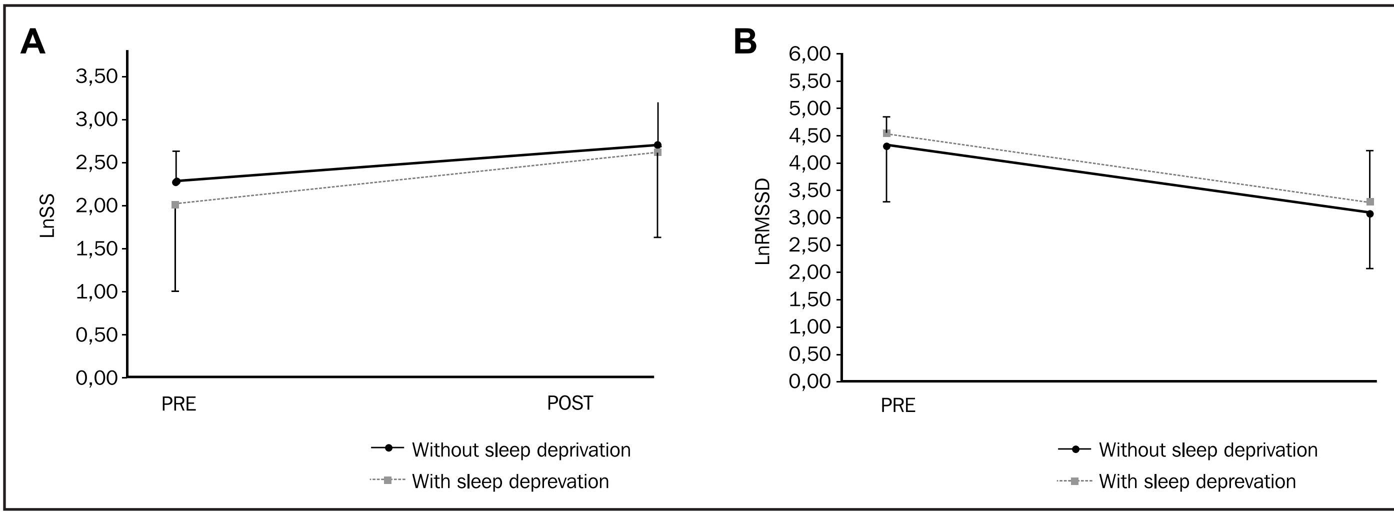
RR: RR interval (ms). SDNN: Standard deviation of the RR intervals. RMSSD: square root of the average of the differences of the sum of the squares between adjacent RR intervals (ms). LnrMSSD: Naperian logarithm of the RMSSD. pNN50: number of adjacent pairs in the RR interval which differ more than 50 ms divided by the total number of RR intervals (%).SD1: transversal axis of Poincare´s Plot. SD2: longitudinal axis of Poincare´s Plot. Stress Score(SS): opposite to the SD2, multiplied by 1000. LnSS: Naperian logarithm of the SS. R-S/Ps: Sympathetic-parasympathetic ratio: quotient between the SS and SD1. Effect size: (d <0.2= trivial, 0.20-0.59= small; 0.6-1.2= moderate; ≥1.2= large.)
The values of p between PRE and POST were all above 0.8. The values of d PRE-POST are shown in order to estimate size of effect. The p value between POST with and without sleep deprivation was >0,5 for all variables and the value of d was <0,2 in all the cases.

Discussion

The main finding of this study is that the physiological and physical stress induced by the simulated treadmill march in experienced and well-trained soldiers is the same with and without sleep deprivation.

We know that the sample is small (N=8) and that this would be an obstacle to the generalization of results, but given that this work is only a pilot study, we preferred to prioritize the fact that the 8 subjects are highly qualified soldiers well trained in mountain military tasks and who have been working together for five years in the same patrol of Special Forces. For this reason, in this pilot study it is very valuable for us to analyze their response to sleep deprivation, taking it as a reference to propose an evaluation test that, logically, should be validated later in different circumstances.

Figure 2. LnSS: Natural logarithm of Stress Score. LnRMSSD: Natural logarithm of the square root of the average of the difference of the sum of the squares between adjacent RR intervals (ms).



Effect Size: d <0.2= trivial, 0.20-0.59= small; 0.6-1.2= moderate; ≥1.2= large.

As indicated above, with such a small sample it was not reasonable to expect significant differences when using conventional hypothesis testing techniques. In fact, there was no significant differences between the pre and post data in any of the situations. However, the effect size was very important (d=0,99 for the LnSS without sleep deprivation; d=1,48 for Ln RMSSD without sleep deprivation; d=1,9 for the LnSS with sleep deprivation and d=2 for LnRMSSD with sleep deprivation), indicating that the changes PRE-POST were highly relevant.

Values of rHR and maximal intensity in the test are not influenced by sleep deprivation as shown by the fact that the effect size is small for the rHR (d=0,53 and trivial for the intensity (d=0,12) (Table 1). The final intensity was 63% for test 1 and 61% for test 2 (Table 1), being the same intensity used by Oliver[4].

The eHR values (Table 2) show practically identical behavior in both situations. As shown in Figure 1, they were not affected by the lack of sleep. These findings are consistent with previous studies by Martin & Haney[27] (1982).

Concerning HRV, we can see in both tests a drop of variables indicating parasympathetic activity (SDNN, RMSSD, LnRMSSD, pNN50 y SD1) and an increase in those indicating sympathetic activity (SD2, SS y LnSS), taking into account that the SD2 value is opposite to sympathetic activity (Table 3). On the other hand, the value of the ratio S:PS is normal at rest but it increases after exercise showing a sympathetic prevalence both with and without sleep deprivation (Table 3). As such, we are observing the expected response after an exercise load. Nevertheless, the question is whether or not the ANS response to this work load is different when the subjects are sleep deprived, or to put it differently, if the internal load representing this test is higher after 24 hours of sleep deprivation.

In this sense, no statistical significance is observed in the p-value for the HRV values in either of the two tests studied (with and without sleep deprivation) (Table 3), possibly due to the reduced sample size, being a pilot study. Regardless, the effect size is relevant for all the variables, especially for those used in this study for the evaluation of sympathetic and parasympathetic states: the LnSS (d=0,99 without sleep deprivation and d=1,90 with sleep deprivation) and the LnRMSSD (d=1.48 without sleep deprivation and d=2,02 with sleep deprivation) (Table 3).

The variation coefficient in our study (VC) for the LnrMSSD increases with the effort test both without sleep deprivation (14% and 34%) and with sleep deprivation (7% and 29%). (Table 3). Although Buchheit[28] observed individual daily fluctuations of this resting variable of around 10-20%, in our study the changes while resting represent inferior values, between 7% and 14%.

The VC for the LnSS, nevertheless, shows much smaller changes with the exercise, both without sleep deprivation (16% and 18%) and with sleep deprivation (13% and 15%). Although there were no references in the literature for the VC of this variable, it is found to be within the margins aforementioned by Buchheit for the LnRMSSD.

We consider that it would be highly useful to have a simple test in order to evaluate the effect of sleep deprivation as a stressor agent. Our data seems to reflect that the proposed effort test induces relevant changes to sympathetic-parasympathetic balance, but that these are exactly the same when subjects are sleep deprived. On another hand, the general test data (intensity and exercising heart rate) are the same with and without sleep deprivation.

This is at least what happens in highly trained soldiers and for that reason can be a good reference to assess the response of other subjects to this circumstance.

Based on these data, we propose to use this test as follow:

- To carry out the proposed test at a constant speed with increasing slopes, and repeat the process the following day after 24 hours of sleep deprivation.
- The exercising HR reached must not differ more than 10% in both tests (Table 2; VC=9% for eHR)
- Sympathetic stress induced by the effort test (LnSS) must be the same with and without sleep deprivation, accepting a maximum difference of +15% (Table 3; VC=15% for the LnSS).

– The decrease in parasympathetic modulation (LnRMSSD), induced by the effort test, must be the same with and without sleep deprivation, accepting a maximum difference of -30% (Table 3; VC= -29%).

The main limitation in this study could be the reduced sample size; but, as it is a pilot study, we have established as a priority the selection of subjects who are members of the same patrol in special mountains operations forces, with 5 years' experience with this type of training. All of them had previous experiences with different stressor agents and competences in extreme environments. In this manner we have guaranteed: a) that the subjects studied have important training in terms of adaptation to stressor agents (sleep deprivation included) and as such their responses may serve as a clear reference to evaluate other subjects; and b) that the sample, although small, is sufficiently homogenous in terms of fitness and training.

Conclusion

The response of HRV after a simulated march on a treadmill did not present differences in trained soldiers when they are deprived of sleep over a 24 hours period.

This simple test would be useful to evaluate the effect of sleep deprivation as a stressor agent.

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Ethics Approval Committee

Santiago´s Military Hospital-HOSMIL-DIVDOC.

Conflict of interest

The authors do not declare a conflict of interest.

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Original article

Previous intakes to a competitive match in young soccer players

Juan D. Hernández Camacho[1], **Elena Fuentes Lorca**[2], **José M. Martínez Sanz**[3]

[1]Departamento de Fisiología, Anatomía y Biología Celular. Universidad Pablo de Olavide. Sevilla. [2]Centro Superior de Formación Europa Sur. Estadio Olímpico de Sevilla. Isla de la Cartuja. Sevilla. [3]Departamento de Enfermería. Facultad de Ciencias de la Salud. Universidad de Alicante. Grupo de Investigación en Alimentación y Nutrición (ALINUT). Alicante.

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Summary

Introduction: It has been shown that nutrition plays a crucial role in sport performance, consequently athletes should pay attention to their nutritional habits. However, it is not completely clear what athletes eat just before the sport competition.
Objectives: Analyze the previous energy and nutrient ingestions to a match in soccer players.
Material and method: Previous intakes from forty-seven players were collected using a 24 hours recall questionnaire. Twenty-four and three hours intakes before the competition were examined using a nutrient´s composition software. Brand names of commercial food were included. Information concerning time of day, cooking methods and amount of food prepared were collected. Height and weight were measured. Players were asked if they have received nutritional directions in previous seasons. Descriptive statics (mean ± SD) and t-student analyses were used.
Results: The mean kcal ingestion was 34.68 ± 16.31 kcal/kg body weight twenty-four hours and 6.89 ± 3.38 kcal/kg body weight three hours before. Carbohydrate average intake was 3.35 ± 1.59 grams/kg body weight twenty-four hours and 0.87 ± 0.43 grams/kg body weight three hours before the match. Proteins mean consumption was 1.49 ± 0.76 grams/kg body weight twenty-four hours and 0.23 ± 0.16 grams/kg body weight three hours before the match. Differences were obtained between players who received nutritional direction and the other players in energy, carbohydrate, proteins and lipids ingested.
Conclusion: The players studied presented a low kcal and carbohydrate ingestion twenty-four and three hours before a competitive match and they did not fulfill nutritional recommendation. However, nutritional directions could improve previous energy and nutrients intakes.

Key words:
Soccer. Nutrition. Nutrients. Energy. Carbohydrates.

Ingestas previas a un partido oficial en jugadores de fútbol jóvenes

Resumen

Introducción: Se ha demostrado que la nutrición juega un papel crucial en el rendimiento deportivo, por ello los deportistas deberían de prestar atención a sus hábitos nutricionales. Sin embargo, no está completamente claro qué es lo que toman los deportistas justamente antes de la competición.
Objetivos: Analizar las ingestas previas de energía y nutrientes antes de un partido en jugadores de fútbol.
Materiales y métodos: Se recogieron las ingestas previas de cuarenta y siete jugadores de fútbol usando un cuestionario de 24 horas. Se analizó la ingesta de energía y nutrientes 24 y 3 horas antes del partido utilizando un software de composición nutricional. Se incluyó nombres de marcas comerciales. Se recogió información sobre el horario, los métodos de cocinado y la cantidad de comida preparada. Se midió la altura y el peso de cada jugador. Se les preguntó a los jugadores si habían recibido recomendaciones nutricionales en temporadas anteriores. Se utilizaron métodos estadísticos descriptivos y análisis t-student
Resultados: La ingesta calórica media fue de 34,68 ± 16,31 kcal/kg de peso veinticuatro horas antes y 6,89 ± 3,38 kcal/kg peso en las tres horas previas. El consumo medio de carbohidratos fue 3,35 ± 1,59 gramos/kg en las 24 horas y de 0,87 ± 0,43 gramos/kg en las tres horas previas. El consumo de proteínas fue de 1,49 ± 0,76 gramos/kg de peso en el día previo y de 0,23 ± 0,16 gramos/kg en las tres horas anteriores al partido. Se obtuvieron diferencias entre los jugadores que recibieron recomendaciones nutricionales y los que no en las ingestas de energía, carbohidratos, proteínas y lípidos.
Conclusión: Los jugadores estudiados presentaron una baja ingesta de kcal y carbohidratos en las veinticuatro y en las tres horas anteriores al partido y no cumpliendo con las recomendaciones alimentarias. Sin embargo, recomendaciones nutricionales podrían mejorar la ingesta de energía y nutrientes.

Palabras clave:
Fútbol. Nutrición. Nutrientes. Energía. Carbohidratos.

Correspondence: Juan D. Hernández Camacho
E-mail: jdhercam@upo.es

Introduction

From long time ago, it is well known that nutrition plays an essential role in sport performance. The pattern of play in soccer is based on intermittent high-intensity actions and soccer particular skills where muscle glycogen and plasma glucose are crucial for energy production[1]. A lot of importance is given to previous ingestion to a sport competition. Mujika *et al*[2] proposed that performance in team sports is often related with nutritional factors, right nutritional directions allow the athletes to be well fueled and hydrated during the games. They recommend that athletes should take 1-4 g of carbohydrate per kg of body weight (BW) 1-4 h before the trials and during the games tasting carbohydrate 30-60 g per hour. A previous study[3] focused on the nutrition on match day; the authors highlighted the combination of a high carbohydrate pre-match meal and a sports drink during the match. A pre-match intake should be composed of low-glycaemic index (GI) carbohydrate foods because this option would result in feeling of satiety for longer and a stable blood glucose concentration.

Another research[4] assessed dietary intake and nutrition knowledge in elite and sub-elite male soccer players. They found that nutrition knowledge was weak and dietary intake did not fulfill with carbohydrate recommendation. Andrews MC, Itsiopoulos[5] examine three days of dietary intake in male soccer professional and semiprofessional players. Their intakes did not fulfill carbohydrate recommendations, even, some interviewed athletes consumed alcohol. A positive correlation between sport nutrition knowledge and carbohydrate intake was described. They speculated that nutritional education would be really useful to improve dietary practices. Additionally, Azizi *et al*[6] showed that nutrition knowledge of young athletes needs to be improved. Another paper[7] determined nutrients intake in Japanese collegiate soccer players. Carbohydrate and protein intakes were lower than recommended targets. The dietary patterns showed a low ingestion of vegetables, milk and dairy products, fruits and eggs.

A previous study[8] evaluated the nutritional intake of soccer players from the junior teams of a Spanish First Division Soccer League Club. The mean energy intake was 2796.4 ± 525.8 kcal, players analyzed ingested 1.6 ± 0.4g/kg BW of proteins and 4.7 ± 1.1g/kg BW of carbohydrate. Russell andPennock[9] examined nutritional habits of professional male soccer players from a youth team of a UK based Championship club. Mean energy ingestion was 2831 kcal. The intake of carbohydrates was 5.9 ± 0.4 g/kg BW/d, proteins ingestion was 1.7 ± 0.1 g/kg BW/d and fat consume was 1.5 ± 0.1 g/kg BW/d. Caccialanza *et al*[10] determined dietary intake of a sample of seventy-five young soccer players. Mean kcal intake was 37.7 kcal/kg BW, mean consumption of carbohydrate was 5.0 g/kg BW, proteins 1.5 g/kg BW and lipids were 87.1 g/kg BW. Few studies have analyzed nutritional intakes on female soccer players or soccer referees, although it has been reported that female soccer player and soccer referees did not completely fulfill nutritional recommendations[11,12].

Taking in consideration all these studies, it seems that generally soccer players do not fulfill dietary intakes recommendations, although it is not completely clear yet. But it seems that nutritional knowledge could be a useful instrument to improve these dietary patterns. The mean objective of the current research was to analyze the twenty-four and three hours previous intakes to a competitive match.

Material and method

Subjects

A total of fifty-eight soccer players from an amateur Spanish team voluntary participated. The mean age was 17.43 ± 2.88 years. They were regularly involved in competitive trainings and matches. The study was conducted during the first months of competitive season. They delivered informed written consents which had been signed by their parents.

Dietary assessment section

Previous twenty-four and three hours dietary intake to a competitive soccer match was recorded with a 24 hour recall questionnaire. Highly skill technicians supervised and helped soccer players to complete the questionnaires in order to collect accurate information. Soccer players were provided with written and verbal indications to record foods and fluids ingested with household measures. Brand names of commercial food were included. Information concerning time of day, cooking methods and amount of food prepared were collected. Questionnaires were reviewed to clarify ambiguous data. Eleven questionnaires were removed because these questionnaires did not express clear information for this reason the final sample was constituted by forty-seven soccer players.

The questionnaires were analyzed with a nutrient's composition software program (DIAL 1.19 version) to determine participant's nutrient intake for the 24 hours and 3 hours period studied. This process was performed by a single trained and experienced technician. This method has been previously validated in young soccer players to analyze food intake[13,14].

Soccer academy where the study was performed had a nutrition area as part of the medical services. Consequently, some of the athletes examined had received nutritional attention in previous seasons as part of nutrition area previous work. Soccer players were asked about if they have received personalized nutritional attention by nutrition area of the soccer academy in previous seasons in order to examine if a previous intervention could have effects in previous food intakes. This nutritional intervention was defined as an individual consultation including nutritional recommendations. The recommendations highlighted the importance of carbohydrates from fruits, cereals and vegetables before and after competition to improve sport performance. High protein foods such as fishes, meats, nuts, milk and dairy products were recommended after sport practice to promote muscular recovery. Soccer players were discouraged to ingest ultra-processed products due to its high level in simple sugars. Weight (kg) and height (cm) were recorded using an electronic weighing machine (Tanita UM-0.76) and stadiometer (Seca).

The experimental protocol was written following the ethics rules from Helsinki Declaration. All experimental procedures were in accordance with the Pablo de Olavide University Ethical Committee rules.

Statistical Analysis

SigmaPlot 12.5 version (Systat software) was used for Statistical Analyses. Descriptive statics (mean ± SD) were reported for the different parameters analyzed. T-student analyses were used in order to determine significant differences. The effect sizes (ES) were conducted according to previous procedures[15,16] using values for Cohen's (<0.2 small effect; <0.5 medium effect; <0.8 large effect). Quantitative differences were assessed qualitative (QA) as a previous reference[17] <1% almost certainly not; 1-5% very unlikely; 5-25% unlikely; 25-75% possible; 75-95% probably; 95-99% very likely and >99% almost certain. The level of significance was set at p<0.05 and all data are reported as means and 95% confidence intervals (CI).

Results

The mean weight and height were 67.77 ± 8.33 kg and 172.92 ± 6.57 cm. Mean intakes of energy (kcal), proteins, carbohydrates and lipids are presented in Table 1. Mean energy ingestion was 2277.55 kcal 24 hours before the match and 457.33 kcal 3 hours before. Carbohydrates consumption was 220.59 grams 24 hours before and 58.04 grams 3 hours before the match. Mean protein ingestion was 97.50 grams 24 hours and 15.83 grams 3 hours before. Lipids consumption was 109.94 grams 24 hours before the match and 19.27 grams 3 hours before.

Figure 1 shows the ingestions of energy and nutrients analyzed 24 and 3 hours before the match. Figure 1 also distinguishes between players who received nutritional recommendations in previous seasons and players who did not received. Soccer players with nutritional recommendations consumed 43.17 ± 14.99 kcal/kg BW, 4.08 ± 1.61 g of carbohydrates/kg BW, 1.91 ± 0.67 g of proteins/kg BW and 2.03 ± 0.80 g of lipids/kg BW 24 hours before the match. While players with no recommendations consumed 30.29 ± 15.40 kcal/kg BW, 2.96 ± 1.46 g of carbohydrates/kg BW, 1.27 ± 0.72 g of proteins/kg BW and 1.47 ± 0.82 g of lipids/kg BW 24 hours before the match.

Soccer player who received nutritional recommendations took 8.60 ± 1.65 kcal/kg BW, 1.09 ± 0.30 g of carbohydrate/kg BW, 0.26 ± 0.08 g of proteins/kg BW and 0.33 ± 0.09 g of lipids/kg BW 3 hours before the match. While players who did not received these recommendations consumed 6.00 ± 3.64 kcal/kg BW, 0.76 ± 0.45 g of carbohydrates/kg BW, 0.22 ± 0.19 g of proteins/kg BW and 0.26 ± 0.20 g of lipids/kg BW 3 hours before the match.

Discussion

The main point of this study was to examine the previous intakes before a match in youth soccer players, the average kcal/kg BW consumption was 34.68 ± 16.31 24 hours before a match, the average protein g/kg BW ingestion was 1.49 ± 0.76 and the mean carbohydrates consumption g/kg BW was 3.35 ± 1.59. Three hours before the match, soccer players consumed 6.89 ± 3.38 kcal/kg BW and 0.87 ± 0.43 carbohydrate g/kg BW.

Differences were found in energy, proteins and carbohydrates consumption 24 hours and 3 hours in soccer players when they have attended to nutritional consultancies.

Few studies have examined nutritional intakes in soccer players, a recent paper[18] evaluated seventy-two young male soccer players from junior teams in Mexican National Soccer league. The authors observed an energy intake of 2500-3100 kcal and a carbohydrate intake 5.4-6.7 g/kg BW/day, showing an optimal carbohydrates energy contribution. Furthermore, these players presented a 1.2 ± 0.1 g/kg BW carbohydrate pre-exercise ingestion. Another research[19] examined eighty-one soccer players from the Arenas Football Club (Bizkaia, Spain). They found a mean consumption of 41.14-54.61 kcal/kg BW, 1.81-2.14 g/kg BW proteins, 1.76-2.20 g/kg BW lipids and 4.57-6.68 g/kg BW carbohydrates. Even, another study[20] evaluated nutrient intake in sixteen England female soccer players. They observed a low energy intake 1904 ± 366.3 kcal, 4.1 ± 1.0 g/kg BW carbohydrate, 1.2 ± 0.3 proteins g/kg BW and 0.9 ± 0.2 fats g/kg BW. Clark *et al*[21] examined fourteen female soccer players. At the beginning of the season, players presented a 2290 ± 310 kcal intake, 5.2 ± 1.1 carbohydrate g/kg BW ingestion and 1.4 ± 0.3 protein g/kg BW consumption.

These studies show that soccer players need enough energy consumption and carbohydrate to maintain energy supplies for sport demands[22]. In our study, the carbohydrate ingestion was greater than the rest of macronutrients in line with the results from previous studies probably due to the impact of carbohydrate ingestion on intermittent sports performance like soccer[1]. However, a lower carbohydrate consumption was detected. As it has been previously mentioned[23] this situation could have negative consequences on sport performance; athletes examined should be encouraged to increase carbohydrates in their diets in order to enhance their muscle glycogen stores before the match. Soccer players analyzed presented a low ingestion of kcal and carbohydrate while they showed an acceptable proteins and lipids consumption. García-Rovés *et al*[24] highlighted that is essential analyzed nutritional ingestions and food preferences to implement successfully a nutritional program in soccer players and they reported that few studies of nutritional ingestion in soccer players are available. Consequently, it could be important to analyze nutrients and energy intake before a nutritional intervention in soccer.

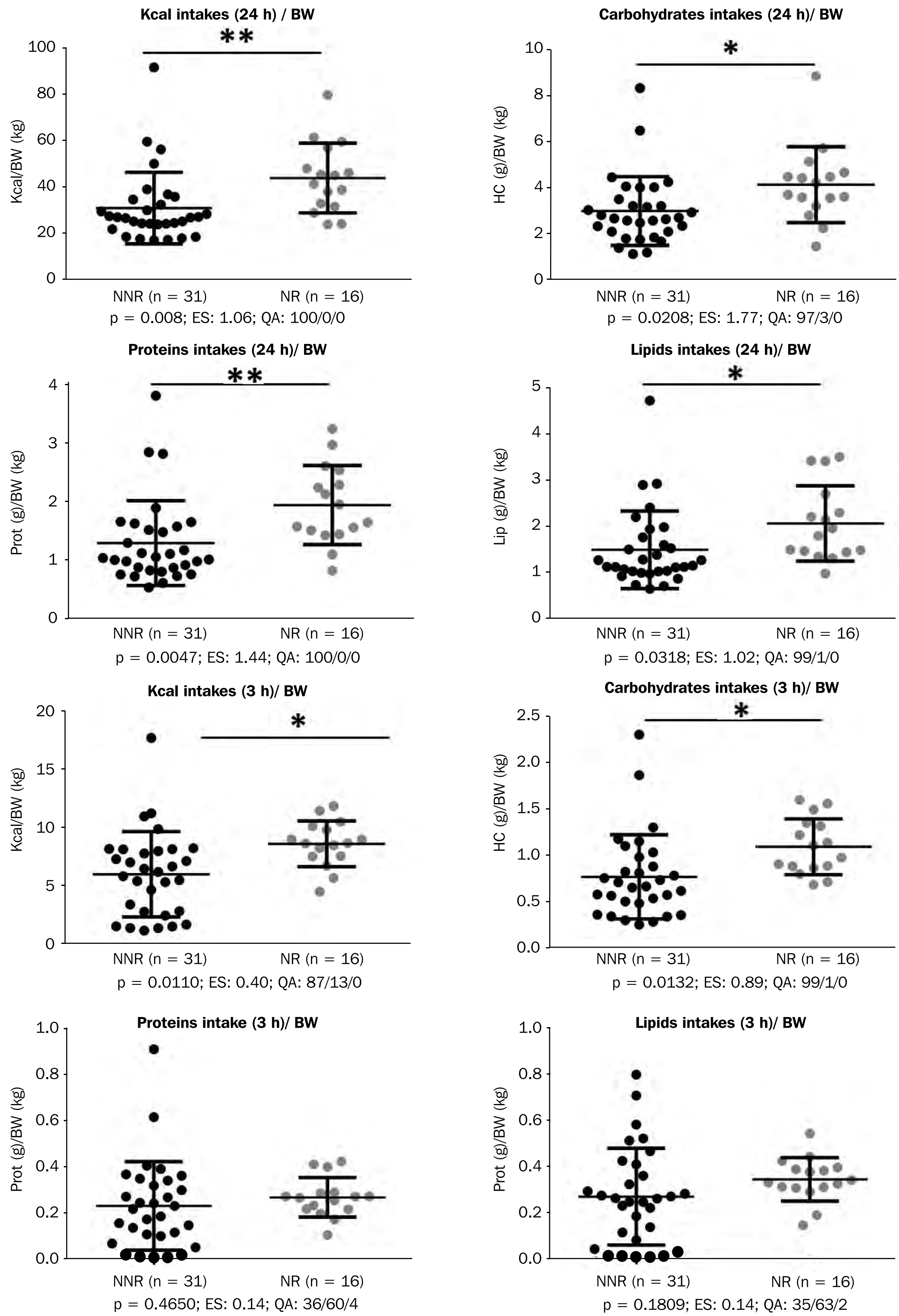
It seems that nutritional interventions could improve previous nutrient ingestions to a competitive match in young players. As it can be seen in Figure 1, nutritional interventions increased total kcal, proteins, carbohydrates and lipids ingestion 24 and 3 hours before the sport competition. However, carbohydrates ingestion per day from players who received nutritional recommendations and who did not receive

Table 1. Energy and nutrient ingestion in the young soccer players studied.

	Intakes (24 hours)	Intakes (3 hours)	Intakes (24 hours) / BW (kg)	Intakes (3 hours) / BW (kg)
Energy (kcal)	2277.55 ± 902.66	457.32 ± 204.74	34.68 ± 16.31	6.89 ± 3.38
Carbohydrates (grams)	220.59 ± 91.44	58.04 ± 26.25	3.35 ± 1.59	0.87 ± 0.43
Proteins (grams)	97.50 ± 42.36	15.83 ± 10.02	1.49 ± 0.76	0.23 ± 0.16
Lipids (grams)	109.94 ± 49.38	19.27 ± 12.10	1.66 ± 0.85	0.28 ± 0.18

Data frequencies for 47 soccer players. BW (body weight).

Figure 1. Energy and nutrients intakes normalizad with body weight.



NNR: no nutritional recommendations. NR: nutritional recommendations.

it were away from recommended intakes (4.08 ± 1.61 and 2.96 ± 1.46 *vs* 6-10 g/ kg BW)[2]. Besides, players who received nutritional guidance fulfilled fuel requirements for match play 3 hours before the game while players did not receive did not fulfilled (1.09 ± 0.30 and 0.76 ± 0.45 *vs* 1-4 g/kg BW)[2]. Molina-López *et al.*[25] supported these results because they proposed that nutritional education programs could lead athletes to adopt appropriate nutritional habits. Another study[26] examined dietary ingestions in professional soccer players obtaining that macro and micro nutrients consumption was inadequate, therefore nutritional intervention could be helpful.

Additionally, a positive correlation between nutrition knowledge and carbohydrate intake was previously obtained[5] and the authors proposed that nutritional education would improve dietary habits in soccer players. Another study[27] suggested that previous nutritional interventions have increased carbohydrate content in soccer player's diets, improving sport performance, as we have obtained in the present study. Additionally, Murphy and Jeanes[28] proposed that there would be a needed assistance in young soccer players to implement nutritional knowledge to increase nutritional intakes indicating that nutritional guidance would be really beneficial for athletes.

The present research is one of the first studies that analyze energy and nutrient ingestions before a match in Spanish young soccer players.

The current study presents limitations. Firstly, there are errors inherent of all dietary recall methods. Furthermore, we have only studied young male nonprofessional soccer players, consequently conclusions obtained cannot be extrapolate neither the rest of soccer players nor other sport disciplines. Another would be the selection no probabilistic of the players evaluated.

Finally, the players studied presented a low kcal and carbohydrate ingestion 24 and 3 hours before a competitive match. However, a nutritional intervention could improve previous energy and nutrients intakes.

Conflict of interest

The authors do not declare a conflict of interest.

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Original article

Cardiac stress associated with display parachuting

Ignacio Martínez González-Moro[1], María Carrasco-Poyatos[2], José L. Lomas-Albaladejo[1], Vicente Ferrer-López[1]

[1]Grupo de Investigación Ejercicio Físico y Rendimiento Humano. Universidad de Murcia. [2]Universidad de Almería.

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Summary

Introduction: Acrobatic skydiving is considered a high risk activity. This risk and the difficulty of the maneuvers are stressors that modify the cardiac activity. Our aim is to analyze the electrocardiographic tracing and the evolution of the heart rate during this paratrooper activity, creating a figure of high difficulty.
Method: We put a Nuubo electrocardiographic monitor on two experienced paratroopers members of the Acrobatic Patrooper Patrol of the Air Force (PAPEA) during the execution of an acrobatic exercise, called "diamond", in which four parachutists are attached during the flight. We analyzed the electrocardiogram (ECG) during the whole activity and we got the heart rate (HR) in the following phases: 1.- Up to the aircraft; 2.-Taking off; 3.- Before jumping; 4.- Preparing the figure; 5.- Formation flight and 6.- Landing. They jumped five times, obtaining the average of each jumper. Previously we made them an ECG at rest and maximal treadmill stress test (ST).
Results: Both jumpers get the largest HR while they fly preparing the formation (165 and 143 beats/min), it is 87% and 77% of the max HR reached in ST. Beats under 95 b/min are not registered in any stage or jump. Each jumper has a different response, depending on the effect that the take-off has on him. In one of them, HR increases gradually until it reaches the maximum peak when they are in formation, and on the other jumper it appears another peak, that is repeated in the five jumps, coinciding with the taking off. There is no other ECG alterations.
Conclusions: We conclude that cardiac stress caused by carrying out this type of exercises is manifested by significant increases in heart rate, around 80% of the maximum heart rate, without other electrocardiographic abnormalities.

Key words:
Heart rate. Skydiving. Electrocardiogram.

Estrés cardiaco asociado a la realización de una formación acrobática paracaidista

Resumen

Introducción: El paracaidismo acrobático es una actividad de alto riesgo. Este riesgo y la dificultad de las maniobras son factores estresantes que modifican la respuesta cardiaca. Nuestro objetivo es analizar el trazado electrocardiográfico y la evolución de la frecuencia cardiaca (FC) durante esta actividad paracaidista creando una figura de alta dificultad.
Método: Colocamos un monitor electrocardiográfico Nuubo a dos paracaidistas experimentados de la Patrulla Acrobática Paracaidista del Ejército del Aire (PAPEA) durante la ejecución de una formación acrobática en la que cuatro paracaidistas se unen durante el vuelo creando una figura denominada "diamante". Analizamos el electrocardiograma (ECG) durante todo el ejercicio y recogimos la FC en las siguientes fases: 1.- Subiendo al avión; 2.- Despegando; 3.- Antes de saltar; 4.- Preparando la figura; 5.- En formación y 6.- Tomando tierra. Se repitió cinco veces, obteniéndose la media de cada saltador. Previamente se realizó un ECG en reposo y una prueba de esfuerzo máxima (PE) en tapiz rodante.
Resultados: Ambos saltadores consiguen la mayor FC mientras vuelan preparando la formación (165 y 143 lat/min), supone el 87% y 77% de la FC máxima alcanzada en la PE. No se recogen FC inferiores a 95 pulsaciones en ninguna fase ni salto. Cada saltador tiene un tipo de respuesta, según le afecte el momento del despegue. En uno la FC aumenta paulatinamente hasta ella llega al pico máximo cuando están en formación y en el otro aparece otro pico, que se repite en los cinco saltos, coincidiendo con el despegue. En el ECG sólo se han observado episodios continuados de taquicardias sinusales.
Conclusiones: Concluimos que el estrés cardiaco producido por la realización de este tipo de ejercicios se manifiesta por aumentos importantes de la frecuencia cardiaca, en torno al 80% de la frecuencia cardiaca máxima, sin otras alteraciones electrocardiográficas.

Palabras clave:
Frecuencia cardiaca. Paracaidismo. Electrocardiograma.

Correspondence: Ignacio Martínez González-Moro
E-mail: ignaciomgm@um.es

Introduction

Stress is understood to be the body's response to environmental demands which exceed its natural ability to cope[1]. This response entails the nervous and endocrine systems regulating and modifying the sensation of pain, energy production, temperature changes, blood pressure and heart rate[2]. The hormones involved include glucocorticoids and catecholamines[3].

Numerous situations or stressors have been described. These range from fear and new situations to the feeling of being watched or scrutinised and facing up to difficult tasks[4].

The physiological and emotional responses to these situations are regulated by the brain and do not necessarily suppose physical and mental health problems, but can be considered a way of preparing for an activity involving these factors[5]. Typical physiological manifestations include an increased heart rate (HR), tremors and a dry mouth, which appear both when suffering from anxiety prior to examination[6] and as an anticipatory response when about to enter into risky activities such as skydiving[7], other high-risk sports or unknown environments[8,9]. Sometimes these responses are very intense, frequent or long-lasting and the stress suffered can lead to health complications[10] by triggering the onset of a latent disorder, complicating the clinical signs or perpetuating the symptoms[11].

Parachuting in itself is considered a high-risk activity and, as such, calls for constant attention and concentration in order to minimise the possibility of having an accident[12]. As a result, physiological reactions are sparked which help prepare the body for this situation as a consequence of the stress produced[13], as occurs in all athletes. This response is mediated by cortisol[14,15].

If to the innate risk of the activity we add the stress corresponding to carrying out an extremely difficult task, such as performing the manoeuvres involved in creating a display formation, then we arrive at a remarkably complicated situation which justifies the production of sufficient adrenaline, cortisol and ACTH, among other substances, to raise the heart rate[16,17].

These specific manoeuvres consist of controlling the parachute canopy in order to approach other teammates, joining parachutes in a specific formation and descending for a few minutes in a coordinated fashion, maintaining the figure formed, and then breaking free without getting tangled up with each other before landing.

The physiological and psychological responses associated with parachute jumping have been studied both in sport parachutists[15,17-19] and military parachutists, in other circumstances such as tactical jumps[20,21], high-altitude jumps or tandem jumps[22], but never in display team jumps.

Stress, together with physical exercise, is known to trigger episodes of arrhythmia, especially tachycardia which can cause sudden death[23], and we also know that psychosocial risk factors related to work lie in the background of many myocardial infarctions[24]. Hence the importance of this study to discover the cardiac response to situations which are highly demanding, more mentally than they are physically. Therefore, our aim is to analyse the electrocardiogram pattern and evolution of the heart rate associated with the stress caused by very difficult precision parachuting.

Materials and method

Population

Two parachutists ("A" and "B") belonging to the Spanish Air Force's Parachute Display Team (PAPEA) with three years' experience in the group and aged between 27 and 26 took part. Both were informed of the objectives of and procedures involved in the study, and signed the corresponding informed consent document. Permission was received from the relevant military authorities and a favourable report was received from the Research Ethics Committee at the University of Murcia.

Procedure

A Nuubo® electrocardiographic monitor was fitted onto each of parachutists during a "diamond with flag" formation in which four parachutists join up during descent (Figure 1). Parachutist "A" occupied the middle right position and parachutist "B", the bottom position with the flag. After leaving the aircraft and freefalling for a few seconds, the parachutists open their parachutes and approach each other in order to perch on another jumper's canopy and then continue to descend, all four together, until they reach the critical altitude at which the formation is broken. At that point, the figure breaks up, the parachutists separate and each one lands independently. The exercise was repeated on five separate occasions over two consecutive days in similar weather conditions.

In a session prior to the jumps, a cardiovascular examination was conducted on each parachutist which included auscultation, taking his blood pressure and an electrocardiogram at rest. They were the subjected to a maximum stress test (ST) on a treadmill (Runner® run 7411), measuring their respiratory response (Cortex®, Metalyzer 3B) and with electrocardiographic stress testing (CARDIOLINE®, Click ECG BT).

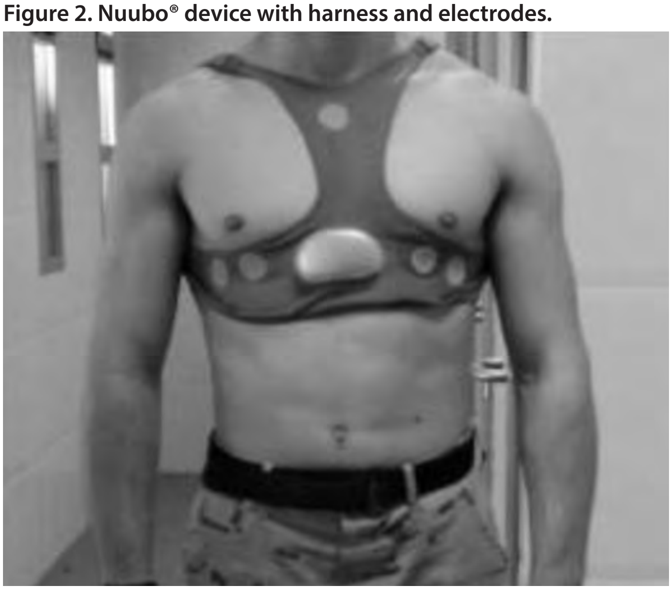
The Nuubo® device was fitted onto an elastic harness on each jumper's chest (Figure 2). The harness bore five electrodes which, with the help of a conductive gel, tracked electrical activity to process and generate the three leads.

The Nuubo® monitor continuously recorded the three electrocardiographic leads from before embarking on the plane until their return to base after the last jump of the day. The electrocardiogram (ECG) was then analysed in search of alterations and the heart rate was determined in each of the stages into which the jumps were divided: 1.- Embarking; 2.- Taking off; 3.- Ready to jump; 4.- Flying to the formation, preparing the figure; 5.- In formation, and 6.- Landing. The jumps were videotaped from the ground with a camera synchronised to the second with the ECG device in order to relate every action with the corresponding heart rate timewise.

To obtain the heart rates, the recording of each of the jumps was viewed, tracking the hour:minute:second, and selection was made of a segment of an ECG lead free of interference spanning five seconds

Figure 1. "Diamond with flag" formation.

Figure 2. Nuubo® device with harness and electrodes.



before and after the moment chosen for each stage and the maximum HR was determined during this interval.

Statistical method

The mean (X) and standard deviation (SD) of the HR of each of the stages for each of the parachutists were obtained. The coefficient of variation (CV) was used to analyse the homogeneity of the measurements (CV=SD / X x 100), considering values of less than 20% homogeneous. The mean values were compared using Student's t-test after checking the normal distribution of the initial characteristics using the Shapiro-Wilk test and the equality of variances using the Levene test.

Results

Table 1 shows the anthropometric descriptive data and the data of the initial assessment of each of the parachutists taking part, including heart rate at rest and maximum heart in the stress test (HRmax ST).

Table 2 shows the heart rates in each of the stages of each jump for parachutist "A" and "B", respectively.

The coefficients of variation of the heart rates of each parachutist in each of the stages show that the values are very homogeneous and, therefore, the variability is minimal. Comparing the mean heart rates of each parachutist in each stage, significant differences can be observed (Table 3); these are more marked on take-off and during freefall before taking up formation (Figure 3).

By calculating the percentages of the mean heart rates in each stage with regard the heart rates at rest and the maximum in the stress test, we obtain the values shown in Table 4.

Table 1. Anthropometric characteristics and initial assessment.

Variables	Parachutist A	Parachutist B
Age (years)	27	26
Years parachuting	4	4
Years in PAPEA	3	3
Height (cm)	182	175
Weight (kg)	70	67
BMI (weight/height2)	21.1	21.8
HR at rest (ppm)	64	72
HRmax ST (ppm)	189	185
BP at rest (mmHg)	120/60	120/65
ECG at rest	No alterations	No alterations
ECG under stress	Compatible normality	Compatible normality

Figure 3. Evolution of the mean heart rate (beats/min) of each parachutist in each stage of the jumps.

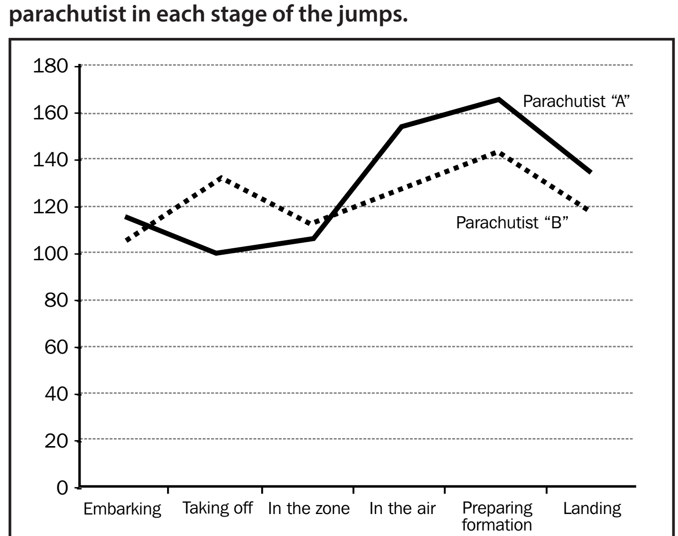


Table 2. Heart rates (beats/min) in each stage, jump and parachutist.

	Jump No. 1		Jump No. 2		Jump No. 3		Jump No. 4		Jump No. 5	
Paracaidista	"A"	"B"	"A"	"B"	"A"	"B"	"A"	"B"	"A"	"B"
Embarking	110	119	90	96	125	88	128	113	124	112
Taking off	101	138	99	144	97	125	95	123	110	128
In jump zone	105	122	103	120	100	117	116	111	104	93
In the air	153	130	156	142	166	122	150	121	150	131
Preparing formation	150	151	184	147	160	137	172	142	162	138
Landing	138	110	117	120	142	126	144	126	135	107

Table 3. Mean, standard deviation and CV of HR (beats/min) in each stage and parachutist.

	Parachutist "A"		Parachutist "B"		
	Mean ± sd	CV	Mean ± sd	CV	Differences (p)
Embarking	115.4 ± 15.8	13.7	105.6 ± 13	12.3	0.316
Taking off	100.4 ± 5.8	5.8	131.6 ± 9.0	6.9	0.000
In the zone	105.6 ± 6.1	5.8	112.6 ± 11.7	10.4	0.270
In the air	155.0 ± 6.6	4.3	129.0 ± 8.5	6.6	0.001
Preparing formation	165.6 ± 12.9	7.8	143.0 ± 6.0	4.2	0.007
Landing	135.2 ± 10.8	8	117.8 ±8.9	7.6	0.025

Table 4. Percentages of HR at rest and at maximum stress in each stage.

	% HR at rest		% HRmax ST	
Parachutist	"A"	"B"	"A"	"B"
Embarking	180.3	146.7	61.1	57.1
Taking off	156.9	182.8	53.1	71.1
In the zone	165.0	156.4	55.9	60.9
In the air	242.2	179.4	82.0	69.8
Preparing formation	258.8	198.6	87.6	77.3
Landing	211.3	163.6	71.5	63.7

Discussion

We considered precision parachuting to be a stressful practice with impact on cardiac activity. To investigate this, we monitored the electrocardiographic tracing and heart rate when completing a highly complex, high-precision parachute display formation.

Situations of anxiety or stress involve stressors which can be identified in each stage of the case we are focusing on.

In the first stage of the jumps, which we have called "Embarking" and consists of the parachutist carrying his equipment to the plane, we observed mean HRs of 115 and 105 beats per minute.

The second stage, "Taking off", occurs within the plane, with the parachutist sitting or standing, but not doing anything else. The increase in HR responds to the stressful situation of preparing for what they are about to do and potential fear of what might happen. The values are similar to those reported at different stages in aircraft pilot training[25]. We noted that the response was different in the two subjects. One maintained an average HR of 100 beats, while the other reached 130, which when compared with the HRs in the other stages suggests that each adapted differently to take-off, conditional on many factors, including different gene expression[26] and the influence of aircraft noise on anxiety and health in general[27].

Certain factors related to risk activities may give rise to fear and anxiety because the participant is endangering his/her health[7]. Some of these are factors external to the parachutist which can affect forming the figure, such as changes in the strength and direction of the wind or equipment failure, which, while not expected, are foreseeable, this being a planned activity in which uncertainty is limited and the environment monitored[28]; these are, therefore, stressors which can be controlled. This is the situation we can observe in the third stage, "in the zone", in which the parachutists are in the plane, flying over the jump zone, ready to exit. The subjects' heart rates were higher than in the previous stage, but lower than those observed in stage 4, "in the air", in which they freefall and open their parachutes to approach each other and take their positions in the formation.

In this fourth stage, the main stressor is the sensation of falling[26], together with those previously mentioned of fear of the parachute not opening and equipment failure.

Another factor contributing to stress is the fear of failure. In our case this would consist of not achieving the objective of the jump, creating the planned figure, due to poor personal handling or discoordination between the members of the team. We can consider this a professional factor and what differentiates these subjects and makes them unique for their mission[29], in a manner similar to that of first-class athletes[30]. The response to this factor lies in the high heart rates shown in stage 5, "preparing the formation". During these few minutes of their descent, the physical exercise the parachutists perform is focused on controlling their parachutes and their relative position in space and with regard the other team members. They are concerned about being in the right place at the right time, occupying the predetermined position. The days on which this study was conducted, all the jumps were valid and were carried out in "privacy", jumping in the vicinity of the air base without spectators. Had the exercise been performed at an exhibition or air show, the stressors mentioned above would be joined by the feeling of being watched and judged by a crowd expecting perfection, coupled with the responsibility of representing their institution (Air Force). Something similar happens at sports championships[31].

At this stage, fear of the parachute failing to open may have disappeared and experience in jumps of this nature exerts its influence. According to Mazureck *et al*[15,18], parachute training may lead to a reduced response to stress and improved autonomic control of the cardiovascular function in novice parachutists.

After achieving the figure, they must descend together without breaking the formation, each maintaining his position; this involves the new emotional burden of not contributing to the failure of the enterprise. After this, they need to separate and descend in order to land independently and safely. This creates a new stressful situation. If they cannot form the figure, they have failed and must try again, reorganising the team and the equipment, and taking off once again, with all the economic implications that would involve.

Other authors have used parachute jumps to assess immune, genetic[26] and hormonal responses to stress, measuring, among other things, cortisol and salivary amylase[7,15,32]. The results of Meyer et al's study[33] suggest that experience may modulate the emotional response involving cortisol reactivity to parachuting, but does not cancel out its appearance altogether. This may be consistent with the data showing that, despite being highly experienced, the heart rates of our parachutists still rose during the different stages of the jump.

Other studies suggest that parachuting may result in reduced vagal activity associated with increased sympathetic tone during jumps. Experienced parachutists, however, are not exposed to high cardiovascular risk[34]. All the same, we agree on the need to study their cardiovascular function when subjected to stressors.

The cardiac response to episodes or situations of occupational stress has been studied in nurses[35], members of the security forces[36] and surgeons[37], among other groups. These studies have focused on tachycardias as manifestations of the anxiety accumulated by the continued practice of the profession[38] within the context of burnout syndromes and responses to specific situations which accentuate personal vulnerability in the professional task being performed. In the case of our parachutists, the pressure to which they are subjected is controlled by experience and planning execution of the exercise.

In order to avoid the consequences of stress[39], each individual should employ coping strategies, i.e. make efforts to deal with the stressful situation[40].

The main limitation of our study is the low number of participants, meaning we cannot arrive at categorical conclusions or make generalisations, but it can be used as a basis from which to guide the response to this activity and propose actions to promote health and conduct further research. It would be interesting to determine the influence of experience by comparing what occurs with novice and veteran parachutists when performing the same task.

Although we have not detected any anomalies, through this study we open the way to using the continuous study of electrocardiographic tracing for the physiological assessment of parachutists, compared with studies which only work with data from before and/or after jumping[22] or ones which do not take tracings into account.

We can conclude that experienced parachutists who perform formation displays undergo cardiac stress, as manifested by significant increases in the heart rate of around 80% maximum heart rate. The electrocardiographic tracings only revealed continuous episodes of sinus tachycardia.

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Conflict of interest

The authors do not declare a conflict of interest.

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Assessment of an APP to measure lift velocity during bench press exercises: preliminary results

Javier Peláez Barrajón, Alejandro F. San Juan

Laboratorio de Biomecánica Deportiva. Departamento de Salud y Rendimiento Humano. Facultad de Ciencias de la Actividad Física y del Deporte – INEF. Universidad Politécnica de Madrid.

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Summary

Introduction: It's becoming more common to find sports mobile applications that have easy access and are easy to use. Nevertheless their general measure precision still needs improvement. The objective of this study was to determine the precision that a Smartphone application (APP) and a Smartphone accelerometer can provide to measure the mean velocity of a bench press (BP) on Smith machine.
Material and method: 5 subjects participated in the study (age 23,8 ± 2,94 years), they had a minimum lifting experience of 1 year. All of them did 3 repetitions with a load of 70% and 90% of the estimated value of 1 Repetition Maximum (1RM), and a lift with their 1RM. In each repetition mean velocity was measured by a validated linear encoder and the APP.
Results: there was a strong positive correlation in mean velocity between linear encoder and the APP (r= 0,685, p<0.001, SEE=0,09 $m \cdot s_{-1}$). Intraclass correlation coefficient (ICC = 0,707) showed a good agreement between both devices. The APP showed significant differences in the mean velocities of lifts with the 90% 1RM (APP= 0,44±0,08 $m \cdot s_{-1}$; Encoder= 0,30 ± 0,03 $m \cdot s_{-1}$), not showing significant differences in mean velocities of lifts with 70% 1RM (APP= 0,54±0,13 $m \cdot s_{-1}$; Encoder= 0,51 ± 0,10 $m \cdot s_{-1}$).
Discussion: At this moment the APP is not totally reliable and valid at low velocity lifts. Nevertheless, with proper signal filters it could be a precise, accessible and easy to use tool to measure lifts velocity in an easy and proper way.

Key words:
Accelerometer. Smartphone. Resistances. Training. Technology. Strength. APP. Test.

Evaluación de una APP para medir la velocidad de levantamientos de *press* banca: resultados preliminares

Resumen

Introducción: Cada vez es más frecuente encontrar aplicaciones móviles relacionadas con el deporte de fácil acceso y uso. Sin embargo, su precisión general de medida tiene aún mucho margen de mejora. El objetivo de este estudio fue determinar la precisión de una Aplicación móvil (APP) Android y del acelerómetro del teléfono móvil, para medir la velocidad media de un levantamiento de *Press* Banca (PB).
Material y método: Participaron en el estudio 5 sujetos (edad 23,8 ± 2,94 años), con una experiencia mínima de un año en el entrenamiento con resistencias en PB. Todos realizaron 3 repeticiones con un 70% y 90% del valor estimado de 1 Repetición Máxima (1RM). En cada repetición se midió y comparó la velocidad media simultáneamente con un Encoder lineal validado y la APP.
Resultados: Observamos una correlación positiva fuerte de la velocidad media entre el *Encoder* lineal y la APP (r= 0,685, p<0.001, SEE=0,09 $m \cdot s_{-1}$). El coeficiente de correlación intraclase (ICC= 0,707) mostró un buen acuerdo entre ambos dispositivos. La APP mostró diferencias significativas en las velocidades medias de levantamientos del 90% 1RM (APP= 0,44±0,08 $m \cdot s_{-1}$; Encoder= 0,30 ± 0,03 $m \cdot s_{-1}$), no encontrando diferencias significativas en velocidades medias con cargas del 70% 1RM (APP= 0,54±0,13 $m \cdot s_{-1}$; *Encoder*= 0,51 ± 0,10 $m \cdot s_{-1}$).
Discusión: La APP no es por el momento totalmente válida y fiable a bajas velocidades de ejecución. Sin embargo, con filtros de señal específicos puede llegar a ser una herramienta de medición suficientemente precisa, accesible, fácil de usar, y que permitirá estimar la velocidad de los levantamientos de forma cómoda y adecuada.

Palabras clave:
Acelerómetro. Teléfono móvil. Resistencias. Entrenamiento. Tecnología. Fuerza. APP. Test.

Correspondence: Javier Peláez Barrajón
E-mail: javi.pelaezb@gmail.com

Introduction

Resistance or weight training has been the method most used to increase muscle strength in athletes[1]. In order to prescribe a resistance training programme based on the capabilities of each individual athlete, it is first necessary to determine the maximum load that this person can move during an exercise or the lift velocity[2].

The performance of a 1 Repetition Maximum (1RM) strength assessment test carries a high risk of injury for novice athletes or more fragile populations such as children and the elderly[3]. Even for high-performance athletes, the 1RM test still entails a risk of injury and could affect the planning of their training sessions[4]. Consequently, different indirect methods have been proposed to estimate 1RM: methods based on muscular endurance[5-7], anthropometric measurement methods[8-11], and those based on lift velocity[12,13].

The 1RM estimation method based on sub-maximal lift velocity has been shown to be a valid and reliable method to accurately predict 1RM without actually performing the lift at maximum load[12,13]. The linear transducer is considered to be the gold standard tool for the measurement of lift velocity[12,13], however its main drawback is that it is expensive. Other methods are available for the measurement of lift velocity, such as the use of video analysis[14,15] or professional accelerometers[16,17]. Moreover, it is becoming increasingly more common to find smartphone sport-related applications, and specifically for the analysis of lift velocity[14], or jumping[18].

Given that present-day smartphones feature inertial sensors (accelerometers, magnetometers and gyroscopes) to determine the position and movement of the device, this technology could be used to measure lift velocity[19]. However, to date, and to the best of knowledge, there is no smartphone Application (APP) that uses this hardware to measure velocity and estimate strength.

The key aim of this study was to establish the reliability and validity of the APP that uses the smartphone accelerometer to obtain the mean concentric velocity of a bench-press (BP) lift on a Smith machine, compared with a validated linear transducer. Moreover, the specific objectives were as follows: 1) to determine the degree of validity of the smartphone accelerometer, 2) to verify the utility of the application in an actual test environment, and 3) to identify any potential errors and disadvantages of the APP in order to correct future software versions.

The following hypothesis is made: the APP will be valid and reliable for the measurement of the mean lift velocity compared with a validated linear transducer.

Material and method

Experimental approach to the problem

Five young male subjects took part in the study, with experience in endurance training and specifically with at least 1 year's experience in BP exercises. All subjects performed 3 BP repetitions on the Smith machine with 70% 1RM, 3 repetitions with 90% 1RM and one attempt at 1RM. These intensities-percentages were selected, given that they have proven to be useful in estimating the 1RM value through a linear equation, as described by Jaric, S.[20]. Each repetition was simultaneously measured with a validated linear transducer[19] (Speed4Lifts, Madrid, Spain), and smartphone (TEL), both attached to the bar. A running armband phone holder was used to attach the TEL (Figure 1) while the velcro strip supplied with the transducer was used to fix it in place. Statistical analysis was used to compare the mean concentric velocities for 70 lifts in order to verify the validity and reliability of the APP..

Figure 1. Position of the linear transducer and the TEL during the experiment.

Participants

5 subjects with at least one year's specific experience in BP resistance training took part in the study (Mean ± Standard deviation: Age = 23.8 ± 2.9 years; Height = 177.6 ± 9.2cm; Weight = 77.5 ± 9 kg; 1-RM BP = 80.8 ± 16.7 kg). The exclusion criteria were as follows: 1) aged under 18 years; 2) consumption of narcotic drugs and/or psychotropic substances before or during the test; 3) any cardiovascular, metabolic, neurological, pulmonary or orthopaedic disease or disorder that could limit performance in the different tests; 4) less than 12 months' experience in BP training. All participants were students at the Faculty of Physical Activity and Sports, where the test was conducted.

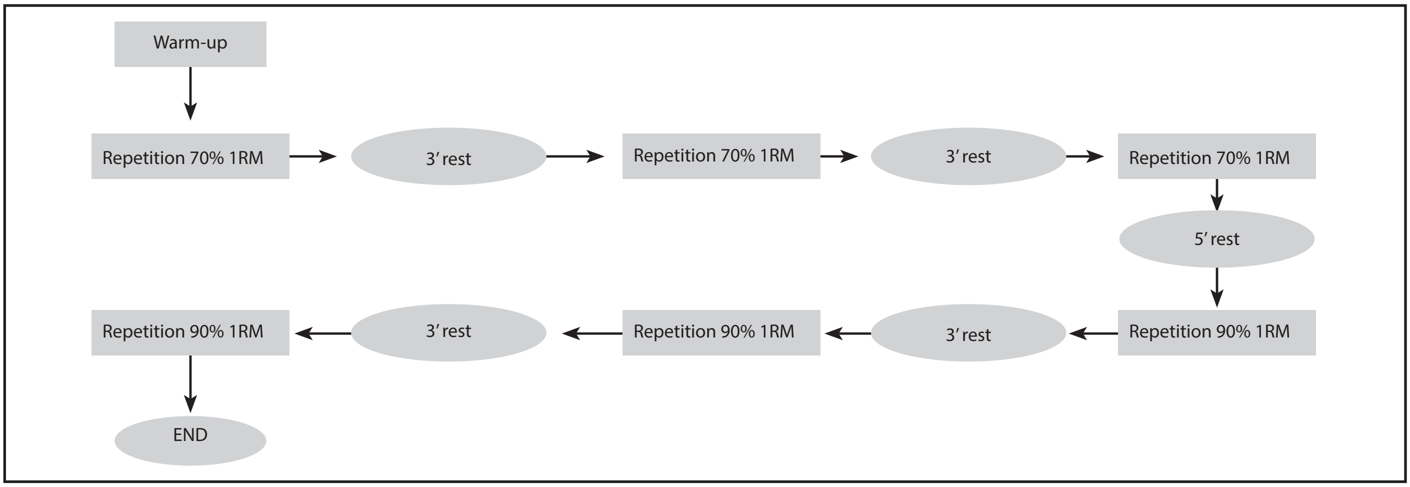
The study was approved by the Ethics Committee of the Universidad Politécnica de Madrid and complies with the principles of the Declaration of Helsinki for research involving human subjects. The purpose of the study was explained to each participant, both orally and in writing through an information sheet, and all participants signed an informed consent form.

Procedure

BP test

All subjects performed a warm-up based on the literature[18,21]. They started with 5 minutes of aerobic exercise and went on to do dynamic stretching (e.g. internal and external shoulder rotations, elbow extensions and wrist rotations), and upper-body joint mobility exercises. This was followed by 2 sets of 5 BP repetitions at approximately 50% of the subject's 1RM and a two-minute rest between sets. To complete the warm-up, the subjects performed two sets of 1 repetition at 50% of their 1RM at maximum velocity in order to suitably prepare the body's muscles.

Figure 2. Flow diagram with the implementation of the BP test.



During the test, each subject performed 3 repetitions at 70% 1RM and a three-minute rest between each repetition. After the final repetition with 70% 1RM, they rested for 5 minutes and then began the 3 repetitions at 90% 1RM, with a three-minute rest between each repetition (Figure 2).

Each repetition started with a 3 second pause after unhooking the bar. The APP gave a beep ("LETS GO") and the subjects performed the eccentric phase of the lift, until the bar touched the chest. After a 1 second pause, the application gave a second beep and the subjects performed the concentric phase of the lift at the maximum possible velocity. Both the APP and the transducer recorded the mean concentric lift velocity. All the lifts were performed on a Smith machine.

All subjects were requested not to train the muscle groups involved in the lift for at least 2 days before the test.

Instruments

The APP was developed at the Android Studio integrated development environment (Google, California, USA), using the Java programming language (Oracle, California, USA). The sensorManager library was used to capture the acceleration values. The APP was installed in a Huawei G620S smartphone (Huawei Technologies Co., Guangdong, China), with an Android operating system (Google, California, USA), and a lis3dh three-axis accelerometer (STMicroelectronics, Geneva, Switzerland). The acceleration sampling frequency was set at 50 Hz. To calculate the mean lift velocity, accelerations were taken from the concentric phase on the smartphone Z axis and the integration principle was used for the integration of these values:

$$\nu = \int a\,dt$$

A trapezoidal rule was developed in code to obtain the approximation of the integration value:

$$\int_b^a f(x)dx \sim h/2\,[f(a)+2f(a+h)+2f(a+2h)+\cdots+f(b)]$$

Where $h = \frac{(b-a)}{n}$ and n is the number of divisions.

The trapezoidal rule divides the area under the curve for the plot of the different acceleration values into n trapezoids of different areas. The sum of the area of all the trapezoids under the curve will give the approximated value of the integral of the said curve. The greater the number of trapezoids, which is in keeping with the number of acceleration events taken during the concentric phase, the greater the precision of the integral approximation[22].

Given the considerable noise of the TEL accelerometer, various signal filtering processes were used. These processes included the use of a "mechanical" filter to eliminate those residual values that ought to be 0 but which were given a higher or lower value by the accelerometer. Furthermore, a low pass filter was used with a filter factor that would smooth-out the acceleration curve, the greater the value.

Statistical analysis

The Shapiro-Wilk test was used for the data normality analysis. Once the normality of the dependent variables had been confirmed, ($p > 0.05$), the results were presented as a mean (M), and standard deviation (SD). Various statistical analyses were used to demonstrate the validity and reliability of the APP in comparison with the linear transducer in the BP exercise on the Smith machine. Firstly, the concurrent validity of the APP was tested using the Pearson correlation coefficient (r). The *Intraclass Correlation Coefficient* (ICC) was used to calculate the APP measurement reliability compared to that of the linear transducer. The calculation of the mean differences between the two measurements was made using a paired-sample *t* test. The standard error of estimate (SEE) was used to show the standard deviation in the measurements. The significance cutoff was set at $p = 0.05$. All calculations were performed using IBM® SPSS® Statistics 23 software (IBM Co., USA).

Results

The concurrent validity of the APP

Following the analysis of all the data for the 30 mean velocities, Pearson's correlation showed a strong positive relationship between the velocities taken simultaneously with the transducer and the APP (*r*= 0.685, *p*<0.001, SEE=0.09 m • s_{-1}) (Figure 3).

Measurement reliability

There was good agreement between the mean velocity values obtained with the APP and the linear transducer, as shown by the ICC and Cronbach's *alpha* (ICC= 0.707; CI= 0.076- 0.886; α = 0.812).

The paired-sample t test used to compare the mean lift velocities obtained by the linear transducer and the APP showed a significant difference in velocities (APP= 0.49±0.12 m • s_{-1}; Transducer= 0.41 ± 0.13 m • s_{-1}; *p* < 0.001) with higher mean velocities measured by the APP (mean difference: 0.08 m • s_{-1}).

The paired-sample t-test was performed to compare the mean velocities at each percentage of 1RM, finding no significant differences between the mean velocities at 70% 1RM measured by the APP and the linear transducer (*p* > 0.05). However, significant differences were found in the mean velocities measured for lifts at 90% 1RM, with the APP measurements being clearly higher (*p* > 0.001) (Table 1).

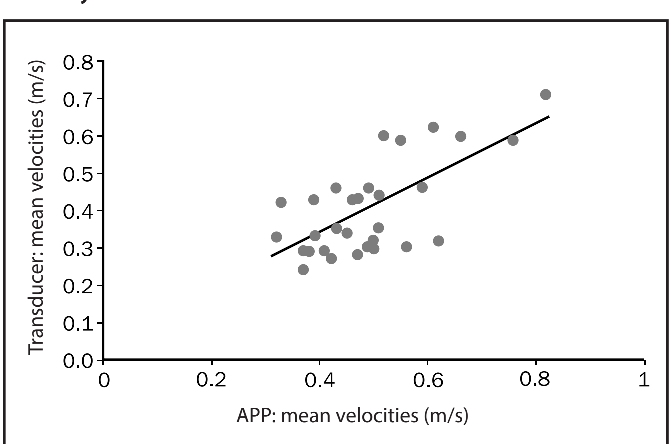
Discussion

The APP did not prove to be totally valid and reliable for the measurement of the mean velocity of a BP exercise on the Smith machine, compared with a validated linear transducer. The mean lift velocity values obtained with the APP were shown to have a strong positive correlation

Table 1 Mean lift velocity (m • s_{-1}) based on the 1RM percentage. The data are presented as mean ± SD (standard deviation).

	App Mean ± SD	Transducer Mean ± SD
Mean velocity 70% 1 RM	0.54 ± 0.13	0.51± 0.10
Mean velocity 90% 1 RM	0.44 ± 0.08	0.30± 0.03

Figure 3. Pearson's correlation between the mean velocities measured by the linear transducer and the APP for the 30 velocities.



(*r*=0.685) with a good level of agreement (ICC = 0.707) compared with the linear transducer. It was also observed that the means velocities measured with the APP were significantly higher than those obtained with the linear encoder (mean difference: 0.08 m • s_{-1}).

Specifically analysing the differences in the velocity measurements at the different 1RM percentages, no significant differences between the mean measurements of the APP and the transducer were observed for lift velocities close to 70% 1RM (APP= 0.54±0,13 m • s_{-1}; Encoder = 0.51 ± 010 m • s_{-1}). However, for velocities close to 90% 1RM, significant differences were found in the mean velocities of the APP compared to the transducer (APP= 0.44±0.08 m • s_{-1}; Encoder = 0.30 ± 0.03 m • s_{-1}).

The APP seems to accurately measure mean velocities for loads close to 70% 1RM, with extremely small errors (0.03 m • s_{-1}). At 90% 1RM, the error in the lift velocity measurements remains constant at around 0.15 m • s_{-1}. This may be due to the fact that the accelerometer signal filtering was not programmed correctly for lower velocities. On the positive side, the results obtained in this exploratory study will make it possible to make finer adjustments to the filtering process for these velocities and thereby obtain results that are closer to, or even as good as those obtained at 70% 1RM lift velocities.

The linear transducer used in this study to compare the accuracy of the APP, measures the velocity of the vertical displacement of the cable attached to the bar through electric signal transduction. For this reason, many authors consider linear transducers to be the gold standard[23] for the measurement of lift velocity. Other systems to measure lift velocity[16,24] and muscle strength (25), based on accelerometers, have been shown to be valid and reliable.

Earlier literature has shown APPs to be valid and reliable for the measurement of lift velocity[14]. The disadvantage of these applications is that it is necessary to correctly select the frames marking the start and end of the lift in order to measure the athlete's range of motion in the exercise. For example, the Powerlift[14] application requires a camera with a high-speed recording capacity, given that the higher the frames/second sampling rate, the greater the accuracy obtained when determining the duration of the lift. Even so, information is always lost with regard to the space between frames, causing data loss in relation to the bar displacement velocity. Measurement of the range of motion must be made following the same procedure and as accurately as possible in order to prevent differences between lifts. This, together with the decisions taken by the observer (which frames are valid and which are not), increases the probability of error and complicates the measurement reproducibility.

This study has combined the use of the smartphone accelerometer with the development of a mobile application (APP) to treat the accelerations obtained during the lift and thereby directly measure lift velocity. In earlier literature, studies were made of the reliability and validity of other accelerometers[19] such as the Beast Sensor, reporting lower reliability and validity at low velocities, in addition to mean velocities that were higher than those of a linear transducer and a considerable loss of repetitions that were not detected correctly by the sensor. APPs such as Powerlift[14] have been shown to give an accurate measurement, yet slightly higher than the mean velocity measured by a linear transducer, while the reliability and validity of the results depend on the Hz recording recording and on the correct measurement of the range of motion. For this reason, these technologies are consistent with our APP in overestimating the mean lift velocity despite the fact that they use accelerometers of a higher quality or manual frame selection and range-of-motion processes.

This study was unable to ensure the validity and reliability of the APP, possibly due to the decision to set the sampling frequency at 50Hz, which is lower than the frequencies adopted by other systems for the measurement of velocity using an accelerometer (e.g. 200 Hz to 500 Hz)[16,24]. Furthermore, the quality of the accelerometers used in these devices (such as Push band, Beast)[16,24], and their price (around USD 350-250), are higher than those used in present-day smartphones, which are not designed to analyse motion with such accuracy and whose price is generally under USD5. Therefore, although in the future it is difficult to expect the APP tested in this study to obtain better measurement accuracy results than those of higher quality accelerometers or linear transducers, the aim of the study was to get as close as possible and to outclass the APPs based on estimations through the use of frames. The APP in this study is an inexpensive approximation of a transducer, making it possible to measure multiple movements. It is easily accessible and will prove useful for trainers and coaches, allowing them to have an approximate idea of the velocity at which a subject is moving a load.

In conclusion, the APP used in this study, which is based on the TEL accelerometer, is not yet valid or reliable for all the mean concentric velocity ranges of a BP lift on the Smith machine, compared with a validated linear transducer.

In future studies, the accelerometer signal filtering will be improved for lifts at low velocities in order to improve the measurement results for ranges close to 90% 1RM and to permit a good estimate of the 1RM value. Moreover, the performance of the APP will be tested with other smartphones and other accelerometers and operating systems, directed at improving and more efficiently adjusting the APP sampling frequency.

Future lines of investigation will explore the use of the accelerometer and inertial sensors within the area of expertise relating to biomechanics in sports and healthcare, as well as at an educational level.

Practical application

This APP makes it possible to measure the mean lift velocity as accurately as possible, thereby offering trainers and coaches an inexpensive, quick and simple way of suitably planning a strength training session, with no additional material required.

Conflict of interest

The authors have no conflict of interest at all.

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Original article

Artificial altitude training strategies: Is there a correlation between the haematological and physical performance parameters?

Diego Fernández-Lázaro[1], Juan Mielgo Ayuso[2], Alberto Caballero García[3], Jorge Pascual Fernández[4], Alfredo Córdova Martínez[3]

[1]Departamento de Biología Celular, Histología y Farmacología. Facultad de Ciencias de la Salud. Universidad de Valladolid. Campus de Soria. Soria. [2]Departamento de Fisiología. Facultad de Ciencias de la Salud. Universidad de Valladolid. Campus de Soria. Soria.[3]Departamento de Anatomía. Facultad de Ciencias de la Salud. Universidad de Valladolid. Campus de Soria. Soria. [4]Centro Salud San Jorge. Pamplona. Navarra.

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Summary

Introduction: Exposure to intermittent hypoxia (IHE) which is used as a complement to conventional training to obtain improvements in key haematological indices to increase athletic performance.
Objective: We assessed hematological and physical performance changes by an IHE program in elite athletes (EA) living and training in moderate hypoxia.
Material and method: For a 4-week normobaric IHE treatment (90 minutes, 7 days a week, 10-13 % FIO2) was applied at 12 EC. Their physical-anthropometric characteristics were established before the start of the study: Blood tests and physical tests were performed at 2 points in the study: a) on day 1, just before the start of the study (T1); b) on day 28, just at the end of the study (T2). The following were measured: reticulocytes (RET.), reticulocyte haemoglobin (Hb-RET), erythropoietin (EPO), complete haematological profile and iron metabolism. Physical performance was determined by evaluation of aerobic potency, anaerobic potency, and velocity and maximum oxygen consumption (CsO_2max).
Results: Between T1 and T2 there is a significant increase in EPO, RET and Hb-RET, as well as a non-significant increase in the haematological variables involved in erythropoiesis HEM, Hb and Hcto. Performance increased in all physical tests, speed (1.96±2.35 %), aerobic power (3.73±5.34 %), CsO_2max (3.36±4.35 %) and was significant in anaerobic power (p = 0.05 with 1.93±1.13 %).
Conclusions: The IHE program of 4 weeks' duration in combination with training is able to stimulate hematological parameters such as EPO, RET, HEM, Hct, and Hb that demonstrate an activation of the erythropoiesis of the athlete and could be the cause of improvements in all performance tests, being only significant the increase in anaerobic potency.

Key words:
Hypoxia. Hematology. Erythropoietin. Erythrocytes. Sports performance.

Estrategias artificiales de entrenamiento en altitud: ¿Existe correlación entre parámetros hematológicos y de rendimiento físico?

Resumen

Introducción: La exposición a hipoxia intermitente (IHE) utilizada como complemento al entrenamiento convencional para obtener mejoras en los índices hematológicos claves para incrementar el rendimiento deportivo. Objetivo: Evaluar los cambios hematológicos y de rendimiento físico por un programa de IHE en atletas de élite (AE) que viven y entrenan en hipoxia moderada.
Material y método: Se aplicó un tratamiento de IHE normobárico de 4 semanas de duración (90 minutos, 7 días a la semana, 10-13 % FIO2) a 12 AE. Se establecieron sus características físico-antropométricas antes del comienzo del estudio: Las analíticas de sangre y las pruebas físicas se realizaron en 2 momentos del estudio: a) en el día 1, justo antes de comenzar el estudio (T1); b) en el día 28, justamente al final estudio (T2). Se midieron: reticulocitos (RET.), hemoglobina reticulocitaria (Hb-RET), eritropoyetina (EPO), el perfil hematológico completo y el metabolismo del hierro. El rendimiento físico se determinó mediante la evaluación de la potencia aeróbica, la potencia anaeróbica y la velocidad y el consumo máximo de oxígeno (CsO_2max).
Resultados: Entre los T1 y T2 existe un incremento significativo de EPO, RET y Hb-RET, además de un aumento no significativo en las variables hematológicas involucradas en la eritropoyesis HEM, Hb y Hcto. Se incrementó el rendimiento en todas las pruebas físicas, de velocidad (1,96±2,35 %), de potencia aeróbica (3,73±5,34 %), de CsO_2max (3,36±4,35 %) y fue significativo en la potencia anaeróbica (p = 0,05 con un 1,93±1,13 %).
Conclusiones: El programa de IHE de 4 semanas de duración en combinación con el entrenamiento es capaz de estimular parámetros hematológicos, como la EPO, RET, HEM, Hct, y Hb que demuestran una activación de la eritropoyesis del deportista y que podrían ser la causa de las mejoras en todos los test de rendimiento, siendo únicamente significativa el aumento potencia anaeróbica

Palabras clave:
Hipoxia. Hematología. Eritropoyetina. Hematíes. Rendimiento deportivo.

Correspondence: Diego Fernández Lázaro
E-mail: diego.fernandez.lazaro@uva.es

Introduction

For long-distance athletes, resistance and/or aerobic capacity is a major element in sporting performance, which is why factors that improve the transportation and use of oxygen on a muscular level take on particular relevance[1]. For this reason, trainers and athletes introduce diverse strategies into their conventional training methods that are able to induce adaptations to improve the functionality of muscular, sanguineous, cardiovascular, respiratory and endocrine-metabolic performance[2]. A particularly outstanding strategy is the use of continued exposure to hypoxia - typical of altitude training - triggering a series of physiological responses and adaptations that are beneficial to athletes' performance[3]. For this to happen, athletes must live and train at altitude for at least 20-day periods[4], which is the time needed for acclimatisation, the primary training phase, the recovery phase and the preparatory phase for returning to sea level, all required to induce improvements in sporting performance at sea level[5]. These periods have a negative influence on the intensity of training, and entail a decline in performance levels[6]. In order to overcome these disadvantages of altitude training, in recent years new devices have been used that aim to simulate the physiological effects of altitute[7].

Simulated altitude-condition training strategies used among elite athletes are: intermittent hypoxic exposure (IHE), which is applied through passive stays in rooms with a hypoxic atmosphere, or by breathing air with a lower oxygen concentration; and intermittent hypoxic exposure during training (intermittent hypoxic training, IHT), which consists in training under hypoxic conditions[5].

The aim of both methods (IHE and IHT) is to simulate the erythropoiesis of the athlete and to generate adaptations that improve the haematological profile, with the final outcome of an increase in the blood's capacity to transport oxygen[8]. This series of physiological responses and adaptations starts with erythropoiesis production (EPO), which entails an increase in the amount of haematies (HEM) and in the total mass of haemoglobin (Hb), and consequently the level of haematocrit (Hct) increases[9]. This change in the athlete's haematological values, allows for an improvement of the physiological parameters linked to performance, such as the anaerobic performance-threshold, and aerobic metabolism (reduced trial time, increase of CsO_{2max} and increase of thresholds)[10].

IHT programmes appear to be considerably more beneficial than those of IHE in stimulating erythropoiesis and sporting performance, because exercise in hypoxia plays an extremely important role in the set of haematological and physiological adaptations[11]. However, IHT entails greater wear, fatigue, immunosuppression, and muscle catabolism during the training periods than training performed under normoxic conditions[12-14]. This makes recovery time between training sessions longer, which could alter a classic training system[8].

All this increase in organic stress caused by IHT, could lead to the modification of our training methods established over 20 years ago, and that we consider suitable given results obtained, with athletes that were Olympic, world and European champions in mid to long distance athletic competitions. Furthermore, in our study the Elite Athletes (EA) lived and trained in Soria, at 1,100-1,200 metres of altitude above sea level, considered "Medium Altitude" with a resting oxygen percentage saturation (% SaO_2) of 95%[15].

This situation led us to propose the analysis of the influence of IHE on haematological changes and on specific physical performance trials, on classic EA training, mid and long distance, with athletes that compete on out-door tracks, that are constantly exposed to a moderate hypoxic situation, entailing a double hypoxic stimulus. This study is new, as far as we know, as in other research studies the athletes are only subject to a single hypoxia stimulus (IHT or IHE).

Material and method

We have studied the effect of IHE on elite athletes (EA) during the pre-competitive training period of one season. The study protocol was approved by the University of Valladolid (Spain) ethics committee (reference 03/2010-11), and we adhered to the recommendations put forward in the Helsinki Declaration. We performed the analytical control on 2 study times: a) on day 1, just before starting the study (T1); b) on day 28, just on the final study (T2).

Subjects

A total of twelve (n=12) elite males from the Soria Centre of High Training and Sports Promotion (CAEP) and the Spanish National Team participated in the study. All the EA were volunteers and were informed about the research protocol. The physical characteristics of the EA are displayed in Table 1. From the total of 12 EA, 8 competed in 800 and 1,500 metre flat specialities, 3 in the 5,000-metre flat speciality, and 1 in the 3,000-metre obstacle speciality. All the subjects signed an informed consent form and completed a medical questionnaire, as well a cardiopulmonary examination and an electrocardiograph before entering the study. None of the subjects smoked or drank alcohol, or took medication able to alter their haematological response. Concomitant pathologies were ruled out with the clinical history and the medical examination. The EA followed a similar diet throughout the season, and in particular, followed the same diet during the study, which was constantly supervised by the CAEP doctor. All the athletes followed the same training programme (Table 2), which consisted in 2 daily sessions, from Monday to Saturday. The morning session comprised specific training (2 hours) and after an hour the athletes performed the hypoxia session. The af-

Table 1. Physical and anthropometric characteristics of the elite athletes (EA)

Characteristics	EA
Age (years)	26.12±2.90
Weight (kilograms)	63.37±9.72
Height (centimetres)	175.872±9.12
Body Mass Index (BMI) (Weight/Height^2)	20.49±8.83
Fat percentage (%) (Yuhasz)	8.93±1.21

The data is expressed Average ± Standard Deviation.

Table 2. Training programme.

Day	Morning	Afternoon
Monday	Lactic capacity	Continuous aerobic capacity work
Tuesday	Aerobic power	Continuous aerobic capacity work
Wednesday	Resistance strength	Continuous mixed work
Thursday	Lactic power	Continuous aerobic capacity work
Friday	Resistance speed	Continuous aerobic capacity work
Saturday	Mixed aerobic-anaerobic	Continuous aerobic capacity work
Sunday	Aerobic capacity	Rest

ternoon session comprised 1 hour of continuous and mixed training. On Sundays, they only performed the morning training session and the hypoxia session. The study lasted for 4 weeks, 3 weeks of high load (high intensity training) and a week of lower load work. This is the week in which we carried out the performance tests, the same tests that were performed before starting the hypoxia study.

Analytical control

We followed the World Anti-Doping Agency (WADA) regulations to collect and transport samples (www.ama-wada.org). All of our samples were collected under baseline conditions and on an empty stomach with a period of at least 12 hours fasting since the last meal. All the blood samples were taken at 08:30 and all the participants rested comfortably in a sitting or lying position. The Vacutainer system was used (10 ml for serum, 5 ml and 3 ml with EDTA). Immediately after extraction, the tubes were inverted 10 times and were stored in a sealed box to be stored at 4ºC. The temperature during transportation to the laboratory was controlled using a specific label (Libero Ti1, Elpro, Buchs, Switzerland), which was used to measure and register the temperature.

The samples were transported under suitable conditions and the time taken to deposit the samples at the laboratory was 30 minutes after extraction. Delays did not affect the analytical quality of the parameters studied. The EDTA (anti-coagulant) samples were homogenised for 15 minutes before being analysed, as recommended by the WADA. The tubes containing blood plus EDTA were centrifuged at 2,000 rpm for 15 minutes. The plasma was extracted using a Pasteur pipette then transferred to a sterile storage tube, kept at -20ºC until the analysis.

The leucocytes (LEU), monocytes (MON), lymphocyte (LIM), haematics (HEM), haemoglobin (Hb) and haematocrit (Hct) were established in a System Coulter Counter MAX-M model haematological counter. To analyse the serum iron (sFe), the Synchron CX model automatic chemical analyser from the Beckman laboratory was used; to establish the ferritin (FER), duplicated aliquots of serum were needed, using the standardised IRMA commercial kit from the Bio-Rad laboratory.

To determine the erythropoietin (EPO), an immunometric and chemoluminescent trial was used in solid phase using the Immulite 2000 Epo analyser (Diagnostic Products Corporation). The reticulocytes (RET) were measured through fluorescence using flow cytometry (Beckman Dickinson, Beckman Coulter). To quantify the contents of the reticulocyte haemoglobin (RET-Hb), the XE-2100 analyser (Sysmex) was used.

The percentage changes in the plasmatic volume (% ΔPV) were calculated using the Van Beaumont equation[16]. Furthermore, the hematologic indicator values were adjusted to the changes in the plasmatic volume using the following formula: Corrected value = Uncorrected value x ((100 +% ΔPV) / 100)[17].

Intermittent hypoxia exposure (IHE) protocol

The EA were in resting conditions and sitting comfortably whilst they received the daily IHE session over a 4-week period, breathing through a hand-held mask for 90 minutes each day. Intermittent breathing was administered in 5-minute bursts of hypoxic conditions followed by 5 minutes of normoxic environmental air. They received a normobaric hypoxic gas through a GO_2 Altitude hypoxic device (Biomedtech, Victoria, Australia). To allow for sufficient adaptation time, and in accordance with the manufacturing instructions, the oxygen concentration in the hypoxic gas was reduced progressively (Table 3). The hypoxic conditions of this protocol entailed subjecting the EA to altitudes classified as "High Altitude" (4,000-5,000 metres) and "Very High Altitude" (+5,000 metres)[15]. The peripheral oxygen saturation for each individual was measured automatically using the GO_2 Altitude hypoxia device, or manually by a research assistant with a finger pulse oximeter (INVIPOX LTD800, Diemer, Biscay, Spain). None of the subjects were acclimatised or exposed previously to altitude or hypoxia, other than that they lived in Soria (1,100 m). Given that this study was performed during the important pre-competition period of the season, the IHE was administered during the training recovery times.

Performance trials

The physical performance of the EA was assessed using the individual test time that was taken on the first day of the study (T1), when the hypoxia treatment had not yet begun, and on the final day of the study (T2) after 4 weeks of IHE. The assessment of the aerobic power, anaerobic

Table 3. Intermittent hypoxia exposure (IHE) protocol

Weeks nº	Duration (minutes)	% Inspired fraction of oxygen (% FI O_2)	% Oxygen saturation (%SaO_2)	Simulated altitude (metres)	Range of altitude classification
1	90	13	88-84	4,000	High altitude
2	90	12	84-80	4,500	
3	90	11	80-77	5,000	
4	90	10	76-74	5,500	Very high altitude

power and speed, were performed on the athletics track at distances of 1,000 metres (m), 400 m and 60 m, respectively. To establish the maximum oxygen consumption (CsO_{2max}), a modified Bruce treadmill protocol was used[18]. The trial included a 5-minute warm-up on a monitored treadmill, at a constant speed of 9 km h^{-1}. We performed constant speed increases of 1 km h^{-1} every 2 minutes, until the EA reached exhaustion. An automated gas analyser was used (Vmax 29, Sensormedics, USA) to register the respiratory parameters every 20 seconds, whilst the athletes breathed environmental air. The trial ended when the EA could no longer keep up the pace set on the treadmill. The CsO_{2max} (ml kg^{-1} min^{-1}) for any 20-second interval was registered as the individual's CsO_{2max}.

Statistical analysis

The statistical analyses were performed using the IBM Statistical Package (SPSS Version 22) and Graphpad Prism (Graphpad Software Version 6.01 San Diego, CA). The data was expressed as average ± standard deviation (SD). The differences in the hematologic parameters were assessed using the paired Student t test parametric to identify significant differences between T1 and T2 independently. After this, the normality of the data was confirmed using the Shapiro-Wilk test to decide to use the parametric analysis. Significant differences were considered for $p < 0.05$.

Results

Haematology

The % ΔPV in the EA between T1 and T2 was a reduction of 4.5%, with all the values analysed in T2 of the study adjusting to this result.

The haematological variables and the performance parameters analysed followed a normal distribution.

Analysing the haematological variables (Table 4) that present the pre (T1) and post (T1) data of the training mesocycle, reveals that in the white series: LEU, MON, LIN, there are no significant differences in any of the variables. Regarding the red series: HEM, HB and HCT there is a slight increase between T1 and T2, but there are no significant differences between the two time periods. Likewise, the same occurs in the control parameters of the iron metabolism: SFe and FER.

Figure 1 reveals that the RET increase from the first time in T1 = 0.94 ± 0.38 % to the later time in T2 = 1.03 ± 0.40 % with significant differences (p = 0.041) between both assessment times in the study. This behaviour is reproduced for the EPO hormone (T1 = 6.18± 1.59 mU/mL and T2 = 7.05 ± 1.43 mU/mL with p=0.010) and for the RET-Hb represented in Table 4.

Performance tests

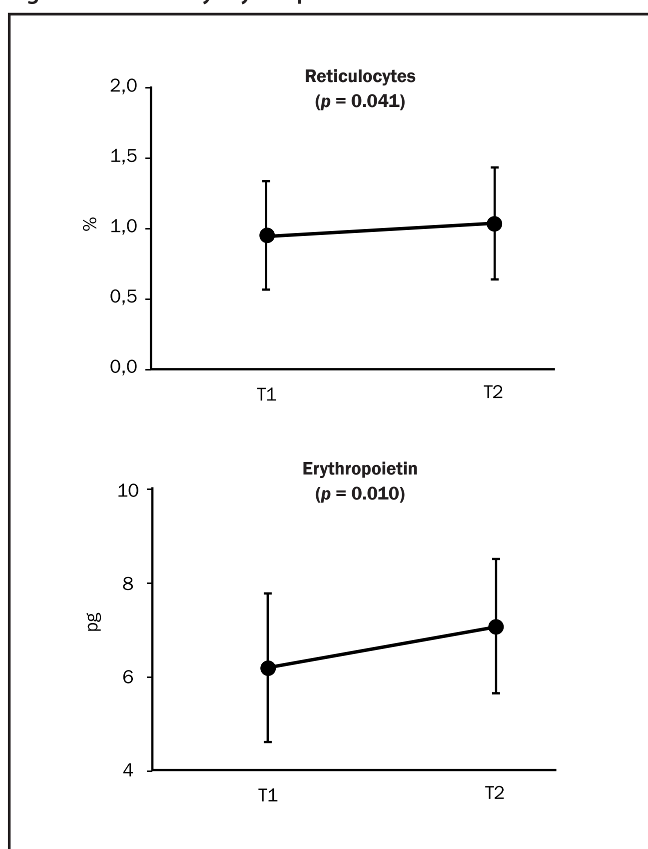
Improvements in performance can be seen in all the tests carried out (Table 5) (p = 0.059) by 1.96 ± 2.35 % in the speed test. The analysis of anaerobic power with the 400-metre trial, revealed significant improvement (p = 0.05) with 1.93 ± 1.13 %. Although the 1,000-metre test analysing aerobic power did not reveal significant improvements (p = 0.112), it did reveal the largest percentage of improvement with 3.73 ± 5.34 %. Finally, the CsO_{2max} improvement (p =0.054) was 3.36 ± 4.35 %.

Table 4. Haematological study variables

Parameter	Time (T)	Average ± SD	p
Leucocytes ($x10^3/\mu L$)	T1	5.29±0.88	0.055
	T2	6.18±1.28	
Monocytes (%)	T1	8.81±1.48	0.270
	T2	8.31±0.88	
Lymphocytes (%)	T1	37.59±9.65	0.911
	T2	37.90±7.89	
Red Blood Cells (106 μL^{-1})	T1	4.96±0.54	0.427
	T2	5.03±0.45	
Haemoglobin ($g.dL^{-1}$)	T1	15.25±1.58	0.227
	T2	15.50±1.24	
Haematocrit (%)	T1	44.51±3.66	0.598
	T2	45.67±2.28	
Reticulocyte haemoglobin (pg)	T1	342.13±10.08	0.024
	T2	356.75±14.57	
Serum iron ($\mu g.\ dL^{-1}$)	T1	106.91±31.53	0.222
	T2	161.20±122.74	
Ferritin (ng/ml)	T1	82.66±38.28	0.246
	T2	89.84±40.47	

The data is expressed Average ± Standard Deviation.
The differences were assessed using a paired Student *t* test parametric.

Figure 1. Precursory erythropoiesis variables.



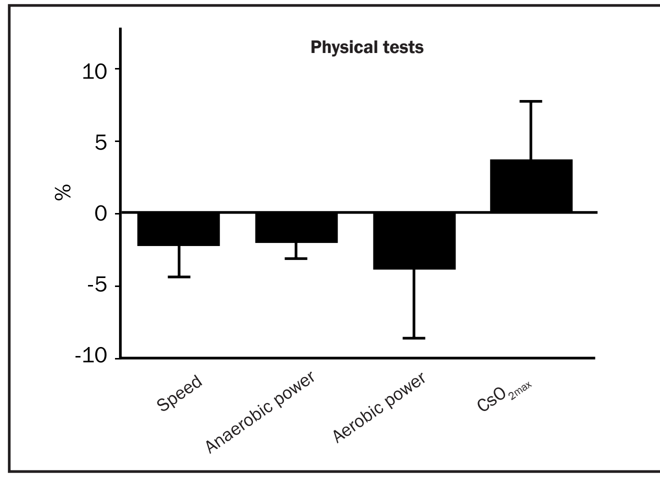
The data is expressed Average ± Standard Deviation.
The differences were assessed using the paired Student t test parametric.

Table 5. Physical performance trials

Test	Time (T)	Average ± SD	*p*	% of improvemen
Speed (Sec) 60 m.l.	T1	6.20±1.21	0.059	1.96±2.35
	T2	5.29±0.88		
Anaerobic power (seconds) 400 m.l	T1	46.65±18.54	0.050	1.93±1.13
	T2	45.70±18.20		
Aerobic power (minutes) 1000 m.l.	T1	2.43±0.25	0.112	3.73±5.34
	T2	2.32±0.09		
Maximum O_2 consumption (ml/min/kg)	T1	83.16±3.14	0.054	3.63±4.35
	T2	86.18±4.80		

The data is expressed Average ± Standard Deviation.
The differences were assessed using the paired Student *t* test parametric.

Figure 2. Improvement percentage in the physical performance trials.



Discussion

The most relevant findings are: the significant increase of EPO hormone secretion, and of specific precursors of the hematopoietic process such as the RET. These increases of 14.7% and of 9.5% for EPO and RET respectively, cause a favourable increase of the haematological parameters: HEM, Hb, and Htc. Bonetti *et al.*[19] have reported benefits in cyclist performance as a result of erythropoiesis stimulation[19]. These advantages translate as improvements in all performance tests (Figure 2) performed on the EA of this study after exposure to normobaric IHE.

The EA use IHE in combination with the training session, with IHE allowing the athletes to *"Live high and train low".* There is a normobaric IHE study that presents discrepancies in the effectiveness of these programmes, due, most probably, to the duration of the session in which the athlete is exposed to IHE and the link to EPO stimulus, in which individuals can respond or not and undergo different responses to acclimatisation[20].

Our study reveals similar results to those found by Knaupp *et al.* who observed changes in EPO secretion after just 5 minutes with a FIO_2 of 10.5% and these changes are significant when the exposure lasts for 120 minutes[21]. As well as this study, Klaursen *et al.* found a 28% increase in the erythropoiesis hormone with a hypoxia programme at 10% of FIO_2 and a 2-hour duration per normobaric IHE session[22]. Likewise, Villa *et al.* reported an increase in EPO hormone secretion after applying a normobaric IHE programme on cyclists during the cycle tour of Spain 2001 *(La Vuelta),* but no modifications to the Hct, Hb or the HEM were observed[3]. Available literature includes a previous study of normobaric IHE, which shares the most similarities to our study, in terms of the hypoxia exposure protocols, results obtained, and limitations, as it also lacked a demographic control group. This study by Hellemans *et al.*[23] of resistance athletes, observes that along with the increase of EPO, there was also an increase in the erythropoietic response of RET (29%), Hb (4%) and Hct (5%). The benefits of normobaric IHE on the haematology of athletes specialising in rowing[24] and cycling[19] are completed with two research studies by the Bonetti *et al.* group, who obtained increases in the RET and the Hb after a similar normobaric exposure time to the protocol used in this research study[19,24].

Analysing the normobaric IHE studies that are not in line with the results obtained in our study or with those described above, we find that two of them do not reveal any modifications in any of the haematological parameters among resistance athletes[25] and swimmers[26]. Other studies, such as that performed by Julian *et al.* [27] on runners, do not reveal any alterations on EPO levels or on any haematological parameter. More recently, Ramos *et al.* – after applying this normobaric IHE programme – also failed to see any increases in any of the determining haematological variables for stimulating erythropoiesis in trained cyclists[28].

A larger number of favourable haematological responses are obtained in hypobaric IHE studies than in normobaric IHE studies, as described in the review by Ramos-Campos *et al*[29]. These results obtained with exposure to hypobaric IHE have a greater capacity to stimulate EPO secretion and to increase the main haematological variables that induce improvements to athletes' performance, and are similar to those observed in our normobaric IHE study. Perhaps the advantage given by the stimulus of the drop in partial pressure of O_2 in hypobaric exposure can be found in this study in the stimulus resulting from the athletes living and training in Soria, at medium altitude and moderate hypoxia. It is possible that this double hypoxic stimulus to which our EA are subjected, could have an additional effect that influences the advantageous outcomes for the EA featuring in our study.

It should be highlighted that some studies that reveal significant improvements in EPO hormone production, or in the haematopoietic precursors, such as RET, also simultaneously present significant increments to the haematological parameters of HEM, Hb and Hct, after exposure to normobaric[19,23,24] or hypobaric[20,30-32] IHE. However, our EA reveal insignificant increases in HEM (1.41%), Hb (1.64%) and Hct (2.60%). The reasons behind this could be the impact of the sporting practice on the haematological parameters that have been used as health and performance indicators (HEM, Hb and Hct), which vary depending on the physical exercise being carried out, the intensity, duration and also the degree of training of the elite cyclists[33] and athletes with a high degree of training[34]. Therefore, high workloads from training or competing and strong psychophysical strains of the athletes and cyclist are the factors leading to drops in haematological variables, which can also remain under the lower limit of the established physiological ranges[35,36]. Furthermore, they are only reverted when physical activity is stopped[33]. This is the line followed by Villa *et al,* who despite reporting significant increases in the EPO, do not observe modifications in HEM, Hb or Hct in the group exposed to IHE, but do demonstrate a drop in these variables in the control group without exposure to IHE, which can be interpreted as a result of the physical efforts performed during the study, taken during the professional cycle trial, the "Vuelta España"[3]. On this basis, if could be affirmed that IHE may have a protective role against training or competition loads (they increase in this pre-competition period among our EA), and that they avoid the drop of blood indicators (they even increase in our study), caused by the high physical demands of elite sport, which could end up leading to over-training among the athletes, resulting in a sharp drop in sporting performance.

FER is the main iron-storing protein and therefore influences the effectiveness of the erythropoiesis process. Just as with the previous blood parameters that we have studied, results are diverse depending on the IHE protocol used[29]. In this study, among rugby players, an insignificant increase of 8.4% has been observed in the FER, along the same lines as results reported by Hinckson *et al.,* who observed an increase of 10.5% in the concentration of this protein[37].

Achieving haematological adaptations in the organism linked to an increase in sporting performance is the main aim of the IHE application. We believe that the response measured by an increase in the EPO secretion that stimulates erythropoiesis and improves the blood oxygen transportation capacity has been fulfilled in this study. This is because in all the tests performed, despite appearing to be modest percentages between 2-3%, the athletes improve upon their previous scores, after training combined with IHE exposure for 4 weeks. For EA that use the "Live high and train low" strategy, this could facilitate an improvement of scores of between 0.8 – 1% in competitions lasting between 45 seconds and 4 minutes. Although this improvement appears minimal, it is not irrelevant. For example, an improved score of between 0.4 – 0.7% means a greater possibility of winning an international 1,500 athletics trial by 10 to 20%[38].

The research results regarding the effectiveness of the IHE programmes on trial time are diverse. Our results present similarities with normobaric IHE programmes with a FIO_2 between 10-13% and that reveal improvements of between 1.5 % and 3% in the trial time[6,23,39,40]. These improvements are reaffirmed and even expanded by other studies, which observe increases varying from 1.7 – 8%[10]. However, there are also studies that do not reveal improvements in trial times upon using normobaric IHE[25,27,29].

The basis of the improvement in speed tests (60 metres) and of the assessment of anaerobic power (400 metres), could be related to the greater capacity of bearing lactate, i.e. the muscle blocking capacity is stimulated after exposure to IHE[41,42]. Furthermore, the transportation of lactate is related to the increase in the content of the MCT1 and MCT4 transporters, an effect that occurs after acclimatisation to the hypoxia phenomena, enabling a better lactate exchange and enhanced elimination, and therefore, a slower reduction of the pH upon performing exercise by cushioning the state of acidosis[43], which produces a direct effect on performance improvement.

When we analyse aerobic performance – via CsO_{2max} and the 1,000-metre trial – we observe higher percentages in improvement than with anaerobic performance. Perhaps the increase observed in both Hb and Hct could allow for a greater O_2 delivery and its muscle absorption, generating an improvement in CsO_{2max}[44]. In this respect, CsO_{2max} depends on three systems: respiratory, cardiac and muscular. The first two are central factors, such as the capacity to transport O_2 and heart production, whilst the last factor is peripheral, such as the use of O_2 by the muscle[45]. The organism defends itself from a lack of O_2 by taking in more air, i.e. by increasing the breathing rate and the volume of air inhaled. Increasing the volume of air entering the lungs by time unit makes it easier to eliminate CO_2. With this comes an improvement of the partial alveolar oxygen pressure, by which oxygen is diffused more easily into the blood, and as a consequence, the partial pressure of oxygen dissolved in the arterial blood ($PaO_{2)}$ is greater. In situations of hypoxia, sympathetic-adrenal activity is stimulated, resulting in an increased heart rate (HR). As a consequence of this, the cardiac expenditure is increased, making the heart pump a larger volume of blood per unit of time[46].

Another possible explanation of the aerobic improvements, could be due to the adaptations achieved through IHE such as the increase of the density and length of the capillaries; the increase of density or the mitochondrial oxidative action; and the over-expression of the hypoxia-inducible factor (HIF-1α)[47]. The capacity to generate more power for a particular CsO_{2max}, or the capacity to use less O_2 to perform a specific power could be due to mechanical efficiency. This is defined in terms of O_2 expenditure to perform an exercise. Improvements of 3-10% are produced in the economy of the exercise with altitude training. This causes lower ventilation expenditure, given the priority use of carbohydrates for phosphorylation and also the improvement of mitochondrial efficiency, which is interpreted as an improvement of CsO_{2max}[48].

Our CsO_{2max} results are closer to the IHT exposure programmes in which the CsO_{2max} can increase around 4%, to the IHE programmes that do not have a positive influence on the CsO_{2max}[10]. These results can be justified because our EA train in moderate hypoxia. In contrary to the effects on CsO_{2max}, IHE programmes do produce improvements in the trial time, as we have highlighted earlier, which could suggest that there may be different mechanisms involved in sporting performance. In our study, the fact we have obtained improvements in both aerobic performance tests (CsO_{2max} and 1,000 metres via IHE) could be because the EA are subject to a second hypoxic stimulus: they live and train in Soria, which could allow them to activate the different mechanisms involved in improving the performance of the EA.

Conclusion

In this study the EA subjected to the two hypoxic stimuli, such as continuous exposure to medium altitude and resting normobaric IHE, enable for the stimulation of haematological parameters such as the EPO, RET, Hct, HEM and Hb, which demonstrate an activation of the erythropoiesis of the athlete and which leads to an improvement in the athletes' aerobic and anaerobic performance as a consequence of an improved oxygen transportation capacity in the blood. Furthermore, this double hypoxic stimulus can improve the results obtained in previous normobaric IHE research studies, reaping all the benefits obtained from other hypobaric IHE or IHT programmes.

Limitations

In our study the main limitation is the lack of a control demographic group, and also the sample size is small. Both limitations are a consequence of the difficulty in obtaining groups of athletes with the anthropometric, physical and sporting characteristics of our professional athletes, and that also live at medium altitude. The inclusion of this control group would provide a foundation to examine if there is a cause-effect relationship between the use of IHE and the possible hematologic fluctuations and the variations of the specific performance tests.

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Conflict of interest

The authors do not declare a conflict of interest.

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Accidental doping. Prevention strategies

Pedro Manonelles[1], Oriol Abellán Aynés[2], Daniel López-Plaza[2], Marta Fernández Calero[3], Carmen Daniela Quero Calero[1], Luis Andreu Caravaca[1], José Luis Terreros[4]

[1]Cátedra Internacional de Medicina del Deporte. Universidad Católica San Antonio de Murcia (UCAM). [2]Facultad de Deporte. Universidad Católica San Antonio de Murcia (UCAM). [3]Facultad de Ciencias de la Salud. Universidad Católica San Antonio de Murcia (UCAM). [4]Agencia Española de protección de la Salud en el Deporte (AEPSAD).

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Summary

There is growing consumption of nutritional supplements aimed at improving performance because the number of athletes, mainly amateurs, is growing very significantly.
This great demand supposes a market of huge proportions, supposing an economic activity that in Spain reached 920 million Euros in the year 2018.
This consumption occurs at all levels of sport, from 13% in global numbers, to 100% in some groups of professional sportsmen and women.
However, the use of these substances in very few circumstances is done under the advice of a professional, and the athlete takes them on their own. This fact, with the possibility that the product to be taken may contain prohibited substances that do not appear on the labeling, means that an adverse analytical finding can occur in a doping control through so-called accidental doping, which is the use of adulterated or contaminated nutritional supplements containing substances prohibited in sport that have not been declared on the labeling.
Between 11.6% and 25.8% of nutritional supplements contaminated with anabolic androgenic steroids have been found to exist. This paper describes the various causes of accidental doping, the substances most frequently used, paying particular attention to the ways of preventing this type of doping based on information and education, product certification and information, the form of prescription, criteria for use and safety of the origin of the products, and precautions followed in case of consumption.

Key words:
Doping. Accidental doping. Amateur sport. Recreational sport. Prevention.

Dopaje accidental. Estrategias de prevención

Resumen

Hay un consumo creciente de suplementos nutricionales destinados a mejorar el rendimiento porque el número de deportistas, fundamentalmente aficionados, está creciendo de forma muy importante.
Esta gran demanda supone un mercado de proporciones gigantescas, suponiendo un actividad económica que en España alcanzó los 920 millones de euros en el año 2018.
Este consume se produce en todos los niveles deportivos, desde el 13 % en cifras globales, hasta el 100 % en algunos grupos de deportistas profesionales.
Sin embargo, el uso de estas sustancias en muy pocas circunstancias se realiza bajo al asesoramiento de un profesional y el deportista los toma por su cuenta. Este hecho, junto a la posibilidad de que el producto que se vaya a tomar pueda contener sustancias prohibidas que no figuran en el etiquetado supone que se pueda producir un hallazgo analítico adverso en un control de dopaje a través del denominado dopaje accidental que consiste el que se produce por consumir suplementos nutricionales adulterados o contaminados que contienen sustancias prohibidas en el deporte que no se han declarado en el etiquetado.
Se ha comprobado que existe entre el 11,6 y el 25,8% de suplementos nutricionales contaminados con esteroides androgénicos anabolizantes.
En este trabajo se describen las diversas causas de dopaje accidental, las sustancias más frecuentemente utilizadas prestando una especial atención a las formas de prevención de este tipo de dopaje que se basan en la información y educación, en la certificación e información de los productos, en la forma de prescripción, en los criterios de uso y seguridad del origen de los productos y en las precauciones que se deben tomar en caso de consumirlos.

Palabras clave:
Dopaje. Dopaje accidental. Deporte aficionado. Deporte recreacional. Prevención.

Correspondence: Pedro Manonelles
E-mail: pmanonelles@ucam.edu

Introduction

An increasing number of citizens engage in recreational sports activities, while federated competitive sport shows an increasing trend of 28% from 3,000,000 to 3,850,000 federated licenses between the years 2000-2018[1]. The most practiced as free time sports are cycling, swimming, running and hiking/mountaineering. Despite the recreational nature of these activities, many practitioners invest many hours of dedication and show a high sense of competition[2]. These athletes often use a variety of strategies to improve performance, to recover from exertion and to reduce fatigue, including the use of nutritional supplements[3-8]. These supplements are defined by the term "ergogenic aids".

Ergogenic aids are very varied and their consumption depends on a variety of factors, including the type of sport, sex, and age of the athlete, with the simultaneous consumption of several of them being very common. The most commonly used are vitamins, minerals, proteins, creatine, carnitine, caffeine and sports drinks[6,9,10]. The market of nutritional supplements has acquired a very important development, assuming at world level an economic activity of hundred twenty-seven thousand sixty thousand million dollars in the year 2016 according to the Association of Dietetics and Food Supplements Companies (AFEPADI)[11] and 920 million in Spain, according to the survey of the Organization of Consumers and Users (OCU), January 2018[12], with a prevalence of very high consumption in sport of all levels[13-16], being 58% in North American athletes[17] and 44-100% in professional athletes, all of which supposes a business of enormous magnitude[18].

However, athletes rarely seek professional advice on the use of these substances[9] and a third part resort to self-administration[19,20].

On one hand, there is a lack of certainty that the product actually contains the substance or dose intended to be used and, on the other hand, the possibility that the preparation contains substances not described on the label that could lead to an adverse analytical finding (AAF) in doping control. In addition, this practice poses a health risk.

But not only the intake of ergogenic aids contaminated with doping substances is a risk for the athlete but also accidental doping can reach them in many ways. Certain meats from some countries with lax legislation and implementation of preventive policies may be contaminated with doping products and end up producing an AAF.

It is possible to take a drug with a perfectly normal medical prescription and engage in accidental doping. Substances on the Prohibited List may be consumed by an ill athlete, but a therapeutic use authorization (TUA) must first be applied for and granted by a therapeutic use authorization Committee (TUAC).

Passive taking and abuse of recreational-type substances can also cause a major problem by ingesting substances on the Prohibited List and producing an AAF.

Athletes who have been notified that they are in a monitoring group of an Anti-Doping Organization and therefore must be traced should also be considered. These athletes must be present at the time and place they have chosen to undergo out-of-competition doping control. Failure to do so several times may be considered an anti-doping rule violation and may result in a sanction.

It must be taken into account that there is a list of people (athletes and their environment) who are already suspended for doping and with whom you can not collaborate (work, hire, train, etc...). Failure to do so could be considered an anti-doping rule violation.

Finally, it cannot be ruled out that, unconsciously (a spectator who passes a drink in good faith) or consciously (an enemy of any kind), may give a drink or food containing doping substances and an AAF may be produced.

This paper aims to describe what is called accidental doping, the ways in which it can occur and how to avoid it.

Accidental doping

Accidental doping is one of the unintentional forms of doping in which a prohibited substance is consumed by chance. It is basically the case of doping caused by the consumption of adulterated or contaminated nutritional supplements containing substances prohibited in a sport that has not been declared on the label.

Contaminated ergogenic aids

It is difficult to know the prevalence of nutritional supplement contamination. A meta-analysis that has investigated studies on this prevalence finds that, in studies conducted with a number of samples greater than 30 products in different countries, in the years 2001-2002, there were between 11.6 and 25.8% of nutritional supplements contaminated with anabolic androgenic steroids (AAS)[21].

In addition, many of these products contain undeclared substances and their concentrations are also not as indicated on the labeling. Geyer *et al.*[22], analyzed 634 nutritional supplements in 13 countries purchased in stores, on the Internet and by telephone from 215 manufacturing companies. Of the 634 samples analyzed, 94 (14.8%) contained prohormones not declared on the label. Thirty-two percent of all contaminated supplements contained nandrolone pro-hormones.

In some cases, especially dehydroepiandrosterone (DHEA), concentrations below 0.01 µg/g could be detected. The amounts of AAS in the tested supplements were much lower than those found in commercially available pharmacological preparations containing at least 10,000 µg DHEA. These low concentrations found in some cases may be interpreted as not intended to improve performance and may be due to cross-contamination, but may lead to adverse analytical findings in doping controls.

Most of the contaminated products found in this study were sold in the United States and Germany, and most of the contaminated supplements were manufactured by companies located in the United States, although in most cases, the label did not clearly indicate where the supplement was produced.

There have been several findings of products contaminated by these substances[23-27] and the supplements that are contaminated are shown in Table 1.

The presence of doping substances in nutritional supplements is mainly due to the following three circumstances:

- Deliberate presence of substances prohibited by doping. In other words, these substances appear clearly on the product label.
- Presence of doping prohibited substances that the manufacturer has deliberately included in the product without indicating it on the label.

Table 1. Examples of nutrition supplements that have been contaminated by doping substances (retrieved from De Hon & Coumans[28].

– Branched-chain amino acids (BCAAs)
– Carnitine
– Chrysine
– Conjugated linoleic acid (CLA)
– Creatine
– Glutamine
– Guarana
– Minerals
– Ornithine-alpha-ketoglutarate (OKG)
– Proteins
– Pyruvate
– Ribose
– Saw palmetto
– Tribulus terrestris
– Vitamins
– Zinc

– The presence of doping prohibited substances found in the product without the manufacturer's knowledge (although it is the manufacturer's responsibility not to do so) and, logically, are not indicated on the label. This may be due to inadvertent contamination in the manufacturing process or contamination of active ingredients at source.

Most accidental doping comes from contaminated nutritional supplements. A nutritional supplement[29] is a product taken orally that contains a"dietary ingredient" intended to supplement the diet. Dietary ingredients" are vitamins, minerals, botanicals, amino acids and substances such as enzymes, organic tissues, glandulars, and metabolites.

Nutritional supplements may be extracts or concentrate in the form of tablets, capsules, gel capsules, gelatine capsules, liquids, powders or bars. They lack the safety requirements that are demanded for medicines and/or pharmaceutical products and, in them, the manufacturer does not have to demonstrate the efficacy and safety of the product, although it cannot advertise that they are products for diagnosis, cure, relief, treatment or prevention of diseases.

It should be noted that most supplements provide neither performance improvement nor health benefit, and many can be harmful. Some supplements contain excessive doses of potentially hazardous ingredients, while others do not contain significant amounts of the ingredients listed on the label. Some of the apparently legitimate nutritional supplements on sale contain ingredients that are not declared on the label but are prohibited by doping regulations.

Contaminants that have been identified include a variety of anabolic androgenic steroids (including testosterone and nandrolone, as well as the prohormones of these compounds) and ephedrine[30]. Stimulants and other substances have also been detected[28]. Tables 2 and 3 show the majority of contaminants found since 2002.

Contaminations by anabolic agents other than steroids have recently been described as selective androgen receptor modulators (MRSA), e.g. andarin, LGD-4033, enobosarm (ostarin). These are principles with

Table 2. Steroids detected in nutritional supplements since 2002 (extracted from Geyer *et al.*[21,28]).

– 17β-hydroxy-2α,17α -dimethyl-5α-androstan-3-one (methasterone)
– 17β -hydroxy-17α-methyl-5 α-androst-1-en-3-one (methyl-1-testosterone)
– 4-hydroxyandrost-4-ene-3,17-dione (formestane)
– 4,17 β-dihydroxyandrost-4-ene-3-one (4-hydroxytestosterone)
– 5α-androstane-3β,17α-diol
– Androst-4-ene-3β,17α -diol
– 5β-androst-1-ene-3β,17β-diol
– 5β-androst-1-ene-3α,17 β-diol
– 17β-hydroxy-5α-androstano-[3,2-c]-pyrazol (prostanozol)
– 6α-methylandrost-4-ene-3,17-dione (6α-methylandrostendione)
– 3β-hydroxy-5 β-androstan-17-one (epietiocholanolone)
– 17β-hydroxy-17α-methyl-5β-androstan-3-one (5β-mestanolone)
– 17α-methyl-5α-androst-2-en-17β-ol (desoxymethyltestosterone)
– 4-Chloro-17α-methylandrost-4-ene-3ε,17β-diol
– Androst-4-ene-3,6,17-trione (6-oxo-androstendione)
– Androsta-1,4,6-trien-3,17-dione (androstatrienedione)
– 3β-hydroxyandrost-4-ene-7,17-dione (7-keto-dehydroepiandrosterone)
– 6ε-Bromandrost-4-ene-3,17-dione
– 17α-Methyl-5α-androstane-3α, 17β-diol
–1 7ß-Hydroxy-5α-androstano-[3,2-c]-isoxazol
– 17ß-Hydroxy-5α-androstano-[2,3-d]-isoxazol
– Estra-4,9-diene-3,17-dione
– 19-Nor-4-androsten-3,17-diol
– 19-Nor-4-androsten-3,17-dion
– 19-Nor-5-androsten-3,17-diol
– 19-Nortestosterone (nandrolone)
– Methandienone
– Stanozolol
– Testosterone

Table 3. Stimulants and other substances detected in nutritional supplements since 2002 (taken from De Hon *et al.*[28]).

– Benzylpiperazine
– Caffeine (off the WADA doping list since 1 January 2004)
– Ephedrine
– Methylenedioxymethylamphetamine (MDMA or XTC)
– Nor-pseudo-ephedrine
– Sibutramine

powerful effects and it should be taken into account that these substances are mostly in clinical or pre-clinical study phases, and they are not approved for human use and some of them are directly discarded for that use. They are highly dangerous for health.

In sports or activities where it is necessary to increase muscle size or strength (strength, speed, power, combat and bodybuilding sports, among others) often resort to the use of nutritional supplements of protein origin. Many of these products are advertised offering an enormous development of muscle mass and strength, the result of new ingredients and formulas that have not actually been approved, possibly non-existent, based on fantasy and ignorance of the user. The reality is that analysis of many of these products shows that they contain endogenous or exogenous AAS in doses even supratherapeutic (more than 1 mg / g) and that they have not been declared on the label. As the manufacturers of these products also prepare other nutritional supplements on the same production line, the risk of cross-contamination with anabolic agents is very high. Such contaminations have been found in vitamin C, magnesium and multivitamin tablets containing small amounts of stanozolol and methandienone with the potential to produce an HAA[31].

Since the early 2000s, designer steroid supplements can be found that are not in any medication or on the lists of banned substances. They were synthesized in the 1960s and did not go through the animal research phase because of their anabolic and androgenic effects. Turinabol, protagonist of the recent doping scandal organized in Russia, and coming from the years of the cold war and doping in Eastern European countries, is worth mentioning. Currently they are only produced for the nutritional supplement market and they are advertised for their anabolic capabilities or as aromatase inhibitors. Their effects on performance and side effects are unknown. In most cases, the labelling of these products contains unapproved and suggestive names and more than 40 designer steroids have been detected[31].

Dehydroepiandrosterone (prasterone, DHEA), androstenedione, androstenediol and similar latestosterone precursors are widely accepted by athletes who want to increase muscle mass and strength and, at least in the United States of America, are legally sold products, although leastways androstenedione and other steroids require a prescription[32]. However, they are widely used[33].

However, it should keep in mind that in Spain the crime of Doping is described in the Penal Code. Article 362 quinquies states that those who, without therapeutic justification, prescribe, provide, dispense, supply, administer, offer or facilitate non-competitive federated sportsmen and sportswomen, non-federated sportsmen and sportswomen who practice sport for recreation, or sportswomen and sportswomen who participate in competitions organized in Spain by prohibited sports entities, substances or pharmacological groups, as well as non-regulatory methods, aimed at increasing their physical abilities or modifying the results of competitions, which due to their content, repetition of intake or other concurrent circumstances, endanger the life or health thereof, will be punished with prison sentences of six months to two years, a fine of six to eighteen months and special disqualification for employment or public office, profession or trade, for two to five years.

In addition, this article explicitly states that special penalties will be imposed when the crime is committed in the event of any of the following circumstances:

- The victim is under-age (minor)
- Deception or intimidation used.
- That the person in charge has prevalidated a relationship of work or professional superiority.

Nutritional supplements adulterated with clenbuterol have also been detected, which are advertised for their weight loss effects as a fat burning effect, specifically a product with a therapeutic dose of 30 micrograms per tablet[34] and another with a suprate therapeutic dose, 100 times higher than the therapeutic dose (2 mg / capsule), without being declared on the label, with the consequent health risk posed by its consumption[31].

One study collected the analysis of 19 such products confiscated or purchased on the Internet[35] that were mostly advertised as erythropoietic products or oxygen transport and utilization boosters, and which declared on the label that they contained "cyanocobalamin". However, the analysis revealed the presence of nickel in one product and cobalt in another 11 products (cobalt was only declared on the labeling of two of these products). Cobalt is included in the list of banned substances as a hypoxia-inducible factor-activating agent (HIF) and has various side effects such as nausea, vomiting, hypothyroidism, goitre and heart failure[36,37]. Nickel is not on the list of prohibited substances, but it has side effects such as contact dermatitis and can cause respiratory tract cancer[38].

In other research on black market products conducted in Germany[39], among other substances, clandestine products related to an increase in erythropoiesis were found, not stated on the label. Specifically they were EPO, (recombinant erythropoietin), hGH (recombinate human growth hormone), CJC-1295, GHRP-2 (pralmorelin), GHRP-6 and ipamorelin which are secretagogues, releasing hormones and growth hormone releasing peptides. Large quantities of anabolic agents and other banned and very dangerous substances such as fibroblastic growth factor, chorionic gonadotrophin, insulin, AICAR (a metabolic modulator) and tamoxifen (an estrogen receptor modulator or SERM) were also found. Another important problem is the contamination of ergogenic aids with stimulants, which would be used as "fat burners" to reduce weight, to improve mood or directly as stimulants before exercise. These contaminated supplements usually contain mainly ephedrine and analogues, sibutramine, methylhexaneamine and methylenedioxymetamphetamie[21,24,30,32,40].

These products are presented in the market in an attractive way, attributing to them an extraordinary power of elimination of body fat, with capacity to suppress appetite, stimulation of the central nervous system and as hormonal boosters of testosterone.

They are presented as amino acids and herbal extracts, designed with a cutting edge formula. Many times pictures of health and medical professionals are used to give them credibility and show certificates of authenticity that are totally false.

Stimulants are on the list of banned substances and cause AAF when detected in doping controls performed in a sport competition.

There are many products that contain these substances and the risk of AAF is due to:

1. Using generic names on labelling. In the case of ephedrine-containing supplements, natural sources of ephedrine such as Ma Huang or ephedra sinica are frequently mentioned on the label instead of the names of the active ingredients (ephedrine, pseudoephedrine, methylephedrine, etc.). In the case of sibutramine-enriched supplements, the ingredient is not showed on the label and the consumer is only provided with information that the product contains 'pure herbal ingredients' that have considerable weight-loss capabilities. Sibutramine can be found in therapeutic or even supratherapeutic doses in capsules, powders and slimming infusions[41,42]. Sibutramine is a synthetic anorexic, approved as a pharmaceutical preparation and available only by prescription. Due to its enormous side effects (risk of stroke and heart attack), the European Medicines Agency recommended in January 2010 that this drug be withdrawn from the market[32].

2. Using substances that have several names and only one of them appears on the lists of banned substances. This is what happens with methylhexanamine, a stimulant included in the list of doping substances as a specific stimulant and which can cause AAF if detected in competition controls. This substance can be found on the labels of products containing it under numerous different names, such as dimethylamlamlamine, dimethylpentylamine, pentylamine, geranamine, forthane and 2-amino-4-methylhexane[17,32].

The list of prohibited substances only mentions the names dimethylphentilamine and methylhexanamine in the group of stimulants, which complicates the identification of the substance as a prohibited compound[32].

In some supplements, geranium root extract or geranium oil is mentioned as a purported natural source of methylhexanoamine. However, methylhexanamine has been shown not to be a natural ingredient of geranium oil[43], meaning that synthetic methylhexaneamine must have been added. Despite warnings, many elite athletes have been adversely affected by HAA in competition.

Food contamination

Until the 1990s, cases of intoxication by meat products, mostly beef liver, by clembuterol were not uncommon.

Clenbuterol is a type of beta-2 agonist, which in the list of prohibited substances is listed in the group of "other anabolic agents" because its stimulating effect on protein synthesis. This is especially noticeable in striated muscle as a consequence of the superior effects of this drug respect to the other of the same group of drugs. These effects are mainly used to increase muscle weight in cattle before slaughter

This substance causes symptoms after 30 minutes to 6 hours of ingestion consisting of palpitations, tachycardia, agitation, nervousness, tremors, myalgia and headache[44,45]. Cases of massive intoxications have been described in restaurants, family parties, etc. Today veterinary inspections in advanced countries have tried to solve this problem, but the World Anti-Doping Agency still admits its presence and possible food contamination in China, Guatemala and Mexico.

In the years 2000, and in the sports persepctive, clenbuterol acquired a great notoriety for a AAF from a famous cyclist who, as a justification, argued that its origin was from a beef steak, something he could not prove, so it was sanctioned.

In 2010, low amounts of clenbuterol were found in an entire team of non-athletes returning from that country, and clenbuterol was found in 22 (79%) of the samples analyzed[46].

In 2011 the Mexican national soccer team had 5 AAFs per clenbuterol in out-of-competition controls. Given the high number of AAFs, FIFA conducted an investigation into potential food contamination as Mexico was to host the 2011 U-17 World Cup. A total of 208 doping controls were carried out and 47 meat samples were analysed in team hotels during the tournament period. In 14 of the 47 meat samples (30%), clenbuterol was detected at concentrations between 0.06 and 11 mg/kg and, during the competition, 109 urine samples from the doping controls (52%) detected the substance at concentrations of 1-1556 pg/ml. Only 5 of the 24 teams had urine samples without clenbuterol. At least one of these teams followed a strict "meatless"diet (due to knowledge of clenbuterol contamination in Mexico). Extensive evidence showed that meat contamination was the most predictable reason for the extraordinarily high prevalence of findings and no player was sanctioned[47].

In May 2019 the World Anti-Doping Agency published rules for Anti-Doping Laboratories and Anti-Doping Organisations on how to investigate cases of urine analysis in clembuterol concentrations. Now it is necessary to analyze possible previous cases in China, Guatemala or Mexico, to prevent the application of potentially unfair sanctions[48].

A substance with similar characteristics to clenbuterol is zearalenone[49], a mycotoxin found in fungi used in American pastures (Mexico, Argentina and other countries in the area) and which presents the risk of AAF from metabolites of zeranol[50]. It is a natural non-hormonal anabolic obtained from the corn fungus (gibberolazeac) and is a catabolic inhibitor that induces anabolic metabolism in cattle, which causes increased muscle mass. In calves and steers it induces muscle weight gains of between 6.5 and 35 kg.

On the other hand, although the use of any hormonal product to increase growth in animal production is prohibited in the European Union, no AAF attributed to the presence of hormones in animal products has been described. It should be taken into consideration that in the USA it is legal to use six hormones or hormone derivatives in cattle farming (17 beta-estradiol, testosterone, progesterone, trenbolone, zeranol and melengestrol acetate) and another one for the pork (ractopamine)[51].

There is one case of AED contamination detected by an atypical steroid profile in which, at the Women's World Cup in Germany in 2011, five players from one team had AED to AED, with enormous amounts of 16 endogenous AEDs listed on the banned substances list. The source of the contamination was considered to be extracts of musk deer meat, used by the team with the aim of improving "mental strength" without knowing that their consumption could cause AAF[52].

Passive doping by inhalation

Cannabinoids (natural and synthetic, except cannabidiol) are included in doping lists and may cause AAF if detected in competition. Passive inhalation of these substances would be an accidental form of doping which, from 2013, is to be avoided by setting the THC detection threshold at 150 ng/ml.

The use of cannabis in food preparation is a growing practice that includes a large number of products such as home-made foods (biscuits, cakes, macaroni...), hemp oil and hemp seed products, tea and commercialized foods (chocolate, lollipops, chewing gum, salt...). In addition, it has been argued that some AAF to tetrahydrocannabinol could be consequence of the ingestion of foods that contained marijuana without realising, in what has been denominated passive ingestion[53].

Since the ingestion of edible products containing tetrahydrocannabinol causes its presence in urine samples[54,55], the athlete must take into account this circumstance.

Finally, it should be remembered that in Spain there is an approved pharmacological preparation (Sativex-Almirall) whose active ingredient is delta-9-tetrahydrocannabinol/cannabidiol, whose only indication is the treatment for the improvement of symptoms in adult patients with moderate or severe spasticity due to multiple sclerosis (MS) who have not responded adequately to other anti-spasticity drugs[56]. This use requires therapeutic use authorisation (TUE).

Intentional contamination by rival

There are athletes willing to do anything to achieve their goals, so some resort to doping. But there have been some cases in which the athlete or the athlete's environment has administered substances to the rival without notifying him, in some cases substances included in the doping lists, which have caused HAA. We want to highlight some cases in football.

The best known took place in the Round of 16 of the 1990 World Championship in Italy when Argentina eliminated Brazil with a Caniggia goal. Branco, a player from Brazil, continues to accuse Argentina of giving Brazilians "water poisoned with narcotics," specifically Rohypnol (flunitrazepam). The player, after drinking water provided by the assistance of the Argentine team, felt bad and, when reproaching the Argentine coach, he said Branco in football anything goes. Apparently, with the game stopped, the Argentine coach and masseur offered the Brazilian players bottles of water with a substance that produced drowsiness. This event was confirmed by Maradona himself[57,58].

The other case concerned the administration of Haldol (haloperidol) injected into the bottles drunk by players from Paris Saint Germain by Marc Fratani, a member of Olympique de Marseille[59].

In the pre-Olympic classification of female field hockey in 2008 in Baku (Azerbaijan) HAA by derivatives of the ecstasy family were detected in two Spanish players. The Spanish team thought they had been intoxicated because they had sudden blackouts from their international players in the night before the final against the hosts. Intentional intoxication was demonstrated by the championship organization and neither the players nor the team was sanctioned[60].

Another case is that of a Japanese canoeist who sabotaged a rival by putting a forbidden substance in his bottle so that he would be suspended and could not compete in the Tokyo 2020 Olympic Games and could go to fifth place for the Japanese selection of K4[61].

Other cases of accidental doping

Three curious cases of accidental doping have been described. The first is a closet HAA that occurred in an athlete as a result of sexual intercourse with a woman taking an intravaginal medication containing clostebol[62].

The second[63] corresponds to an American athlete who showed a probenecid AAF. The sportsman was exonerated because the sanctioning procedure ended admitting that the analytical finding was a consequence of the kisses that were given with his partner who was taking a medication that was transmitted to the sportsman.

The third corresponds to a French tennis player of the highest level who had a HAA to cocaine in 2009 the day he retired from the Miami Masters 1000 for a right shoulder injury, and was sanctioned with a year of suspension, punishment that appealed and that the Court of Arbitration for Sport (CAS) in Lausanne reduced to two and a half months. The court ruled that the sportsman ingested the cocaine for which he tested positive (1.46 micrograms) "unintentionally" by kissing a woman seven times[64].

Athletes who have been notified that they are on an Anti-Doping Organisation Monitoring Group and therefore must be traced should also be considered. These athletes must be at the time and place they have chosen to undergo out-of-competition doping control. Failure to do so several times may be considered an anti-doping rule violation.

It should be borne in mind that there is a list of people (athletes and their environment) who are already suspended for doping and with whom you can not collaborate (work, hire, train, etc ...). An inadvertent failure to ascertain this could be considered an anti-doping rule violation, in that case the athlete would receive a warning and if it persisted he could be sanctioned for doping.

Prevention strategies

By its very nature, accidental doping is avoidable and every effort should be made to prevent such cases of unintentional doping.

Prevention consists of several aspects such as publication of results, education of athletes and development of methods to differentiate between intentional and inadvertent doping[31].

The prevention of accidental doping, focused on the consumption of nutritional supplements, is based on information and Table 4 describes the main methods of prevention.

Education and information

It is essential that the athlete and athlete support personnel have been trained and informed, preferably through a comprehensive anti-doping education program, to warn athletes not to take supplements that may contain prohibited substances and ways to learn about these aspects[65].

Product information and certification

The first step in preventing accidental doping is to obtain information about the substances contained in the product (food supplement) and to ensure that none are on the lists of substances prohibited by doping. The World Anti-Doping Agency (AMA-WADA) publishes this list every year (https://www.wada-ama.org/en/content/what-is-prohibited). If the substance in question is listed, it should not be used. In Spain, the list is published in the Official State Gazette and is also available on the website of the Spanish Agency for Health Protection in Sport (AEPSAD): https://aepsad.culturaydeporte.gob.es/inicio.html. There are computer applications that provide information about substances and medicines (https://aepsad.culturaydeporte.gob.es/inicio/nodopapp-nodopweb.html).

Table 4. Methods to prevent accidental doping.

- Education and information.
- Product information and certification.
- Product prescription.
- Criteria of risk of use and safety on the origin of the product.
- Precautions.

The World Anti-Doping Agency recommends not taking a product if you are unsure of its contents. Ignorance is never an excuse and the athlete will be responsible for the consequences of a positive test caused by a badly labelled supplement[66].

It is advisable to check on the various websites dedicated to the evaluation of the purity of supplements that the product purchased, with its corresponding batch, is free of prohibited substances. Examples of websites of interest are; informedsport, informedchoice (Informedsport. Global Sports Supplement Testing Program, http://www.informed-sport.com/ Informed choice. Banned Substance Testing Service. http://informedchoice.org/). It is also necessary to verify that the products to acquire have some certification that guarantees the absence of doping products in its composition (http://blog.aepsad.es/complementos-alimenticios/).

The European Committee for Standardisation (CEN) is currently working on a project to harmonize the manufacturing methods of sports supplements in Europe, in order to ensure that they are free of doping substances[67].

Product prescription

Nutritional supplements should only be used if they have been prescribed by a doctor or recommended by health professionals, but if it is decided to use these products without advice, special attention should be paid to the rest of the recommendations in this section, considering, moreover, that nutritional supplements are not exempt from health risks and bearing in mind that the combination of substances, which is common in many sportsmen and women can modify the effects of each of the substances by boosting or attenuating them but, in any case, increasing the health risks.

If changes in performance related to the consumption of these substances are noted, the trainer/preparer should be consulted and if symptoms appear in relation to the consumption of these substances, the doctor should be consulted.

Criteria of risk of use and safety on the origin of the product

The purchase of nutritional supplements in unreliable contexts, such as the internet, sports facilities without sales authorization and private individuals, should be avoided. Similarly, products that are advertised with extreme claims of muscle growth, strength gain, and weight loss have an enormous risk of containing prohibited substances[68].

The purchase of nutritional supplements should be avoided if the packaging does not specify components and doses and does not indicate an objectifiable tax domicile[22].

Products that use generic names on the label are at risk. In the case of ephedrine-containing supplements, natural sources of ephedrine such as Ma Huang or ephedra sinica are frequently mentioned on the label instead of the names of the active ingredients (ephedrine, pseudoephedrine, methylephedrine, etc.). In the case of sibutramine-enriched supplements, the ingredient is not declared on the label and the consumer is only provided with the information that the product contains "pure herbal ingredients"[32].

Precautions

It is recommended to keep the purchase receipt of the product, together with a package of the sealed product and the same lot, of which you are going to consume. In this way, if an adverse analytical finding were to appear, it would be possible to verify the legal purchase and that the product consumed contained the substance or substances not indicated on the labeling, provided that it is sealed. These measures, in the event of an adverse anti-doping result being determined by the doping control, may result in a reduction of the sanction.

However, there is no absolute certainty that with all the precautions indicated there is no product that could be contaminated with substances prohibited by doping.

Conflict of interest

The authors do not declare a conflict of interest.

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Body composition characteristics of handball players: systematic review

Alejandro Martínez-Rodríguez[1], María Martínez-Olcina[1], María Hernández-García[1], Jacobo Á. Rubio-Arias[2], Javier Sánchez-Sánchez[3], Juan A. Sánchez-Sáez[4]

[1]Universidad de Alicante. [2]Universidad Politécnica de Madrid. [3]Universidad Europea de Madrid. [4]Universidad Católica San Antonio de Murcia.

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Summary

Background: Handball play is complex and multifactorial, characterized by high-intensity explosive movements. Due to the high physical demands of handball, players require highly developed anthropometric and physical qualities. The evaluation of body composition (BC) is a key issue, especially the body content of fat and skeletal muscle.
Purpose: The aim of this systematic review is to determine the anthropometric and BC characteristics of handball players according to different characteristics such as age categories, playing position and gender.
Search strategy: The search for articles for this study was carried out in three different databases, PubMed, SPORTDiscus (EBSCO) and Web of Science.
Study selection: The inclusion criteria were; Studies recruiting male and female handball players at any age category and competitive level as participants, original investigations that present and compare anthropometric characteristics between handball players of different gender, competitive levels, playing positions, and/or age categories, and articles that present anthropometric characteristics as body weight, height, % fat mass, % muscle mass or % lean body mass, skinfolds and somatotype.
Results: 486 articles were identified after the searching process, 38 articles were selected and assessed for eligibility. This review presents the anthropometric characteristic of handball players, males and females of all ages. Height, body mass, BMI, fat mass, muscle mass, lean body mass and sum of skinfolds are presented and differentiate between gender, age and playing position.
Conclusions: This review provides a framework to help professionals effectively prepare players for the physiological demands of handball. Although the results are not very homogeneous, since elite athletes have better characteristics, the goal of every handball player would be to present similar results and by coaches evaluate players accordingly. But due to the limitations detected in the reviewed studies it is suggested that future research should adopt a longitudinal and multidimensional perspective.

Key words:
Body composition. Handball. Anthropometry. DXA. Bioimpedance.

Características de la composición corporal en jugadores de balonmano: revisión sistemática

Resumen

Antecedentes: El balonmano es un deporte complejo y multifactorial caracterizado por movimientos explosivos de alta intensidad. Debido a las altas exigencias físicas que se presentan, los jugadores requieren cualidades antropométricas y físicas específicas. Evaluar la composición corporal (CC) es esencial, principalmente el contenido de grasa y de masa muscular.
Objetivo: El objetivo de esta revisión sistemática es determinar las características antropometrías y CC de los jugadores de balonmano según edad, posición de juego y sexo.
Estrategia de búsqueda: La búsqueda se realizo en tres bases de datos diferentes: PubMed, SPORTDiscus (EBSCO) y Web of Science.
Selección de estudios: Los criterios de inclusión fueron; estudios que reclutan a jugadores y jugadoras de balonmano de cualquier categoría de edad y nivel competitivo, estudios que presentan y comparan características antropométricas entre jugadores de balonmano de diferentes géneros, niveles competitivos, posiciones de juego y/o categorías de edad, y artículos que presentan características antropométricas como el peso corporal, la altura, el porcentaje de masa grasa, el porcentaje de masa muscular, los pliegues cutáneos y el somatotipo.
Resultados: La búsqueda inicial fue de 488 artículos, tras la selección, eliminación de duplicados, y evaluación de los criterios de inclusión y exclusión, se evaluaron 38. Se presentan características antropométricas de los jugadores y jugadoras de balonmano de todas las edades; altura, masa corporal, IMC, masa grasa, masa muscular, masa corporal magra y suma de pliegues cutáneos según sexo, edad y posición de juego.
Conclusiones: La presente revisión proporciona un marco para ayudar a los profesionales a preparar de forma eficaz a sus jugadores. Aunque lo resultados no son muy homogéneos, el objetivo de todo jugador de balonmano sería presentar resultados similares a los de élite. Debido a las limitaciones detectadas en los estudios revisados, se sugiere que las investigaciones futuras adopten una perspectiva longitudinal y multidimensional.

Palabras clave:
Composición corporal. Balonmano. Antropometría. DEXA. Bioimpedancia.

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Correspondence: Alejandro Martínez-Rodríguez
E-mail: amartinezrodriguez@ua.es

Introduction

Handball is an Olympic sports ball game that is characterized by a defensive action and a fast paced offensive action during the game with the aim of scoring goals[1]. Handball made its Olympic debut at the XI Olympic games in Berlin, 1936, but this was a grass version with 11 players. The sport was then not included on the program, and it reappeared in its indoor version with seven players at the XX Olympic games in Munich, 1972[2]. Nowadays all clubs and federations are listed by the International Handball Federation (IHF), which regulates the rules of handball at a competitive level, and periodically holds competitions and events.

In handball there are five well differentiated playing positions: 1) goalkeeper: in control of stopping the ball; he may not leave the six-meter area with the ball in his hand, but may touch it outside the area if it is passed by a teammate; 2) central: the axis of the team and the extension of the coach on the field; he is the one who commands in attack and defense, marks the plays, places the players and indicates where the static attacks should start from; 3) wing: are those who break the closed defenses from the goal area and assist, on most occasions, to the ends; 4) pivot: is responsible for getting into the defensive wall and open holes where possible, and 5) back: are those who begin the moves of static attack, moving the defense and throwing to goal, if there is space[3].

To score goals, offensive players (6 players and a goalkeeper) try to establish an optimal position for the throwing player through fast moves over short distances by making powerful changes in direction (with and without the ball)[4], individual action against defensive players and passing the ball using different offensive tactics.

Describing team handball play, especially to determine the factors influencing performance, is difficult because team handball play is complex and multifactorial, characterized by high-intensity explosive movements. Handball team must coordinate well their movements to run, jump, push, change direction and specific movements of team handball to pass, catch, throw, control and block. The intensities during play always change between standing and walking, jogging and running moderately, running and advancing fast, sideways and backwards[5,6], therefore a high specific level of endurance is important to maintain a high level of play throughout the game, in concrete two parts of 30 minutes each.

However, considering the intermittent nature of handball, it has been stated that performance is associated with the ability to produce high power in short time periods (anaerobic power) and the ability to recover between such high-intensity activities (aerobic power)[6]. For that, due to the high physical demands of handball, players require highly developed anthropometric and physical qualities (linear speed, change-of-direction speed, aerobic capacity, muscular strength and power) to succeed[7].

The profiling of players can be a valuable tool when identifying talent, determining strengths and weaknesses, assigning playing positions, and optimizing the design of strength and conditioning training programs[1,4,8]. Thus, the evaluation of body composition (BC) is a key issue in sports science as well as sports practice with special reference to the body content of fat and skeletal muscle[9]. Previous research has indicated that certain physical characteristics are related to high level handball performance[10,11]. A high body mass and stature is commonplace among players[11]. Granados *et al.*[12] showed that the higher values of fat free mass resulted in a higher performance, especially because of the increase in the muscular power and strength. There are findings that also indicate relatively heterogeneous physical characteristics across all player positions in the team[10,11].

Examination anthropometric profiles could have great importance for optimal construction of training regimens to improve handball performance. Therefore, the collation of existing research to provide a clear understanding of the importance and development of physical qualities for handball players would be beneficial for research and practice. For this reason, the purpose of this review was to 1- present the anthropometric qualities of handball players by gender; and 2 - critically appraise the literature surrounding body composition using different methods, drawing information based on population characteristics (age, playing positions or performance level).

Methods

Search strategy

The present systematic review was conducted according to the Prederred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines[13]. Database searches were performed independently by three authors (AM, MM and MH). The reviewed articles were selected from an extensive search process including major computerized databases: PubMed (all database) SPORTDiscus (EBSCO) and Web of Science (all database), since their inception until now. Search strategy was developed to identify all relevant studies assessing the BC on handball athletes and it was: "handball" AND ("body composition" or "DXA" or "DEXA" or "Anthropometry" or "Impedance"). The review was registered in the prospective international register of systematic reviews; PROSPERO.

Inclusion and Exclusion Criteria

The inclusion criteria was according to the Population/Intervention/Comparison/Outcome(s) (PICO) criteria: a) Studies recruiting male and female handball players at any age category and competitive level as participants (population), b) original investigations that presents anthropometric characteristics between handball players of different gender, competitive levels, playing positions, and/or age categories (intervention), c) articles comparing anthropometric characteristics between handball players of different gender, competitive levels, playing positions, and/or age categories (comparison) and d) articles that present anthropometric characteristics as body weight, height, % fat mass, % muscle mass, skinfolds and somatotype (outcomes).

The exclusion criteria included: a) comments, opinions, and commentaries, interviews, letters to the editor, editorials, posters, conference abstracts, book chapters, and books; b) studies not present anthropometric characteristics of handball players of different gender, competitive levels, playing positions and/or age categories; c) studies which present players with diseases or injuries and d) lacking quantitative information and details. Articles with these characteristics were not included in the review.

Data collection and analysis

A critical review of the papers was done to confirm the validity of the studies and to verify that they answered the research question, that design and sample were correct and if there were variables, or characteristics that could influence the interpretations and conclusions. The purpose was to collect the most relevant information from each included article. Three reviewers (AM, MM and MH) independently extracted data from included studies. The following variables were abstracted into a preformatted spreadsheet: authors, year of publication, characteristics of study participants (n, age, years, category), anthropometric variables (height, body mass, BMI, % fat mass, % lean body mass) and results.

Risk of bias across studies

To assess the methodological quality, the main tools were used according to the type of study[14] Articles included in this review are cross-sectional studies, the scale used was ARHQ Methodology Checklist. Data extraction, quality assessment and risk of bias were performed independently and in duplicate by two investigators.

Results

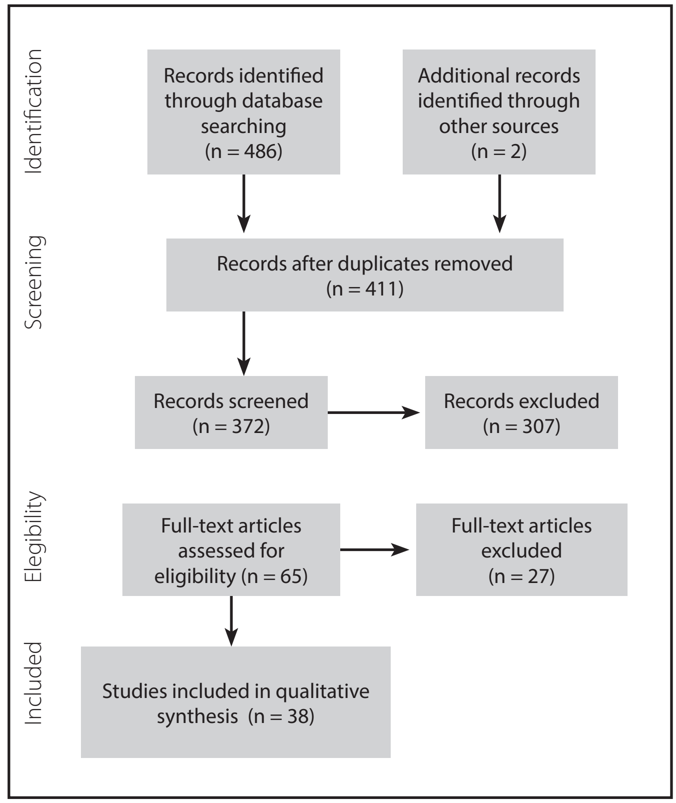
The search strategies yielded a preliminary pool of 486 possible papers. The full text of 65 articles were retrieved and assessed for eligibility according to the inclusion criteria. After a careful review of their full texts 27 articles were excluded and the remaining 38 articles were eligible for inclusion in the review (Figure 1). Particularly, 38 papers examined anthropometric profile of handball players according to their age categories[12,16,17,23,26,28–30,40,42,51], playing positions[15,18,20–22,24,28,31,32,37,39,41,43–45,48], gender[15,38] or competitive levels[12,23,47,49,51,25–27,30,34–36,46]. A number of the studies described the players body compartments using different formulas, however six studies used bioimpedance with TANITA[37–42] and two used DXA[50,51]. The results of Risk of bias have been showed at Figure 2.

Table 1 shows an overview of articles included in the qualitative synthesis, presents the sample size, nationality, playing position (if analyzed), category, genus of the sample, age, height (cm), weight (kg), BMI, sum of skin folds (mm) (if there has been measurement of skin folds that allow it), fat mass (%), muscle mass (%), bone mass (%) and free fat mass (kg) of male players who were measured BC with anthropometry. Table 2 presents the same data described above but for male players who were measured BC with anthropometry and DXA or bioimpedance or only with DXA or bioimpedance. Table 3 presents the same data as described above but for female players who were measured for BC by anthropometry. Table 4 presents the same data described above but of female players who were measured BC with anthropometry and DXA or bioimpedance or only with DXA or bioimpedance.

Nationality

Most of the studies performed on handball players were made in Spanish[12,17,19,37,41,44,47,49], in both females and males. In the case of men, the second most repeated nationality among the studies is Serbian[24,27,30,34,39,40] followed by Portuguese[23,26,27]. Four of the studies were performed on players of different nationalities[18,32,36,51], but all of them Caucasian race. Only two studies did not specify the nationality of the players[15,46].

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta Analyses) Flow diagram of the study selection process.



Elite team

Data on the anthropometric characteristics of elite handball players provides specific information that can help lead players to the most appropriate game[45]. In addition, coaches and researchers may be able to use this data in the talent selection process. Analyzing the type of sample chosen by the different studies, a total of 32 of the studies present elite/professional players in their sample, namely 21 studies of male players and 11 of female players.

Body composition

The basic anthropometric variables analyzed in female players under 18 years of age present an average height (cm) of 167.53 ± 5.63, a weight (kg) of 60.56 ±7.90 and a BMI of 21.58. For the general variables in female players over 18 years of age, they present an average height (cm) of 170.59 ± 6.33; weight (kg) of 66.89 ± 8.78 and BMI of 23.18. Female goalkeepers had an average height (cm) of 173.77±5.06 and a weight of 71.06±8.70 (kg). The wings show an average height (cm) of

Table 1. Body composition characteristics of handball male players measured with anthropometry.

Reference, Year	Mean (n)	Nationality	Position (n)	Category (n)	Gender	Age (years)	Height (cm)	Body mass (kg)	BMI (m²/kg)	Sum. of Skinfold (mm)	Body fat (%)	Muscle mass (%)	Bone mass (%)	Lean Body Mass (Kg)
Pires, 1986[15]	79		Golakeeper	National league	Male	17.97 ±0.92	181.58±7.68	75.48 ±7.4	22.89	-	9.892±2.33	-	-	-
			Wings			17.8 ±1.15	178.26±4.75	69.94 ±8.12	22.01	-	8.97 ±2.31	-	-	-
			Back			17.73 ±1.05	181.32±6.21	76.01 ±10.91	23.12	-	9.03 ±2.27	-	-	-
			Pivot			17.8 ±1.05	175.56±4.78	66.56 ±9.28	21.60	-	9.28 ±3.46	-	-	-
Jaric *et al.*, 2001[16]	18	Yugoslav		Yugoslav national team	Male	20.4±1.1	191.2 ± 6.3	87.7	23.99	-	11.1 ±2,6	52.1 ± 3.3	-	78.4 ± 7.4
Ibnziaten *et al.*, 2002[17]	251	Spanish		Cordoba Handball Federation (CHF) /All- 251/	Male	12 ± 1.38	159.96 ±13.31	53.74 ±13.7	21.00	-	-	-	-	-
				CHF- 10 YEARS /45/		10	143.8	40.27	19.47	-	16.19	42.23	19.33	-
				CHF - 11 YEARS /47/		11	151.3	45.96	20.08	-	15.32	43.21	19.26	-
				CHF -12 YEARS /51/		12	158.32	53.43	21.32	-	14.93	45.11	18.9	-
				CHF - 13 YEARS /60/		13	167.94	59.77	21.19	-	14.35	46.23	19.06	-
				CHF - 14 YEARS /48/		14	175.29	66.77	21.73	-	13.73	45.9	18.66	-
Srhoj *et al.*, 2002[18]	49	European countries (Croatia, Bosnia and Herzegovina, Slovakia and Hungary)	All /49/	Senior	Male	24,49	190.79±6.59	91.29 ±7.57	25.08	71.92[a]	-	-	-	-
			Goalkeeper /9/				191.86	91.79	24.94	71.95[a]	-	-	-	-
			Wings /19/				187.02	85.12	24.34	68.35[a]	-	-	-	-
			Back /37/				194.42	94.28	24.94	71.4[a]	-	-	-	-
			Pivot /9/				183.85	92.58	27.39	81.58[a]	-	-	-	-
Gorostiaga, *et al.*, 2005[19]	15	Spanish		Elite	Male	31 ± 3	188.7 ± 8	95.2 ± 13	26.94	-	13.8 ± 2	-	-	81.7 ± 9
	15			Amateur	Male	22.2 ± 4	183.8 ± 7	82.4 ± 10	24.61	-	11.6 ± 3	-	-	72.4 ± 7
Bezerra and Simão, 2006[20]	63	South American	All /56/	Athletes of Amazon Club	Male	24.52 ± 5.26	176.34±7.77	77.85 ±11	25.12	99.3 ± 40.2[b]	23.1 ±10.6	-	-	59.04 ± 7
			All /7/	Selection of Amazon Cup		22.1 ± 4.9	176.71±11.5	74.51 ±11.28	24.05	65.85±17.81[b]	14.57 ±3.94	-	-	63.57±9.48
			Goalkeepers /11/			26 ± 6	175 ± 5.7	78.6 ± 22.3	25.67	118.2 ±39.3[b]	28.1 ±10.7	-	-	55.5 ± 4.8
			Outside-left /9/			23 ± 3	175.1 ± 5.6	75 ± 6.9	24.46	81.6 ± 30[b]	18.3 ± 7.4	-	-	60.9 ± 5.7
			Outside-rigth /4/			28 ± 8	174 ± 4.4	66.7 ± 3.2	22.03	64.3 ± 16.7[b]	14.8 ± 4.5	-	-	56,7 ± 2.6
			Center /12/			24 ± 4	172.1 ± 8.9	77.7 ± 14.8	26.23	113.6 ±48.5[b]	27 ± 14.8	-	-	55.3 ± 8.1
			Left Guard /6/			22 ± 2	183.5 ± 8.2	86 ± 7.6	25.54	99.4 ± 36.5[b]	22.7 ± 9.8	-	-	66.2 ± 7.8
			Right Guard /9/			22 ± 5	181.4 ± 7.8	77.3 ± 6.6	23.49	84.7 ± 34.9[b]	19.2 ± 9.2	-	-	62.2 ± 7.4
Hasan *et al.*, 2007[21]	63	Asia	Goalkeeper /12/		Male	25 ± 1.9	186.5±0.044	80.8 ± 7	23.23	33.9 ± 11.4[c]	10.5 ± 3.3	49.8 ± 5.5	-	-
			Wing /18/			25 ± 0.8	184.2±0.055	81.6 ±7.4	24.05	31.9 ± 5.4[c]	10.4 ± 2.6	51.2 ± 6.2	-	-
			Back /15/			24 ± 1.5	185.8±0.047	82.5 ±5	23.90	34.2 ± 6.9[c]	10.5 ± 1.7	52.2 ± 7.3	-	-
			Center /18/			26 ± 1.9	183.7±0.024	84.7 ± 8.9	25.10	41.7 ± 11.5[c]	10.8 ± 3.3	53.8 ± 7.7	-	-
Vrbik *et al.*, 2011[22]	37	Croatian	All /37/	Elite and junior male Croatian national handball	Male	-	189.32 ±5.92	89.44 ± 10.32	24.9 ±2.01	-	14.69 ±4.48	-	-	-
			Goalkeeper /5/			-	191.7±2.33	92.88 ±11.36	25.24 ± 2.68	-	18.21 ±4.11	-	-	-
			Wings attackers /9/			-	181.84 ±2.96	78.72 ±5.05	23.82 ±1.7	-	13.33 ±3.69	-	-	-
			Back court players /17/			-	192.14 ±4.75	91.71 ±8.52	24.81 ±1.76	-	14.18 ±3.49	-	-	-
			Pivot /6/			-	190.55 ± 5.2	96.21 ±9.94	26.45 ±1.96	-	15.27 ±7.27	-	-	-
Massuça and Fragoso, 2011[23]	187	Portuguese		Top elite /24/	Male	26.38 ±4.08	188.11 ±5.36	86.88 ±9.46	24.55	-	8.9 ± 3.65	-	-	88.23 ±3.95
				Moderate elite /53/		26.38 ±4.9	182.2 ±6.55	82.35 ±11.22	24.1	-	12.43 ± 5.1	-	-	81.67 ±6.99
				Sub-elite /31/		23.81 ±3.7	179.67 ±6.5	79.37 ±11.08	24.59	-	13.26 ± 5.67	-	-	79.46 ±6.34
				Moderate trained) /32/		24.22 ±5.11	178.47 ±6.6	78.28 ±15.52	24.58	-	15.03 ±7.86	-	-	75.82 ±10.3
				Junior elite /47/		18.13 ±0.88	179.49 ±16.5	80.53 ±12.21	25.00	-	10.91 ± 5.61	-	-	83.44 ±7.48
Ilić *et al*. 2011[24]	32	Serbian	All /32/		Male	20.43± 1.16	190.7±5.23	88.44±8.98	24.33 ±2.34	-	13.61 ± 5.86	50.44±2.57	-	-
			Goalkeeper /4/			-	191.15 ±2.71	92.05±7.6	25.17±1.66	-	17.81±3.69	49.36±2.84	-	-
			Wings /10/			-	187.08 ±4.92	82.28±8.1	23.53±2.4	-	10.49±3.07	51±1.6	-	-
			Back /14/			-	193.61±4.38	89.83±8.69	23.97±2.16	-	12.35±3.98	51.22±1.64	-	-
			Pivot /4/			-	189.08 ±5.71	95.41±5.8	26.74±2.25	-	21.65±9.72	47.38±4.8	-	-
Nikolaidis *et al.*, 2013[25]	44	Greek		TEAM A (First of league - Greek championship) /14/	Male	24±5.7	185.1±6.5	87.6±9	25.57±2.4	-	16.6±3.6	-	-	72.8±5.3
				TEAM B (Second in the league) /17/		27.2±6.7	188.2±6.1	87.5±9.8	24.70±2.4	-	17.8±4	-	-	71.7±6.2
				TEAM C (Eighth of the league) /13/		25±5.8	179±4.7	81.8±8.7	25.53±2.7	-	18.6±4	-	-	66.4±5.5
Muratovic *et al.*, 2014[26]	15	Serbian		Handball premier league in Serbia	Male	23.13±0.22	190.79±6.59	91.29±7.57	24.47±0.65	-	12.41±0.08	52.85±0.8	15.29±0.36	-
Massuça *et al.*, 2014[27]	167	Portuguese	All (167)	All (167)	Male	23.6±5.3	-	-	-	-	-	-	-	-
				Top-Elite /41/		26.2±4.9	187.58±5.62	87.51±10.82	24.87	-	10.53±5.46	46.66±4.63	-	-
				Non-Top-Elite /126/		25.2±4.8	180.53±6.56	80.42±12.39	24.68	-	13.33±6.14	45.28±5.65	-	-

(continúa)

Reference, Year	Mean (n)	Nationality	Position (n)	Category (n)	Gender	Age (years)	Height (cm)	Body mass (kg)	BMI (m²/kg)	Sum. of Skinfold (mm)	Body fat (%)	Muscle mass (%)	Bone mass (%)	Lean Body Mass (Kg)
Rousanoglou *et al.*, 2014[28]	60	Greek	All Elite Greek Junior National Teams /60/	Elite Greek Junior National Teams	Male	17.6±1.15	183.8±5.9	82.7±9	24.48	-	14.4±3	-	-	-
			All U 16 /20/	U 16		15.9±0.4	182.4±6.6	78.2±8.2	23.50	-	14±2.4	-	-	-
			All U 18 /19/	U 18		17.4±0.5	184.1±5.8	84.2±9.9	24.84	-	14.6±3.3	-	-	-
			All U 20 /21/	U 20		19.3±0.6	184.7±5.2	85.5±7.7	25.06	-	14.5±3.2	-	-	-
			Goalkeeper /12/			-	184.5±4.9	84.1±9.3	24.71	-	15.3±3.1	-	-	-
			Wings /13/			-	178.9±6	76.6±7	23.93	-	13.2±2.3	-	-	-
			Back /15/			-	188.1±4.6	85.3±9.4	24.11	-	14.3±4	-	-	-
			Center /10/			-	181±4.1	77.2±4.9	23.56	-	13.5±1.4	-	-	-
			Pivot /10/			-	185.5±4.7	90.2±6.2	26.21	-	15.8±2.4	-	-	-
Moraes *et al.*, 2014[29]	44	South American		Child /21/	Male	13.52±0.6	162.94±7.01	53.57±8.59	20.18	-	15.86±6.24	-	-	-
				Youth /23/		15.61±0.72	171.57±5.27	64.02±11.13	21.75	-	20.18±7.43	-	-	-
Massuça and Fragoso 2015[30]	212	Portuguese		All /212/	Male	23.6±5.2	-	-	-	-	-	-	-	-
				Top Elite /37/		25.9±4.7	187.24±5.25	86.59±10.52	24.70	-	10.53±5.46	51.54±3.68	-	74.67±9.65
				Moderate Elite /54/		26.4±4.9	182.16±6.5	82.61±11.27	24.90	-	12.61±5.26	50.33±2.95	-	67,5±11.43
				Sub Elite /35/		24.3±4.2	179.87±6.25	79.14±10.71	24.46	-	13.02±5.51	50.3±4.1	-	63.04±9.34
				Moderate Trained /33/		24.2±5	178.56±6.52	78.18±15.28	24.52	-	14.85±7.81	48.31±4.94	-	59.66±14.8
				Junior Elite /53/		18.2±0.9	179.56±15.59	80.06±12.42	24.83	-	10.87±5.6	48.4±5.34	-	66.63±13
Barraza *et al.*. 2015[31]	74	Chilean	Goalkeeper /9/		Male	15±1	177.1±3.2	86.3±15.4	27.52	110.6±40.8[a]	30.5±2.7	42.6±2.8	-	-
			Wings /19/				169.5±4.9	61.8±5.2	21.51	69±25.9[a]	26.1±3.9	44.4±3.1	-	-
			Back /37/				175.7±6.9	68.7±8	22.25	60.3±24.1[a]	27.8±4.6	44±3.5	-	-
			Pivot /9/				177.7±8.8	84.7±11.3	26.82	109.5±47.5[a]	30.1±5.1	42.8±3.3	-	-
Ramos-Sánchez F, 2016[32]	19	1 Montenegrin / 1 Serbian / 2 Slovenian / 15 Spanish	Goalkeepers		Male	28.00±8.00	194.2	82.9	22.4	-	10.3	49.6	15.7	89.7
			Wings				196.8	96.7	24.6	-	10.6	50.4	15.0	89.4
			Extrems				177.6	80.2	25.4	-	10.8	51.1	13.8	89.2
			Pivots - Backs - Wings				195.2	114.5	30.3	-	15.6	47.5	12.8	84.4
			Central				191.2	88.8	24.5	-	10.3	51.5	14.4	89.7
Franz, J 2017[33]	22	Brazialian			Male	14.91±1.15	175.22±10.32	68.38±10.36	22.34±2.58	-	17.66±4.95	-	-	-
Masanovic, B 2018[34]	15	Serbian		Junior premier league	Male	16.93±0.95	181.51±5.33	74.73±10.17	22.66±2.83	-	16.39±3.28	48.58±4.03	17.03±2.49	-
Hermassi, S 2018[35]	22	Tunisian		Junior: 14 - National / 9 - international	Male	19.1±1.7	187±0.08	86.7±10.1	24.4 ±5.1	-	13.4±0.5	-	-	-
Peña J, 2018[36]	15	Different nationalities		First division profesional	Male	25.50±4.10	191.03±5.66	94.01±8.89	-	-	12.54±1.73	-	-	-

BMI: Body Mass Index; [a] Sum of 6 skin folds (Triceps, Subscapular, Abdominal, Supraspinal, Front thigh and Medial Calf); [b] Sum of 7 skin folds (Triceps, Subscapular, Abdominal, Breastplate, Axillary medial, Thigh and Suprailiac); [c] Sum of 5 skin folds (Biceps, Triceps, Subscapular, Suprailiac and Anterior Thigh.); [d] Sum of 8 skin folds (Triceps, Chest , Mid-Axillary, Subscapular, Suprailiac, Abdominal, Anterior thigh, and Calf).

Table 2. Body composition characteristics of handball male players measured with anthropometry and DXA or bioimpedance or only with DXA or bioimpedance.

Reference, Year	Mean (n)	Nationality	Position (n)	Category (n)	Gender	Age (years)	Height (cm)	Body mass (kg)	BMI (m²/kg)	Sum. of Skinfold (mm)	Body fat (%)	Muscle mass (%)	Bone mass (%)	Lean Body Mass (Kg)
Ramos Campo *et al.*, 2014[37]	28	Spanish	All /8/	Handball Spanish professional national league (ASOBAL)	Male	28.4±0.9	191.6±1.4	97.1±2.3	26.45	-	-	-	-	-
			Goalkeeper/4/			30.67±3.79	193±6.93	98.8±17.69	26.52	-	18.67±2.57	46.77	-	-
			Center/Wing /7/			26.57±2.64	187.57±4.5	87.84±5.6	24.97	-	13.24±3.69	49.79	-	-
			Handed /12/			28±3.22	194.25±4.86	106.65±14.73	28.26	-	11.27±3.39	45.58	-	-
			Pivot /5/			28.25±6.4	191.42±7.51	95.18±8.57	25.98	-	12.93±7.45	61.44	-	-
Francesco Piscitelli, 2015[38]	22	Italian			Male	21.2±4.3	179.4±6.7	80.0±11.8	25.0±3.1	-	16.4±4.7	-	-	-
Ilic *et al.*, 2015[39]	32	Serbian	All /32/	Serbian National U20	Male	20.43±1.16	190.7±5.23	88.44±8.98	24.33±2.34	-	13.61±5.86	50.44±2.57	16,74±0,99	-
			Goalkeeper /4/			-	191.15±2.71	92.05±7.6	25.17±1.66	-	17.81±3.69	49.36±2.84	16.2±0.4	-
			Wings /10/			-	187.08±4.92	82.28±8.1	23.53±2.4	-	10.49±3.07	51±1.6	17.27±0.89	-
			Back /14/			-	193.61±4.38	89.83±8.69	23.97±2.16	-	12.35±3.98	51.22±1.64	16.6±0.93	-
			Pivot /4/			-	189.08±5.71	95.41±5.8	26.74±2.25	-	21.65±9.72	47.38±4.8	16.45±1.5	-
Jakovljevic, 2016[40]	20	Serbian		Elite level	Male	23.7±3.72	189±4.15	91.6±8.14	25.7±2.31	64.82[a]	10.7±3.76	-	-	-
Sebastia-Amat, 2017[41]	12	Spanish	Goalkeepers	Inferior cathegories	Male	11.5±1.5	160.35±7.42	53.25±8.04	20.7±2.81	-	12.36±6.52	-	44.03±6.05	-
	9					15±1.0	172.10±7.92	68.33±9.91	23.12±3.26	-	12.83±7.85	-	55.73±7.77	-
	5					18.5±1.5	183.40±4.03	88.94±9.32	26.58±2.3	-	16.66±4.71	-	70.18±4.88	-
Hoppe, 2017[42]	10	Germany		Junior	Male	18±1	184±0.3	81.8±6.3	24.00±1.3	-	10.8±1.7	-	72.8±4.1	-
	11			Adults		26±1	190±0.3	92.0±3.5	25.6±0.8	-	11.9±1.3	-	81±2.8	-

BMI: Body Mass Index; [a] Sum of 6 skin folds (Triceps, Subscapular, Abdominal, Supraspinal, Front thigh and Medial Calf); [b] Sum of 7skin folds (Triceps, Subscapular, Abdominal, Breastplate, Axillary medial, Thigh and Suprailiac); [c] Sum of 5 skin folds (Biceps, Triceps, Subscapular, Suprailiac and Anterior Thigh.); [d] Sum of 8 skin folds (Triceps, Chest, Mid-Axillary, Subscapular, Suprailiac, Abdominal, Anterior thigh, and Calf).

Figure 2. Analysis methodological quality studies present review. Checklist for cross-sectional studies.

ARHQ Methodology Checklist for Cross-Sectional/Prevalence Study - Every item use "*", " ", or " " to judge

Item	15	16	17	18	19	20	21	43	22	23	24	50	51	44	12	25	26	27	28	29	37	38	46	45	30	39	31	32	40	41	42	33	34	35	36	47	49	48
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3		*			*					*		*	*	*	*	*	*	*	*			*	*	*	*	*		*		*	*		*	*	*			
4	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*		*	*	*
5																																						
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7																							*									*		*		*		
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Table 3. Body composition characteristics of handball female players measured with anthropometry.

Reference, Year	Mean (n)	Nationality	Position (n)	Category (n)	Gender	Age (years)	Height (cm)	Body mass (kg)	BMI (m^2/kg)	Sum. of Skinfold (mm)	Body fat (%)	Muscle mass (%)	Bone mass (%)	Lean Body Mass (Kg)
Pires, 1986[15]	44		Goalkeepers Wings Back Pivot		Female	18.21 ±1.57 17.22 ±1.59 16.98±1.8 18.12 ±0.7	165.47±3.67 159.7 ±7.68 165.00±5.80 161.55±3.94	59.87 ±7.34 56.57 ±5.35 58.53 ±7.91 58.83 ±7.8	- - - -	- - - -	20.03 ±4.12 19.36 ±3.40 19.64 ±3.39 21.63 ± 4.91	- - - -	- - - -	- - - -
Čižmek *et al.*, 2010[43]	37	Croatia	All /37/ Goalkeeper /6/ Wings attackers /12/ Back court players /13/ Pivot /6/	Croatian First league /37/	Female	24.49 ±4.14 24.21 ±3.93 24.43 ±4.12 25.14 ±4.25 23.47 ±4.97	174.74 6.75 180.8±2.87 169.3±5.37 177.0±5.82 174.5 ±6.78	69.46 ± 8.57 76.88 ±8.16 62.17±5.95 71.95±6.58 71.21±8.15	22.7 ± 1.99 23.48 ±1.96 21.69 ±1.9 22.97 ±2.08 23.34 ±1.57	- - - - -	19.39 ± 4.5 23.15 ±3.89 16.5 ± 3.38 20.67 ±4.83 18.65 ±2.73	- - - - -	- - - - -	- - - - -
Vila *et al.*, 2012[44]	130	Spanish	All /130/ Goalkeeper /19/ Center (/6/ Wings /41/ Back /36/ Pivot /18/	Elite (Spanish professional handball league)	Female	25.74±4.84 26.47±5.92 27.94±4.39 24.85±4.91 25.4±4.61 25.68±4.05	171.31±7.42 174.96±6.3 169.95±5.37 165.49±4.83 174.19±6.21 176.19±8.62	67.55±8.06 69.27±7.66 65.65±6.3 61.23±4.29 71.13±7.8 74.65±6.66	22.97±1.86 22.6±1.89 22.71±1.72 22.35±1.13 23.44±2.32 24.07±1.71	95.5[a] 101.69[a] 91.13[a] 90.14[a] 94.46[a] 207.64[a]	23.49 26.1 27.22 18.59 23.29 25.29	37.024 35.672 38.370 38.037 37.073 35.754	- - - - - -	- - - - - -
Granados *et al.*, 2013 [12]	30	Spanish		Elite team in 2003 /16/ International team in 2009 /14/	Female	23.56±4 27.06±3	175.4 175.7	69.3 70.3	22.53 22.77	- -	19.6 18.6	- -	- -	55.2 57
Bon *et al.*, 2015[45]	87	Slovenian	All /87/ Goalkeeper /15/ Wings /23/ Back /39/ Pivots /10/	Junior and senior national team /87/	Female	22.52 ± 4.7 - - - -	175.43± 6.68 178.33 168.73 177.68 177.73	69.85 ±8.81 74.6 63.55 69.92 76.93	22.81 23.46 22.32 22.15 24.35	- - - - -	20.03 ±4.44 21.43 20.59 19.04 20.55	45.36 ±3.35 45.29 44.16 45.87 46.3	15.82 ±2.68 15.21 15.36 16.05 16.9	- - - - -
Moss, 2015[46]	120	English		Non-elite/47 European league Elite /44/ European international Top-elite /29/	Female	15.7±1.3 15.8±1.3 17.1 ±1.1	165.4±5.8 169.3±6.3 176.3±6.6	61.1±7.8 64±9.4 71.8±8.6	22.33 22.32 23.10	94.8±21.59[a] 92.2±22.48[a] 82.9±16.51[a]	19.48±3.56 20.02±3.91 17.97±2.83	- - -	- - -	49±5.39 - 57.8±5.99
A.B. Ramos-Angulo, 2018[47]	19	Spanish		Senior - División Honor élit	Female	22.84±5.24	168.3±5.9	63.64±6.79	22.4±1.27	88.6 ±18.3[a]	16.93±2.66	42.84±2.33	11.74±0.65	-
Bojić, 2018[48]	48	Croatian	Pivots - Backs - Wings	Cadetes	Female	13.88±0.46	165.5±6.49	56.95±7.43	22.35±1.9	-	17.44±3.2	-	-	-
C, Ferragut, 2018[49]	28 51	Spanish		Top Elite Elite	Female	26.4±4.5 24.0±4.4	174.3±7.7 166.7±5.6	70.6±7.8 64.1±7.6	23.2±1.5 23±2.2	- -	- -	37.11±2.6 37.28±2.4	- -	- -

BMI: Body Mass Index; [a] Sum of 6 skin folds (Triceps, Subscapular, Abdominal, Supraspinal, Front thigh and Medial Calf); [b] Sum of 7skin folds (Triceps, Subscapular, Abdominal, Breastplate, Axillary medial, Thigh and Suprailiac); [c] Sum of 5 skin folds (Biceps, Triceps, Subscapular, Suprailiac and Anterior Thigh.); [d] Sum of 8 skin folds (Triceps, Chest , Mid-Axillary, Subscapular, Suprailiac, Abdominal, Anterior thigh, and Calf).

Table 4. Body composition characteristics of handball female players measured with anthropometry and DXA or bioimpedance or only with DXA or bioimpedance.

Reference, Year	Mean (n)	Nationality	Position (n)	Category (n)	Gender	Age (years)	Height (cm)	Body mass (kg)	BMI (m²/kg)	Sum. of Skinfold (mm)	Body fat (%)	Muscle mass (%)	Bone mass (%)	Lean Body Mass (Kg)
Milanese *et al.*, 2011[50]	43	Italian	All Elite level /26/	Elite level Sub-elite level	Female	26.4±5.77	169.2±6.04	67±7.91	23.4±5.33	112.9±26.06[d]	23.3±5.33	-	-	47.98±4.66
			All sub-elite lvel /17/			17.3 ±2.25	166±5.1	64.4 ± 10.47	23.3±4.01	133.3±27.82[d]	28.6±4.01	-	-	42.97±5.32
			Goalkeeper /7/			24±6.63	169,3±7.41	74.7±11.63	25.9±2.29	149±22.27[d]	29.7±4.5	-	-	48.89±5.38
			Wings /18/			21.8±6.49	165,2±4.4	61 ± 6.6	22.3±2.16	113.5±27.56[d]	24.4±5.03	-	-	43.25±4.72
			Back /14/			23.2±7.04	171±5.8	67.7±7.53	23.1±1.78	118.4±24.62[d]	25.1±5.56	-	-	66.99±7.4
			Pivot /4/			23.7±6.24	167±4.32	66.6±4.95	23.9±1.44	114.2±32.2[d]	22.7±6.29	-	-	65.99±4.99
Milanese *et al.*, 2012[51]	43	Caucasian (37 Italian, 1 Ukrainian, 1 Slovenian,		Italian national championships (PRE) /43/	Female	22.8±6.49	167.9±5.84	65.6±9.89	23.23±2.49	102.5±22.15[d]	25.3±6.2	-	43.02±5.84	-
		1 Romanian, 1 Polish, 2 Argentine)		Italian national championships (POST) /43/		22.8±6.49	167.9±5.84	65.2±9.58	23.00±2.32	105.4±26.01[d]	24.9±5.59	-	43.13±5.7	-
				Elite level /26/		26.4±5.77	169.2±6.04	67±7.91	23.40±5.33	-	-	-	-	-
				Sub-elite level /17/		17.3±2.25	166±5.1	64.4±10.47	23.30±4.01	-	-	-	-	-
Piscitelli, 2015[38]	24	Italian			Female	21.2±4.3	166.2±7.0	62.2±12.0	22.3±3.4	-	26.6±5.8	-	-	-

BMI: Body Mass Index; [a] Sum of 6 skin folds (Triceps, Subscapular, Abdominal, Supraspinal, Front thigh and Medial Calf); [b] Sum of 7skin folds (Triceps, Subscapular, Abdominal, Breastplate, Axillary medial, Thigh and Suprailiac); [c] Sum of 5 skin folds (Biceps, Triceps, Subscapular, Suprailiac and Anterior Thigh.); [d] Sum of 8 skin folds (Triceps, Chest , Mid-Axillary, Subscapular, Suprailiac, Abdominal, Anterior thigh, and Calf).

167.18 ± 4.87, and an average weight (kg) of 61.99±5.61. The back shows an average height (cm) of 174.97±5.943, and an average weight (kg) of 70.18 ± 7.30. The pivot players position show an average height (cm) of 171.39±5.92 and an average weight (kg) of 69.64± 6.89.

For men, if the sample is separated by age range, >18 years and <18 years, we observe that the mean of the anthropometric measurements are as follows: male players under 18 years of age present an average height (cm) of 175.04 ± 6.77, a weight (kg) of 69.29±9.69 and a BMI of 22.45. The goalkeepers present an average height (cm) of 179.34±5.44 and an average of 80.89 ±11.40 weight (kg). The wings show an average height (cm) of 173.88 ± 4.83, and an average weight (kg) of 65.87± 6.66. The back shows an average height (cm) of 178.51±6.56 and an average weight (kg) of 72.36± 9.45. The pivot position players show an average height (cm) of 176.63±6.79 and an average weight (kg) of 75.63±10.29. For the general variables in male players over 18 years of age, they present an average height (cm) of 183.95± 6.38; weight (kg) of 84.24±10.07 and BMI of 24.83. Male goalkeepers have an average height (cm) of 187.330±4.345 and a weight of 88.60±13.675 (kg). The wings show an average height (cm) of 184.601±4.647, and an average weight (kg) of 81.795± 6.725. The back shows an average height (cm) of 190.489±4.498 and an average weight (kg) of 92.996±10.205. The pivots show an average height (cm) of 187.043±6.38 and an average weight (kg) of 91.869 ± 8.903.

Most of the studies in this review of handball players assessed BC with anthropometry and from these studies most used the anthropometric method of Jackson and Pollock[52,53] to obtain the percentage of fat mass. As for female players over 18 years of age, to whom this formula was applied, the average results were height (cm) of 175.36±5.52; weight (kg) of 70.18±7.48 and fat percentage 19.51±3.87. Comparing the players if they are elite or not elite: as elite, the average height (cm) was 175.36±5.52, weight (kg) of 70.33±7.48 and fat percentage 19.49±3.87, and as non-elite players the average height (cm) was 175,40 ; the weight (kg) of 69.30 and the fat percentage 19.60%. As for male players over 18 years of age, to whom this formula was applied, the average results were height (cm) of 183.38±6.99; a weight (kg) of 84.09±11.03 and a fat percentage 14.28±5.40. In addition, thanks to the eight studies that could be grouped by this method, it was possible to differentiate between elite male players with an average height (cm) of 185.22±7.30; a weight (kg) of 85.89±10.53 and a fat percentage 13.18±4.65 and non-elite male players with an average height (cm) of 179.03±6.61; a weight (kg) of 78.83±12.17 and a percentage of 16.56±7.17.

Other studies, specifically three[38,50,51] on female players and six[37–42] on male players, used the bioimpedance method to measure the BC of athletes. In the case of the female handball players the average height (cm) was 172.38±5.99; weight (kg) 69.69±9.67 and fat percentage 22.74±5.76. In the case of the male players the average height (cm) was 186.68±4.07; weight (kg) 89.93±7.89 and fat percentage 13.94±4.36.

Regarding the sum of skin folds, it was observed that most of the studies that calculated this parameter calculated the sum of 6 skin folds, (triceps, subscapular, supraspinal, abdominal, front thigh and medial calf). Specifically, the average sum of 6 skin folds in elite female players was 93.81±22.36 and non-elite 94.8±21.59. As for elite male players the average of this value was 68.37 and non-elite 87.35

Discussion

The aim of this review was to present the anthropometric qualities of handball players from different nationalities, drawing comparisons between age categories, and playing positions. Generally, the results show that in terms of BC, female handball players have a proportion of fat mass of around 20%, being somewhat lower in elite players. As for male players the proportion of fat mass is considerable, around 14%, being higher in non-elite players.

Evaluating and monitoring BC is a key issue in sports practice due to its link to performance and injury risk prevention[9]. In fact, body mass can influence an athlete's speed, endurance, and power, whereas BC can affect an athlete's strength and agility[27]. A greater muscle mass is often an advantageous characteristic in sports, as in team handball, where speed is so much of the essence.

In indoor team sports, the BC depend on the playing position and the sport discipline, being the BC results of the specific game actions of each playing position[37]. It seems to be that specific BC and morphometric parameters could be considered as an important factor contributing to the athlete's respective performance in addition to the technique and sport experience[40]. Morphological characteristics can influence the ability of players to respond better to the requirements of the certain position in the game.

Body composition in females

Women's handball is a sport that has experienced an accelerated development in the last decade, although it is true that studies of anthropometric characteristics are scarce. The correlation between some morphological characteristics of the body of handball players and their playing position is evident. This is attributed to the different technical and tactical tasks that players occupying different playing positions must execute.

As far as the playing position is concerned (considering 4 positions: back, wing, pivot and goalkeeper), the wings are the ones that show the most pronounced differences in the morphological parameters of the body, in comparison with other groups of players. They are significantly smaller and have significantly lower body mass[43–45]. The data observed in this review coincide with the above, the anthropometric values of the wings show the lowest weight and height compared to the other positions: height (cm)167.180 and weight (kg) 61.98. This is due to the fact that the wings cover the largest field area and carry out most of the counterattacks, therefore they need lighter and faster bodies with the capacity for rapid changes of movement and agility[48].

Female back players are characterized by being tall, Bon *et al.,* 2015[45] value that has also been reflected in the analysis of this review, as they have the highest value of height 174.968 cm. Female goalkeepers are the heaviest of all players according to their position in the game. Due to the function of saving the goal, they have a more static role in the game, with fast and short acyclic activities[43]. The data observed for the female goalkeepers in this review corroborate this, as they have the heaviest weight compared to the rest of the playing positions, 71.064 kg.

As for pivots, during an attack, they must catch the passes and are hindered by high defense players, therefore, high body height values can give them an advantage over defense players. The robustness of the body is also particularly important as they must carry out different actions in direct physical contact with the guards of the opposing team. However, looking at the results of this review, there is some controversy as the values do not stand out from any other position. The position specifications of the rear court players propose tall and strong players who must make different tactical and play assignments to the opponent's defense zones[43].

As for the changes that occur in BC throughout the season, Milanese, C[51], showed that the anthropometry of handball players does not change significantly during the competitive season, except for some redistribution of fat; however, BMC increases in the extremities and lean mass in the upper extremities after the season. These results are independent from the competitive level (elite/subelite) and playing position.

Comparing between the different competitive levels (elite; not elite), according to Milanese 2011[50], the results show that elite players have lower fat percentage , coinciding with what was observed in this review (Elite = 19.493%; No elite = 19.600%). In addition, it is also observed in relation to the sum of six folds of fat, elite players have lower values (93.81 mm) and non-elite players have higher values (94.8 mm). The current results suggest that the most experienced, powerful and aerobically conditioned players have an advantage in women's handball at the international level[12,46,49]. Therefore a greater amount and intensity of training is needed to achieve a physical and corporal composition similar to that of the most successful teams.

Body composition in males

In general, the most successful teams are higher and have less body fat than the least successful (Hasan *et al.*, 2007). Gorostiaga *et al.*[19] found that elite team-handball players were heavier and had a higher fat-free mass than the amateur team-handball players did and concluded that this seems to be advantageous in team handball. As regards the upper limb lengths (i.e., radiale-dactylion length), it seems that these measures are important for a better handball shot execution (the larger the radius of action the greater the power of the technical gesture) and for some defensive actions (e.g., blocking). Massuça and Fragoso, 2011[23] also concluded that the best athletes are taller, heavier, had higher fat-free mass, lower fat mass, higher socioeconomic status and higher weekly energy expenditure. Additionally, they have a higher value in arm span and muscle mass[49].

The differences are manifested considerably in the circular measures of the body volume and in dimensions of the skeleton. Back court players and goalkeepers are superior in the mentioned measures. With the findings of this review, wings and pivots have somewhat lower values of longitudinal dimensionality[18] wings and pivots under 18, height 173.8 cm and 176.63 cm and wings and pivots over 18 height 184.6 and 187.04. Height of goalkeepers and backs are bigger in all cases. In addition, it would seem that, handball goalkeepers show an advanced age of maturity[41].

However, there is a bit of controversy in some positions, as in another study[54], they determine that the goalkeepers, central and wing generally stand out for their high stature, with the central ones being more athletic (greater muscle mass) and the wing ones more corpulent, with a powerful shot. The back are fast, agile, lightweight players with great jumping capacity, so they often have less height, less weight and lower fat percentage. Pivots are robust players (higher weight, fat mass and volume) who function well in the body to body. These characteristics must be evaluated prior to the incorporation of the players to the team, since morphological optimization is fundamental to achieve the optimal development of the sports performance of each player[54].

Ramos-Sanchez F, 2016[32] analyzed the first team of the Valladolid squad. According to their results, it seems that pivots are the heaviest players (with the highest percentage of fat mass); the wings, together with the pivots, the highest. No BMI differences were observed in the groups. The greatest differences between the pivots and wings were established in body height, leg length, arm length, ankle breadth, body weight and calves circumference[41,48].

In terms of age, although comparison has been difficult, it appears that from 10 to 14 years, the percentage of fat mass decreases, and there is a change in the distribution of subcutaneous fat[17]. In addition, in line with the results of this review, it has been shown that height and body mass increase with age. It can be seen, there is a bit of controversy in determining, depending on the playing position, which are the tallest and heaviest. According to our results, the highest are the wings and pivots, while the heaviest are the goalkeepers and backs.

In terms of nationalities there are few studies that compare the same competitive level of teams from different countries, however Ilic, 2015[39], establishes comparison between some anthropometric results from nationalities such as Spanish, Serbian, English, kina, Japanese, Korean, Kuwait, Saudi Arabia, French, Italian, Croatian and Tunisian. According to this study, successful teams in the 1994 Asian games were higher and had less body fat than less successful teams. Compared with similar research, Serbian handball players had higher values of body height, body weight, and body fat than British, French, Asian, or Spanish division III handball players. The percentage of muscle mass was higher than that found in Saudi and Japanese handball athletes, but considerably lower than that found in Chinese, Korean, and Kuwaiti handball players. Despite the higher values of muscle mass, Kuwaiti players did not perform well during the Asian match period.

On the other hand Milanese, 2011[50] made the comparison in Italy between competitive levels (Elite *vs.* Sub-elite) as well as with players from other championships. The study suggested that players in Italian championships need a greater amount and intensity of training to achieve a physical and BC similar to those from the most successful national teams.

From all the studies analyzed, it can be deduced that the higher the quality level of the players, the greater their height and body mass and the lower their percentage of subcutaneous fat. Although it is true that there is a degree of heterogeneity in the results, both height and weight seem to increase with age. The higher players should be oriented to the positions of the players at the back. As for the pivots, coaches must consider, in addition to the height of the body, robustness. For goalkeepers, body height is very important; however, robustness criteria are also important. In the case of wings, body height is not a decisive factor and smaller players can also occupy this position, but a lower weight is favorable for this position.

Limitations

The main limitation of the present study was the variation in BC formulas used by several studies to measure one parameter, making it difficult to compare the findings of the collected studies. For instance, body fat percentage has been calculated using different formulas that cannot be used interchangeably, making a comparison impossible between the studies. However, a strength of this study was that it reviewed a large number of studies and parameters. Despite the variety of methods used, conclusions on the variation of the parameters by age, performance level, and position can be safely drawn when considering the within-study comparisons.

Future research

Future research is required to optimize talent identification and development programs. Future research should include intervention-based studies and quantify the training burden of athletes to understand the most appropriate strategies for improving physical qualities. In addition, studies should understand the relationship between physical qualities and match performance, while providing further consideration of the holistic development of the handball player, including technical ability, tactical knowledge, psychological characteristics, and the occurrence and reduction of injuries.

Conclusions

This review provides a framework to help professionals effectively prepare players for the physiological demands of handball. Since elite athletes have better characteristics, the goal of any handball player would be to present similar results. But due to the limitations detected in the studies reviewed it is suggested that future research should adopt a longitudinal and multidimensional perspective.

Conflict of interest

The authors do not declare a conflict of interest.

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   All tables as well as figures will be numbered with Arabic numbers following the order of appearance in the text.

   At the end of the text document the tables and figures captions will be included on individual pages.

8. The Journal's Editorial Staff will communicate the reception of submitted articles and will inform about its acceptance and possible date of publication.

9. After hearing the reviewers' suggestions (journal uses peer correction system), may reject the works which are not suitable, or indicate the author the modifications which are thought to be necessary for its acceptance.

10. The Editorial Board is not responsible for the concepts, opinions or affirmations supported by the authors.

11. Submissions of the papers: Archives of Sports Medicine. By e-mail to FEMEDE'S e-mail address: femede@femede.es. The submission will come with a cover letter on which the work's examination for its publication in the Journal will be requested, article type will be specified, and it will be certified by all authors that the work is original and has not been partially or totally published before.

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All authors that sign the articles accept the responsibility defined by the World Association of Medical Editors.

The papers sent to the journal for evaluation must have been elaborated respecting the international recommendations about clinical and laboratory animals' researches, ratified in Helsinki and updated in 2008 by the American Physiology.

For the performance of controlled clinic essays the CONSORT normative shall be followed, available at http://www.consort-statement.org/

Campaña de aptitud física, deporte y salud

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

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

UCAM Universidad Católica San Antonio de Murcia

Campus de los Jerónimos,
Nº 135 Guadalupe 30107

(Murcia) - España

Tlf: (+34)968 27 88 01 · info@ucam.edu

UCAM UNIVERSIDAD CATÓLICA DE MURCIA