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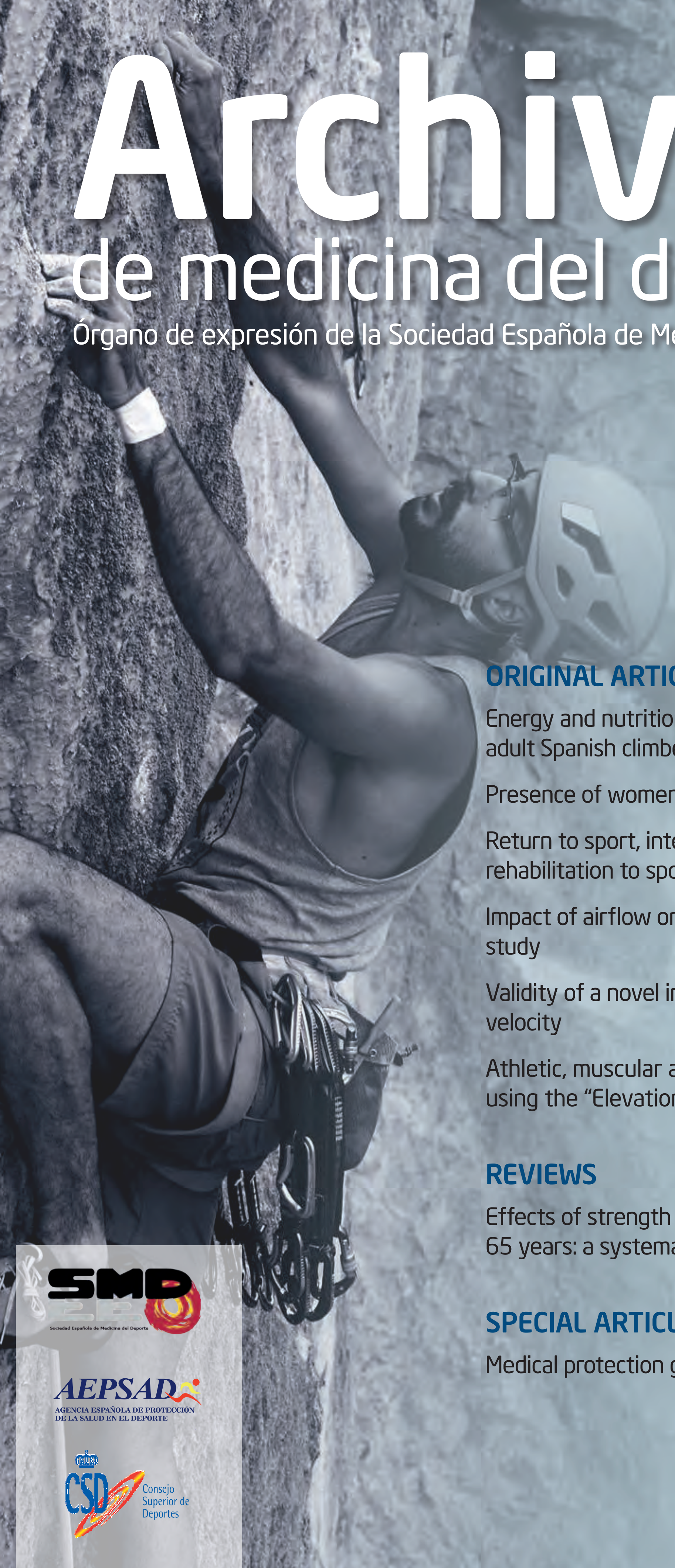

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Archivos de medicina del deporte

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Summary / Sumario

Obesity, the "other" pandemic

Obesidad, la "otra" pandemia

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Obesity is considered to be a chronic metabolic disease with a multifactorial etiology, characterised by an accumulation of excess body fat or adipose tissue.

According to recent studies, the prevalence of overweight and obesity in developed countries is around 50% and has tripled over the last 35 years. The report on the *Prevalence of overweight and obesity in Spain* conducted by the Spanish Agency for Food Safety and Nutrition (AECOSAN) and the Ministry of Health puts the figure at around 54% (overweight + obesity) with a greater prevalence in men. This highlights how concerning this situation is and so much so that it is no exaggeration to say that obesity is the "other" pandemic of the 21st century.

Traditionally, five types of measures have been employed to treat obesity: pharmacological, surgical, psychological, dietary and physical exercise. These treatments can be used either independently or in combination. This latter strategy has been shown to be the most effective, to such an extent that today, for example, a diet to lose weight is considered to be inseparable from a physical exercise program. Diet without exercise tends to promote the loss of metabolically active muscle tissue and, therefore, leads to a reduction in the basal metabolic rate, which can even be as much as 60% of the total daily energy expenditure. Neither will exercise alone have the desired effect given that, with no dietary control, it will be extremely complicated to achieve a correct balance between intake and caloric output.

In this regard, as strategies to address the treatment of obesity, the World Health Organisation (WHO) recommends limiting the intake of fat and sugars, increasing the consumption of fruit, vegetables and pulses, whole grains and dried fruits, and regularly undertaking physical activity, with specific considerations for different age groups and taking a range of special circumstances into account.

The primary objective of a programme of physical exercise for overweight or obese individuals must be to reduce the percentage of body fat while seeking to increase the lean body mass at the same time. It must therefore be understood that this may not necessarily be synonymous with a total loss of weight, something which the person involved in the programme may not find easy to accept. As is the case with other diseases, the exercise programme must also give priority to seeking to improve the aerobic capacity of its participants, given that this will promote the reduction of other potential risk factors that are frequently associated with excess weight (diabetes or insulin resistance, hypertension, dyslipidemia, etc.).

The beneficial effects that physical activity and exercise can have on our body are all too well known, at a physical level and also at a psychological and social level. We would also like to emphasise the fact that, when conducting a physical exercise program for health purposes, there is a need to observe the different general training principles, such as personalisation. Given that it is evident that not everyone will respond in the same way to a particular stimulus, when analysing the options for the treatment of obesity, one of the basic mistakes that is often made is to start from the principle of equality. In other words, to accept that obese and non-obese individuals necessarily have the same response capacity to the training stimulus. Furthermore, there is a need to be aware of the frequent limitations associated with these patients. Such limitations could have an effect on the cardiocirculatory or locomotor systems, thermo-regulatory control, and other circumstances of a psychosocial nature, such as self-confidence levels and depression, thereby conditioning the practice of physical activity.

Taking all these considerations into account, the question is *What is the most suitable type of physical exercise for overweight or obese individuals?*

For many years it was thought that long-duration aerobic exercise with a low-moderate intensity was the best and only way to reduce the body fat percentage in overweight and obese individuals. However, today, it is known that that there are disorders in the adipose and muscle

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tissue in these individuals that either prevent or make it difficult to use the fat as an energy source through this type of exercise. This may be due to modifications to the neuroendocrine system, specifically to those hormones related to muscle hypertrophy and to the use of fats (insulin, leptin, GH testosterone, cortisol, catecholamines, etc.). On the other hand, account should also be taken of the fact that these individuals have an extremely limited capacity to use fatty acids, due to their lipoprotein metabolism. Weight loss with exercises of this type is generally the result of muscle mass loss (sarcopenia), which is in no way desirable.

The last few decades have seen a proliferation of studies that highlight the virtues of strength training for overweight or obese individuals and, as indicated above, these are necessarily combined with an adequate diet. It has been observed that exercises of this type, when performed with suitable loads, generate a stimulus that promotes a hormonal environment that is far more favourable to burning fat, contrary to the case above (long-duration low-intensity aerobic training). On the other hand, the hypertrophy generated by strength training will promote an increase in the energy expenditure due to the effort required during the training sessions (as there is more muscle mass, more energy will be required to move the body) and also to the increase in the basal metabolic rate.

Recent investigations directed at answering the same question addressed here, reveal that overweight and obese individuals will benefit the most from those interventions that combine high-intensity interval training (HIIT) with strength training. Their conclusions are based on the reductions found in subcutaneous fat and abdominal adiposity (reduction in waist circumference), increased lean body mass (modification of body composition), improved structural protein synthesis, increased consumption of intramolecular triglycerides, increased insulin sensitivity, at an acute and chronic level alike, and the post-exercise basic metabolic rate, as well as an improvement in the cardiorespiratory capacity, making it possible to mitigate the negative effects of obesity on the health of these individuals.

On the basis of the above, we would recommend collaboration between physicians and physical and sports educators, to ensure that the former take account of these findings when prescribing physical exercise, following a diagnosis and assessment of the patient in question. Only in this way can the physical and sports educator design effective supervised exercise programmes that will achieve the proposed goals. Likewise, the treatment of this disease will greatly benefit from a multidisciplinary approach, with the collaboration of other professionals in the health area, such as dieticians, psychologists and/or physiotherapists (multidisciplinary work teams).

In conclusion, we would point out that the loss of fat is a complex process that requires metabolic modifications to the body composition. Therefore, diet, exercise and behaviour modification still remain the pillars of treatment of what we have termed the "other" pandemic of the 21st century.

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Original article

Energy and nutritional inadequacies in a group of recreational adult Spanish climbers

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Summary

Introduction: Although nutrition is determinant in the performance of athletes, few publications on this topic are available for climbers.
Objectives: To measure body composition and dietary intake in a group of recreational Spanish climbers.
Material and method: For body composition data we performed the measurements included in the ISAK anthropometric restricted- profile. Daily dietary intake was self-recorded on 3 days of the week: a non-climbing day, a climbing-gym training day and a rock- climbing day. Results were compared to Spanish nutritional recommendations.
Results: 61 climbers (44 men, 17 women), aged 34 ± 8 years, volunteered. Body fat % was 8.1 ± 1.5% in men and 15.7 ± 3.0% in women. A negative correlation was found between body fat % and climbing ability ($P<0.0005$). Intake of energy and carbohydrates was 40% below estimated targets and that of proteins was 20-25% below. Moreover, macronutrient contribution to energy was unbalanced (protein: fat: CHO: alcohol was 17: 38: 42: 3%). We observed an elevated intake of SFA and sugars and low consumption of MUFA and fiber. Micronutrient intakes were acceptable except for iodine, zinc and vitamin D in both genders and iron and folate in women. Mean Adequacy Ratio of diet was higher in advanced/elite climbers compared with those in the intermediate level showing a possible relationship between climbing ability and diet quality.
Conclusions: This study evidences there is a need of nutritional recommendations targeted to climbers. Our findings can contribute to the design of evidence-based food guides to help climbers optimise health and performance outcomes.

Key words:
Rock climbing. Nutritional assessment. Body composition. Dietary inadequacies.

Deficiencias energéticas y nutricionales en un grupo de escaladores recreacionales españoles adultos

Resumen

Introducción: Existen pocos estudios sobre la relación entre dieta y rendimiento en escaladores.
Objetivos: Averiguar la composición corporal y la dieta en un grupo de escaladores recreativos.
Material y método: Se midió el perfil antropométrico restringido ISAK. La ingesta fue autoregistrada en un día sin escalada, un día de entrenamiento en el rocódromo y un día de escalada en roca. Los resultados se compararon con las recomendaciones nutricionales españolas.
Resultados: Participaron 44 hombres y 17 mujeres, de 34±8 años. El % de grasa corporal fue 8,1±1,5% en hombres y 15.7±3.0% en mujeres. Se encontró una correlación negativa entre grasa corporal y el grado de escalada ($P<0{,}0005$). La ingesta de energía y carbohidratos fue un 40% inferior a la estimada para cubrir los requerimientos y la de proteínas un 20-25% inferior. El perfil calórico de la dieta estaba desequilibrado (proteína: grasa: CHO: alcohol = 17:38:42:3%). El consumo de AGS y azúcares fue elevado y bajo el de AGM y fibra. Se observaron carencias en yodo, zinc y vitamina D en ambos sexos y en hierro y folatos en las mujeres. La calidad de la dieta fue mayor en los escaladores avanzados/élite comparada con la de los de nivel intermedio, lo que indica una posible relación entre esta y el grado alcanzado en escalada.
Conclusiones: Se evidencia la necesidad de recomendaciones nutricionales dirigidas a los escaladores. Nuestros hallazgos pueden contribuir al diseño de guías alimentarias basadas en la evidencia, que optimicen la salud y el rendimiento de estos deportistas.

Palabras clave:
Escalada. Evaluación nutricional. Composición corporal. Deficiencias dietéticas.

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Introduction

Sport climbing is becoming increasingly popular. Climbing can be performed for recreational purposes or as competition, on both natural rocks and indoors[1]. In Tokyo 2021, sport climbing will debut in the Olympic Games in three categories: leading, bouldering and speed climbing.

Several studies have focused on the anthropometric and physiological characteristics of climbers. These have observed a high heart rate and VO_{2peak} together with an increased lactate concentration, possibly resulting from repeated isometric contractions, indicating a contribution of both aerobic and anaerobic energy systems during climbing[2,3].. Previous studies also found anthropometric features in elite climbers characterized by a small stature, with high muscular endurance, high flexibility, low body mass and body fat content and high handgrip strength related to body mass[4-7]. These characteristics could play a major role in determining sport success[8].

However, other studies, like that of Mermier *et al* (2000)[5], found that training variables explained 58.9% of the total variance in climbing, whereas anthropometric and flexibility components explained only 0.3% and 1.8%. Most of the variability in climbing performance can, therefore, be explained by trainable variables and climbers do not necessarily need to have specific anthropometric characteristics to be successful at sport rock climbing. Several authors have also shown that high performance in climbing is mainly based on strength and endurance[3,4,9,10].

It is evident that the determination of components related to climbing performance needs further investigation. In particular, there is a lack of scientific research focusing on the role of nutrition in sport climbing performance. Nutrition is a key determinant of sport performance. In addition to anecdotal references to eating disorders and unrealistic weight reduction practices in climbers, the limited published data in this area report a 20-40% energy deficit compared to target-based recommendations[11-13].

Specific nutritional recommendations for climbers do not currently exist. Nutrition strategies should focus on providing adequate substrate stores to meet the fuel demands and nutrient requirements of the sport, while supporting an adequate body composition and reducing or delaying factors that would otherwise cause fatigue[14].

The aim of this study was to study the dietary adequacy of a group of Spanish rock climbers on three different days: non-climbing, climbing-gym training and rock-climbing training days, as well as their body composition, in order to identify possible inadequacies in the diet that could be affecting their athletic performance.

Material and method

The study was designed as an observational, descriptive, cross-sectional study.

Participants

An invitation to participate in the study was sent by email to the members of all the mountain-sport clubs and climbing-gyms listed on the web page of the Mountaineering Federation in the Community of Madrid (Spain). The email explained the aim of the study, the inclusion and exclusion criteria and gave a detailed explanation of what was expected from the participating volunteers. This invitation was also disseminated through social media channels. Climbers interested in participating were asked to contact the research team for a personal interview to clarify their participation in the project and to book a second visit to take measurements and complete the questionnaires.

Inclusion criteria were: Healthy men and women over 18 years old, to not be following a special diet, to have been practicing climbing for at least one year and to have practice outdoor rock-climbing regularly (at least once a week) during the study period. Exclusion criteria included: Individuals with a chronic illness or who experienced any type of injury immediately before and/or during the study period, and for women, being pregnant or breastfeeding.

A total of 105 volunteers replied to the invitation and the final sample population was composed of 61 individuals. Written informed consent was obtained from each participant according to the study design approved by the Committee for Ethical Research of the Universidad CEU-San Pablo, CEU Universities, Subcommittee on Clinical and Human Trials (code: 246/18/09). Participants received individual feedback to improve their food intake and body composition.

Anthropometry

Two ISAK (International Society for the Advance of the Kineanthropometry) Level III-certified anthropometrists performed the measurements included in the anthropometric restricted- profile[15].

Body mass was measured using a portable scale (SECA 710, precision 0.1 kg) while height was evaluated to the nearest 1 mm with a portable stadiometer (SECA 213). Body mass index (BMI) was then calculated from these measurements as weight (kg)/height (m)^2.

Skinfold measurements were taken using a Harpenden® skinfold caliper (measuring range: 0 mm to 80 mm, measuring pressure: 10 g/mm^2, precision 0.2 mm). Skinfolds were then used to estimate fat percent using the equation designed by Carter, according to the gender of the volunteer[16]. Arm span and girths were evaluated using an anthropometric metallic tape, precision 1 mm (CESCORF, Brazil). Bone breadths were measured with a small bone caliper (Holtain, UK) to the nearest 1 mm.

All measurements were taken following the international standards for anthropometric assessment[15], on the right side of the volunteers a minimum of two times. A third measurement was taken when both measurements differed by more than 5%.

The anthropometric measurements were used to calculate the somatotype components of the subjects according to the Heath-Carter method[17].

Dietary Intake

Daily dietary intake was self-recorded on 3 days of the week: a) during one day without climbing b) during a day in which the volunteer trained at the climbing-gym and c) during a day in which the volunteer went rock climbing. Food amounts were recorded as common household measures. To ensure the accuracy of data, volunteers received specific oral guidelines and detailed written instructions on what to do, and were clearly requested not to alter their usual dietary behavior during this period. A telephone number was available for participants to clarify any doubts that could arise. Food records were carefully reviewed immediately after completion. During analysis of the questionnaires, when necessary subjects were contacted to clarify ambiguous information about portion sizes, types of foods, brand names, or cooking methods.

Reports were analyzed using nutrient analysis software (DIAL®, Alce Ingeniería 2012).

To assess dietary adequacy, intakes were compared with the following recommendations:

- For energy intake, a personalized target was assigned to each participant, according to their energy needs for each of the three days studied. To determine individual energy needs, energy expenditure was calculated as follows: On the same day reported in the food diary, each volunteer filled in an activity diary in which he/she gave a detailed account of the time devoted to performing different work, leisure, daily life and sports activities during that day. The time dedicated to each activity was multiplied by the corresponding MET[18] and the daily average MET/24h was then estimated. Finally, total energy expenditure was estimated by multiplying the average MET/24h by the basal metabolic rate of the subject, which had been calculated using WHO equations[19].
- For protein intake, two targets were established. The first one 1.7 g x kg body weight, following recommendations for strength type sports included in the position paper of the Academy of Nutrition and Dietetics, Dietitians of Canada, and the American College of Sports Medicine[14]. The second target for protein intake was established as 15% percent of total energy intake, according to the Acceptable Macronutrient Distribution Ranges (AMDR) specified in the Spanish Nutritional Objectives by the Spanish Society for Public Health Nutrition[20].
- The same procedure was followed to establish targets for carbohydrate (CHO) intake. The first target was 6 g/kg body weight, a recommended target for endurance training programs (1–3 h/d)[14]. The second target was 50-55% of total energy intake, AMDR in the Spanish Nutritional Objectives for a healthy population. For sugars, an intake less than 10% of total energy intake was recommended[20].
- Fat target recommendations were those from the Spanish Nutritional Objectives[20]. Total fat intake 30-35%; Saturated fatty acids (SFA) 7-8% of total energy intake; Monounsaturated fatty acids (MUFA) 20% of total energy intake; Polyunsaturated fatty acids (PUFA) 5% of total energy intake; Trans fatty acids less than 2g/day.
- Recommendations for general population were followed to study the adequacy of fiber intake: 25g/day was the target for women and 35g/day for men[20].
- Recommended Nutrient Intake for the Spanish population[21] was used as targets for vitamin and mineral intakes.

Compliance with the above recommendations was calculated as (nutrient intake x 100)/recommended intake. Overall diet quality was measured by calculating Mean Adequacy Ratio (MAR)[22]. This index quantifies the overall nutritional adequacy of a population, based on an individual's diet using the recommended allowance for a group of nutrients of interest. For this population group, nutrients considered of interest by the researches were those related to energy intake and to muscular and skeletal health: energy, proteins, carbohydrates, thiamin, riboflavin, niacin, vitamin B6, folates, vitamin B12, calcium, iron and magnesium.

First, the NAR, Nutrient Adequacy Ratio was calculated for each of the mentioned nutrients, as the percentage of an individual's nutrient intake relative to the recommended allowance of the nutrient for his or her age and sex. NAR values over 100% were set to a maximum of 100%. Then the MAR was obtained by estimating the mean of all the NAR values:

$$\text{MAR} = \sum \text{NAR}/\text{number of nutrients}$$

The MAR was reported on a scale from 0 to 100%, where 100% indicates the requirements for all the nutrients were met.

General questionnaire

A specific questionnaire was designed to record socioeconomic data (age, sex, profession, and interest in other sports) medical history (diseases, pharmacological treatments, injuries background) and climbing background and habits (years of practice, days of training/week (minimum one hour of training per day), main sporting achievements, onsight and redpoint grade).

According to their redpoint grade, climbers were classified following the IRCRA (International Rock Climbing Research Association) scale and then categorized into 5 groups: low grade, intermediate grade, advanced grade, elite and high elite grade[23].

Statistics

Results for categories are reported using frequencies and percentages, while continuous variables are reported using mean ± standard deviation.

Differences in nutrient adequacy between men and women were analysed by the student *T* test; while differences among the three studied days were analysed by a Friedman test for repeated measures, followed by a T test for paired variables when statistical differences were found.

Relationships between the quality of the diet and climbing performance were studied after grouping the volunteers according to the number of training days (2 days/week; 3 days/week; 4 day/s week). In each group, a Spearman's correlation was performed between MAR and IRCRA level and differences in MAR in the different IRCRA categories were analysed by a Kruskall Wallis test.

For all statistical analyses, differences were considered significant at $P<0.05$. Statistical analyses were performed using SPSS v.24.0 (IBM Corp., Armonk, NY, USA).

Results

A total of 61 climbers (44 men, 17 women), mean age of 34 ± 8 years, participated in the study. Participants' climbing background, training and grade reached are shown in Table 1. Volunteers had been climbing for an average of 8 ± 6 years without significant gender differences. Climbing ability, according to both onsight and redpoint grade, was significantly greater in males compared to females ($p<0.05$). A total of 42% of men and 58% of women were classified as intermediate climbers; 42% of

Table 1. General characteristics of climbers (age, climbing background, training and reached grade) by gender groups.

	Men (n=44)	Women (n=17)
Age (years)	34.3 ± 8.0	34.9 ± 8.5
Climbing background (years)	9.2 ± 6.5	7.6 ± 5.7
Training days/week	3.6 ± 1.1	2.7 ± 0.7*
Bouldering (% of participants)	61.1	41.7
Sport climbing (% of participants)	100	100
Traditional Climbing (% of participants)	41.7	58.3
Onsight grade (IRCRA Scale)	16.6 ± 3.7	12.8 ± 1.9*
Redpoint grade (IRCRA Scale)	19.1 ± 3.9	14.5 ± 2.3*

Data are expressed as mean ± standard deviation
IRCRA: International Rock Climbing Research Association
*P<0.05 between men and women.

Table 2. Anthropometric and body composition data of climbers by gender groups.

	Men (n=44)	Women (n=17)
Height (cm)	176.3 ± 6.2	163.1 ± 4.1*
Weight (kg)	69.4 ± 6.9	56.4 ± 4.1*
BMI (kg/m^2)	22.3 ± 1.8	21.2 ±1.8*
Arm span (cm)/height (cm)*100	103.1 ± 2.7	101.8 ± 2.9
% body fat	8.1 ± 1.5	15.7 ± 3.0*
Endomorphism	2.1 ± 0.6	3.4 ± 0.9*
Mesomorphism	4.7 ± 1.0	4.0 ± 1.0*
Ectomorphism	2.9 ± 1.0	2.6 ± 0.9

Data are expressed as mean ± standard deviation
P<0.05 between men and women.

men and women in the advanced level and 17% of men in the elite group. As expected, the greater the number of training days a week, the higher the level obtained (P< 0.05).

Anthropometric and body composition data are shown in Table 2. Average BMI of participants was in normal range[24], while body fat percentage was at low-healthy levels[25] in both men and women. Average arm span/height*100 ratio, was over one hundred units in both genders. Somatotype values indicate a mesomorphic body shape characterized by a moderate muscular and bone mass development. As expected, men had significantly less % body fat, a lesser endomorphic index and a higher mesomorphic one. Consequently, the BMI was significantly higher in men than in women. No differences were seen in the ape index. We observed statistical differences (P<0.05) in the percentage of body fat according to the different levels of the IRCRA classification. Elite climbing men had a lower body fat percentage compared to intermediate and advanced participants. Also, a statistically significant negative correlation was found between percentage of body fat and range in the IRCRA scale (P<0.0005), this correlation being stronger in men than in women.

Global dietary intakes and intakes on each of the three analyzed days are shown in Table 3. Energy intake was low compared to the estimated energy expenditure in both genders: 41% energy deficiency was observed in men (they met 59% of their energy requirement) and 38% in women (they met 62% of their energy requirement), on the average three evaluated days. This deficiency was more remarkable on the rock-climbing day (57% of deficiency in men and 36% in women) and on the climbing- gym day (43% of deficiency in men and 37.5% in women) than on the non-climbing day (28% of deficiency in men and 25% in women) with statistical differences among the three days (P<0.001). Protein and CHO intakes were also lower than the targets (20-25% of deficiency in proteins and 43-49% for CHO). These results were quite similar in men and women and also on the three days studied. The macronutrient distribution range of the energy is shown in Table 3. Lipid contribution to energy intake was high in both genders and on all the days, when compared to Spanish Nutritional Objectives[20] and to athlete's recommendations[14], while the carbohydrate contribution to energy was below recommendations. We observed an elevated intake of SFA and a low MUFA intake. Sugar consumption was high and fiber was low on all evaluated days and in both genders.

Micronutrient intakes (Table 4) were acceptable except for iodine, zinc and vitamin D in the case of men. Zinc, iron, folate, vitamin D and vitamin E intakes showed deficiencies in women. Intakes of iron and folate were significantly lower in women (P<0.05) than men on the non-climbing day.

There was a positive correlation between climbing ability and the quality of the diet (MAR) on the non-climbing day (P=0.005). After grouping the climbers by similar loads of training (number of training days per week) (Table 5), we observed a higher MAR in advanced/elite level climbers compared to intermediate level volunteers, on the three different days and in the average of the 3 day study period, being statistically significant in the average 3 day study period (P=0.046) and on the rock climbing day (P=0.043) in the group that trained 3 days a week.

Discussion

The present study examined the diet of a group of Spanish climbers on three different days: non-climbing, climbing-gym training and rock-climbing day, as well as their body composition. This study is unique in that it takes into account the whole dietary intake of participants of this sport.

Men trained significantly more days a week than women and reached a higher grade (19 *vs* 15 redpoint grade). Anthropometric characteristics (height, weight, BMI, % body fat) of volunteers were similar to those reported in some previous studies[2,5,26,27] and have slightly higher values from others studies performed in elite climbers[4,6,28-31]. In any case, our results show that climbers are not small in stature[32], and have a low body mass and low body fat percentage. For some authors[13,33], the central issue appears to be specific body proportions rather than body size, and characteristics such as arm span may be of greater importance when selecting subjects for competitive sport climbing. In our study, arm span was greater than body height in men and women and, consequently, the index arm span/height (or ape index) is over 1.0, as also shown by other authors[6,29,31,33].

Table 3. Macronutrient intake compared to estimated targets. Average of the 3 day study period, non-climbing day, climbing-gym day training and rock climbing day training.

		Average 3 day-study period				Non-Climbing Day (A)				Climbing Gym -Day (B)				Rock Climbing- Day (C)				
	Target	Total (N=45)	Men (N=34)	Women (N=11)	*P*	Total (N=45)	Men (N=34)	Women (N=11)	*P*	Total (N=45)	Men (N=34)	Women (N=11)	*P*	Total (N=45)	Men (N=34)	Women (N=11)	*P*	Comparison between days
Energy																		
%ETR	personalized	61.2±15.1	59.3±12.1	62.3±21.5	NS	72.8±24.0	72.1±23.7	75.2±26.0	NS	58.3±18.8	57.3±18.0	62.5±23.0	NS	47.8±16.7	43.4±10.8	64.0±24.8	0.002	A vs B *P*=0.002 A vs C *P*=0.0005 B vs C *P*=0.001
Proteins																		
% ETR	personalized	80.0±24.1	80.2±24.9	79.4±22.9	NS	82.7±34.8	83.1±33.8	81.3±39.6	NS	83.0±31.5	84.6±33.5	78.3±25.0	NS	74.9±23.2	72.4±24.5	81.9±18.7	NS	NS
% Total energy intake	15%	17.0±4.2	17.4±4.5	15.8±3.0	NS	17.1±5.2	17.5±5.4	15.8±4.5	NS	18.0±4.9	18.1±5.0	17.4±4.5	NS	16.0±4.9	16.6±5.3	14.3±3.1	NS	NS
Carbohydrates																		
% ETR	personalized	54.0±15.4	53.8±16.1	54.7±14.0	NS	51.9±17.2	52.1±18.1	51.3±14.7	NS	53.3±25.3	55.3±26.8	46.5±19.2	NS	57.4±16.3	54.4±15.6	65.7±16.0	0.05	NS
% Total energy intake	50-55%	41.2±6.3	41.4±5.5	40.6±8.3	NS	40.7±8.2	40.6±7.4	41.2±10.7	NS	40.3±10.4	41.1±9.6	37.9±12.9	NS	42.5±7.6	43.0±7.6	41.2±7.7	NS	NS
Fat																		
% Total energy intake	30-35%	36.9±6.7	36.4±6.2	38.4±8.0	NS	37.5±8.0	37.3±7.2	38.2±10.4	NS	37.4±9.7	36.7±9.2	39.9±11.2	NS	35.5±8.2	34.6±7.8	38.6±9.0	NS	NS
SFA																		
% Total energy intake	7-8%	11.6±3.6	11.3±3.4	12.5±4.2	NS	11.9±4.3	11.7±3.9	12.3±5.6	NS	11.3±4.6	10.8±4.0	12.8±5.8	NS	11.8±4.0	11.5±4.1	12.6±4.0	NS	NS
MUFA																		
% Total energy intake	20%	15.1±3.1	15.2±3.2	14.8±2.8	NS	15.5±3.9	15.9±4.2	14.3±2.7	NS	15.8±5.0	15.7±5.2	15.9±4.3	NS	13.9±4.1	13.6±3.9	14.8±4.8	NS	NS
PUFA																		
% Total energy intake	5%	6.3±2.4	5.9±1.8	7.2±3.6	NS	6.4±3.4	6.0±2.5	7.6±5.2	NS	6.3±2.9	6.0±2.1	7.3±4.6	NS	6.2±3.2	5.8±2.8	7.2±4.1	NS	NS
TFA																		
g	< 2 g/day	0.3±0.3	0.3±0.3	0.3±0.4	NS	0.2±0.3	0.2±0.3	0.2±0.4	NS	0.4±0.6	0.4±0.5	0.5±0.8	NS	0.3±0.4	0.2±0.5	0.3±8.3	NS	A vs B P=0.027 B vs C P=0.05
Sugars																		
% Total energy intake	< 10%	19.0±4.8	18.2±4.5	21.4±4.9	NS	19.3±5.5	18.4±5.2	21.9±5.8	NS	18.7±7.6	17.6±7.0	22.0±8.5	NS	18.9±5.8	18.8±6.3	19.3±7.1	NS	NS
Alcohol																		
% Total energy intake		2.6±2.9	2.5±2.8	2.9±3.4	NS	2.3±3.7	2.3±3.4	2.4±4.5	NS	1.8±3.0	1.7±2.8	2.3±3.6	NS	3.8±5.4	3.7±5.9	4.0±3.9	NS	B vs C P=0.05
Fiber																		
g	> 25g/day women > 35g/day men	23.1±7.9	23.6±8.6	21.5±5.2	NS	23.9±8.8	24.7±9.3	21.3±7.0	NS	24.1±10.1	25.4±10.8	20.2±6.5	NS	21.4±9.9	20.8±10.3	22.9±8.7	NS	NS

Data are expressed as mean ± standard deviation.
%ETR: Percentage of Estimated Target Recommendation. Energy Target was personalized to individual total energy expenditure for each of the days; Protein intake was targeted to 1.7 g x kg body/weight and Carbohydrate intake target was estimated as 6 g x kg body weight.
SFA: Saturated fatty acids; MUFA: Monounsaturated fatty acids; PUFA: Polyunsaturated fatty acids, TFA: Trans fatty acids.

Regarding body fat, in our study, climbers with better performance (elite level) had a lower percentage body fat than those in the advanced or intermediate level. A statistically significant negative correlation was found between percentage of body fat and range on the IRCRA scale, and this correlation was stronger in men than in women. In this regard, although these anthropometric characteristics are not necessarily required to attain the top level of climbing performance, they may be considered beneficial for success in climbing[33].

The main nutritional findings in this study were that energy, protein and carbohydrate intake were low compared to estimated targets in both genders. In the case of energy and carbohydrates, an approximate deficiency of 40% was observed, and for proteins 20-25% deficiency was reported. Whereas protein and carbohydrate intake were similar on the three evaluated days, energy consumption was significantly different, being the lowest on the rock-training day. Climbers usually report a lack of appetite on the rock-climbing training day. It is well-documented that

Table 4. Percent of Spanish Dietary Recommended Intakes (%DRI) covered by the diet of volunteers. Average of the 3 days study period; non-climbing day, climbing-gym day training and rock-climbing day training

	Average 3 day-study period				Non-Climbing Day (A)				Climbing Gym -Day (B)				Rock Climbing- Day (C)				
	Total (N=45)	Men (N=34)	Women (N=11)	*P*	Total (N=45)	Men (N=34)	Women (N=11)	*P*	Total (N=45)	Men (N=34)	Women (N=11)	*P*	Total (N=45)	Men (N=34)	Women (N=11)	*P*	comparison between days
Minerals																	
Calcium	81.2±23.6	80.4±21.7	83.3±29.2	NS	78.8±29.4	77.6±28.6	82.3±33.0	NS	78.5±30.7	77.3±28.0	82.1±39.4	NS	85.5±37.6	87.4±38.8	84.2±35.6	NS	NS
Iron	129.5±54.1	149.9±46.9	71.7±21.5	0.0005	131.6±62.8	154.3±53.8	61.3±24.0	0.0005	133.3±66.4	153.0±63.6	72.5±26.3	0.0005	12.3±62.9	145.5±65.4	83.6±17.3	0.004	NS
Iodine	68.0±23.9	65.8±25.8	74.1±16.8	NS	70.0±33.7	68.8±35.9	73.6±27.1	NS	64.3±33.3	62.9±33.2	68.8±34.8	NS	69.5±36.6	65.3±38.9	81.1±27.6	NS	NS
Zinc	63.3±20.5	64.7±20.7	59.3±20.4	NS	61.3±22.1	64.8±22.5	50.4±17.4	NS	69.4±31.4	70.9±32.8	65.0±27.4	NS	59.9±26.2	58.7±26.4	63.3±26.6	NS	Bvs C P=0,05
Magnesium	92.5±26.5	93.1±28.7	91.0±19.8	NS	86.6±26.4	88.1±28.4	81.9±19.2	NS	98.0±39.3	100.6±43.1	89.9±23.7	NS	95.1±34.9	92.2±35.7	103.4±32.5	NS	NS
Potassium	82.1±21.3	85.0±22.9	73.7±13.5	NS	83.7±26.1	87.8±26.9	71.0±19.2	NS	87.5±28.1	91.1±30.0	76.3±185	NS	74.6±25.6	75.4±27.9	72.6±19.9	NS	NS
Phosphorum	202.7±53.7	206.6±51.8	191.5±59.6	NS	197.3±63.3	203.4±61.2	178.3±69.0	NS	207.2±73.3	213.9±72.2	186.6±76.4	NS	206.8±72.4	205.1±75.8	211.5±65.3	NS	NS
Selenium	162.2±49.6	158.6±49.1	180.3±49.4	NS	162.7±80.3	158.2±79.3	176.5±85.5	NS	176.3±78.6	174.2±77.6	182.9±85.4	NS	153.6±59.0	140,9±62.1	189.6±28.0	0.02	NS
Vitamins																	
Tiamin	127.7±68.8	137.1±73.7	101.2±44.8	NS	142.2±105.4	157.4±104.6	95.0±69.0	NS	119.1±54.3	122.9±52.2	107.1±61.4	NS	123.8±55.5	131.5±59.8	102.2±34.5	NS	NS
Riboflavin	109.1±54.0	112.9±60.3	98.2±29.5	NS	120.7±125.2	130.5±123.4	90.3±37.3	NS	102.8±45.2	103.8±46.6	99.5±42.8	NS	103.1±49.8	103.7±54.4	101.5±35.9	NS	NS
Niacin	261.1±206.2	245.4±228.8	305.5±261.2	NS	267.1±204.6	251.9±231.8	314.4±294.8	NS	271.6±201.8	253.1±220.2	328.8±284.4	NS	164.1±66.0	172.6±71.2	140.2±42.6	NS	NS
vit. B6	141.1±41.9	148.7±44.6	119.5±22.5	0.04	132.1±82.5	142.1±91.1	101.2±33.9	NS	131.6±48.0	132.2±52.0	117.5±30.6	NS	129.0±49.7	129.7±53.5	127.3±39.2	NS	NS
Folate	74.8±26.2	78.7±27.5	63.7±19.6	NS	77,6±38.8	85.0±40.3	54.5±22.7	0.02	76.3±37.3	78.4±39.1	70.1±32	NS	71.2±35.4	72.9±39.5	66.4±20.4	NS	NS
vit. B12	279.6±126.9	290.4±130.4	248.9±116.4	NS	293.8±253.6	295.2±257.6	289.5±252.1	NS	299.2±190.1	304.1±200.9	283.8±159.4	NS	251.9±149.4	66.4±20.4	201.8±85.3	NS	NS
vit. C	247.4±129.4	248.4±135.1	241.0±117.2	NS	267.3±178.4	271.2±193.6	255.2±127.1	NS	269.3±156.9	264.3±156.1	284.5±166.1	NS	194.3±142.8	200.8±160.3	175.8±77.7	NS	AvsB P=0.001 BvsC P=0.0005
vit. A	160.9±78.4	158.3±77.4	168.4±84.2	NS	118.7±74.7	122.0±80.7	108.3±53.9	NS	97.5±74.6	91.8±65.1	115.1±100.1	NS	85.2±64.7	76.9±53.5	108.3±88.3	NS	AvsB P=0.007
vit. D	20.4±15.5	23.4±16.5	11.8±7.0	NS	19.9±16.9	21.8±17.1	14.1±15.8	NS	22.5±24.0	25.5±26.3	13.5±11.5	NS	18.5±24.3	21.9±27.7	8.9±3.4	NS	NS
vit. E	81.5±35.0	84.8±37.1	72.2±27.2	NS	82.1±61.0	83.9±63.3	76.8±47.3	NS	91.5±53.2	991.1±56.3	67.9±34.4	NS	71.9±44.8	70.1±47.2	77.0±38.8	NS	NS
vit. K	112.3±160.7	104.0±56.5	136.0±67.9	NS	114.0±85.4	113.1±92.5	117.0±61.6	NS	131.8±113.2	116.8±82.5	178.0±175.5	NS	87.5±79.7	79.2±79.8	110.4±78.5	NS	NS

Data are expressed as mean ± standard deviation.

Table 5. Differences in Mean Adequacy Ratio (MAR) between intermediate and advance/elite climbers by groups of training load. Average of the 3 days, non-climbing day; climbing-gym day and rock-climbing day.

	Average 3 day-study period	*P*	Non-Climbing Day (A)	*P*	Climbing Gym -Day (B)	*P*	Rock C limbing- Day (C)	*P*
3 d/w training								
Intermediate	76.6±2.6		71.2±10.6		77.6±6.4		68.2±12.05	
Advanced/Elite	79.6±9.6	0.046	78.2±11.4	0.128	78.2±11.5	0.647	82.710.6	0.043
4 d/w training								
Intermediate	78.6±7.9		74.9±7.3		73.8±10.8		78.5±13.9	
Advanced/Elite	79.6±3.3	0.481	79.6±10.6	0.659	79.11±9.4	0.649	72.8±2.2	0.600

Data are expressed as mean ± standard deviatio.

exercise decreases orexigenic peptide (acylated ghrelin) and increases anorexigenic peptides (*i.e.*, PYY and GLP-1) during and immediately after an acute bout of exercise[34]. Exercise can also influence other hormones related to appetite, such as cortisol and insulin[35]. These hormonal changes often coincide with a transient reduction in subjective appetite responses, described as "exercise-induced anorexia". Additionally, climbing is a stressful situation. Stress activates anorexigenic pathways leading to a decreased food intake. The general assumption can be made that acute or repeated restraint stress results in decreased food intake resulting in stress-induced anorexia[36]. Furthermore, compensation intake does not occur when energy deficits are generated by exercise[37]. Both factors (exercise and stress) could lead to LEA (low energy availability) a situation with negative health and performance outcomes[38] that should be further study in climbers.

Similar results to ours were found by Zapf *et al.* and Merrells *et al.*[11,12] in adult elite climbers and Michael *et al.*[13] in adolescent rock climbers. Therefore, all results together show the urgent need for nutritional advice in this group of athletes.

The mean macronutrient contribution to energy was unbalanced (protein: fat: CHO: alcohol to energy intake was 17: 38: 42: 3% respectively) and this macronutrient distribution, as well as other dietary characteristics (elevated intake of SFA and sugars and low MUFA and fiber intakes), are similar to those found in studies of the general Spanish population[39].

To the best of our knowledge, this is the first study to assess micronutrient intake in climbers. Intakes of vitamins and minerals were acceptable except for iodine, zinc and vitamin D in the case of men. On the other hand, zinc, iron, folate, vitamin D and vitamin E were deficient in women. Intakes of iron and folate were significantly lower in women than men on the non-climbing day. Both nutrients are critical for the correct transport of oxygen by blood and the prevention of anemia. Folate also plays an essential role in amino acid metabolism and DNA synthesis. These inadequacies were similar to those shown by Partearroyo *et al.*[40] in the ANIBES study in Spain in the general population, indicating that the volunteers of the present study had typical Spanish eating habits rather than an athlete´s diet in which nutrition strategies focus on providing adequate substrate stores to meet the fuel demands and nutrient requirements of the sport[14]. It is important to bear in mind that dietitians do not usually work in climbing-gyms in Spain; so, apart from personal interest, it is not easy to find nutritional advice or recommendations when practicing this type of sport even when aiming to professionalize.

Despite the lack of available advice, in general the quality of the diet calculated as the Mean Adequacy Ratio (MAR), which focuses on the nutrients involved in energy metabolism and bone-muscular health, was adequate for men and women on the three days evaluated. After grouping the volunteers by similar training load, i.e. those training for 3 or more days a week, we observed a higher MAR in advanced/elite level climbers compared with intermediate level ones, being statistically significant on the rock-climbing day. Furthermore, there was a positive correlation between climbing ability and MAR on the non-climbing day. These results indicate a potential relationship between climbing ability and the quality of the diet that could, therefore, be responsible for a significant part of the factors involved in performance. Consequently, we consider that acquiring good food habits could significantly improve climbing performance, although this should be studied in larger samples in the future.

Conclusion

This study in recreational climbers reveals that they have anthropometric characteristics similar to other studies performed in this sport, which differ according to climbing ability (with less body fat related to better performance). However, the dietary intakes failed to meet recommendations for energy, macronutrients and some micronutrients, which could negatively affect their physical performance. We described a possible relationship between climbing ability and the quality of the diet that should be evaluated further. Results indicate a need for specific nutritional recommendations for climbers. The present research could help to better understand the real needs of participants of this sport and support a need for evidence-based food intake recommendations specifically targeting this population.

Strengths and limitations

The main strength of the present study is the novelty of the dietary data, recorded on three different days: non-climbing day, climbing-gym day and rock-climbing day, including, in this way, all possible training situations and assessing the difference between them, in addition to a "rest day". Furthermore, anthropometric measurements were assessed by two ISAK level III-certified anthropometrists, ensuring the accuracy of the measurements.

However, some limitations should also be noted. First, the self-reported dietary records introduce the possibility of under or over reported food intake. The need to estimate portion sizes is also a well-known limitation of the register method in household measures. We tried to limit this by giving oral and written instructions and by double-checking the final reports.

Finally, it is impossible to know the exact number of people practicing climbing in Madrid, as the the Mountaineering Federation in the Community of Madrid (Spain) does not distinguish between members who practice climbing and those who practice any other mountain sport. This, together with the fact that only one of every four people who practice climbing is officially federated makes it impossible to determine the real statistical power of the sample size. In spite of this, comparing our findings with other research studies of the same population and taking into account the unique nature of the target population, we believe that the present results can be considered as representative.

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Authors' contributions

The study was designed by NÚ; data were collected and analyzed by NÚ, CL-C and ÁG-G; data were interpreted by ÁG and NÚ; manuscript preparation was undertaken by NÚ and ÁG. All authors approved the final version of the paper.

Conflicts of Interest

The authors do not declare a conflict of interest.

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Original article

Presence of women in futsal. A systematic review

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Futsal. Female. Sport. Review.

Summary

Futsal is one of the sports that has been gaining in number of practitioners worldwide. Among the groups in which the practice has grown in recent decades, women stand out. Thus, the objective of this review is to offer a vision of the most recent scientific publications in relation to the presence of women in futsal. For this, a systematic review was carried out from 2015 to 2020, searching with the terms of the UNESCO Thesaurus: "futsal" and "woman" in the Scopus and Dialnet databases, allowing the selection of original articles (experimental, descriptive, quasi -experimental and / or case studies) that included information on this line of research. A total of 381 articles were found, although after applying the inclusion criteria of the review they were reduced to 27 articles. These publications were divided into three main categories: 1) Research related to conditioning factors of training and competition in women, 2) Research related to injuries and other psychological variables in women and 3) Other topics investigated; doing a discussion about each of these categories. In conclusion, this systematic review makes it possible to quickly and easily observe the analysis of women's futsal research within the international context in recent years, as well as to identify the most relevant scientific issues today. Thus, there is a scarce number of publications on the presence of women in futsal in all the topics of study, and therefore, it is necessary to cover with greater scientific contribution given the great boom, extension and popularity that has been acquiring the figure of the woman in this sport.

Presencia de la mujer en el fútbol sala. Una revisión sistemática

Resumen

El fútbol sala es uno de los deportes que ha ido ganando en número de practicantes a nivel mundial. Entre los grupos en los que ha crecido la práctica en las últimas décadas, se destacan las mujeres. El objetivo de esta revisión es ofrecer una visión de las publicaciones científicas más recientes en relación a la presencia de la mujer dentro del futsal. Para ello se realizó una revisión sistemática desde 2015 hasta 2020, buscando con los términos del Tesaurus de la UNESCO: "futsal", "mujer" en las bases de datos Scopus y Dialnet, permitiendo seleccionar los artículos originales (estudios experimentales, descriptivos, cuasi-experimentales y/o estudios de caso), que incluían información sobre esta línea de investigación. Se encontraron un total de 381 artículos, aunque tras la aplicación de los criterios de inclusión de la revisión quedaron reducidos a 27 artículos. Estas publicaciones se distribuyeron en tres grandes categorías: 1) Investigaciones relacionadas con condicionantes del entrenamiento y la competición en la mujer, 2) Investigaciones relacionadas con lesiones y otras variables psicológicas en la mujer y 3) Otras temáticas investigadas; haciendo una discusión sobre cada una de estas categorías. Como conclusión, esta revisión sistemática permite observar de forma sencilla y rápida el análisis de las investigaciones de la mujer en el futsal dentro del contexto internacional en los últimos años, así como identificar los temas científicos más relevantes en la actualidad. Así pues, se halla un escaso número de publicaciones sobre la presencia de la mujer en el futsal en todas las temáticas de estudio, y por ello, resulta necesario cubrir con mayor aportación científica dado el gran auge, extensión y popularidad que ha ido adquiriendo la figura de la mujer en este deporte.

Palabras clave:
Fútbol sala. Mujer. Deporte. Revisión.

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Introduction

Futsal is one of the sports that has been gaining in number of practitioners worldwide. Among the groups in which the practice has grown in recent decades, women stand out[1]. Futsal, like soccer, has always been recognized as a sport played by men. This culture, for a long time, prevented girls from practicing this modality but, currently, there is a growing expansion of women's futsal with the creation of federated championships, leagues, national teams and clubs[2,3]. Futsal is a sport with a growing popularity, as well as its level of performance, both in men and women[4].

Women's futsal and soccer are modalities that had their practice made official recently, only at the end of the 20th century and, because they are not valued practices, they have few studies presented in the literature[5,6]. Investigating the development of elite women's sports careers can be a way to better understand how gender issues and the specific conditions of women's sports practice have influenced the lives and personal experiences of athletes[7]. Women face many barriers, discrimination, and stereotypes to participate in a worldwide sport. The findings of these authors[8] indicated several variations of the social construction of female futsal players through a process of objectification, dialectics externalization, and internalization on futsal. On the other hand, despite this growing expansion of women's futsal, few studies have investigated the specific physiological demands of women within this sport[9].

Likewise, the area of evaluation of the functional state of the neuromuscular system and its impact on the physical fitness characteristics of futsal women players is not sufficiently substantiated[10]. However, the inclusion of women in futsal in recent years has become a topic of interest for the academic community[11]. The presence of women in the sports field of futsal shows the change in mentality that there are sports for men and others for women; maybe that's the paradigm shift. In fact, women are increasingly involved with bodily practices, previously restricted to the male gender[12]. However, the incentive to practice women's futsal at Brazilian universities is still timid, despite being a very popular sport practiced in Brazil[13].

The purpose of this study has been to carry out a review of the scientific literature from 2015 to 2020 that addresses the field of futsal, selecting only articles related to the presence of women for content analysis. Therefore, the objective of this study is to determine the amount of scientific papers that are published related to women in futsal, to analyse which are the most investigated topics in this field and thus establish which aspects are a little-studied field of research and therefore they offer more possibilities.

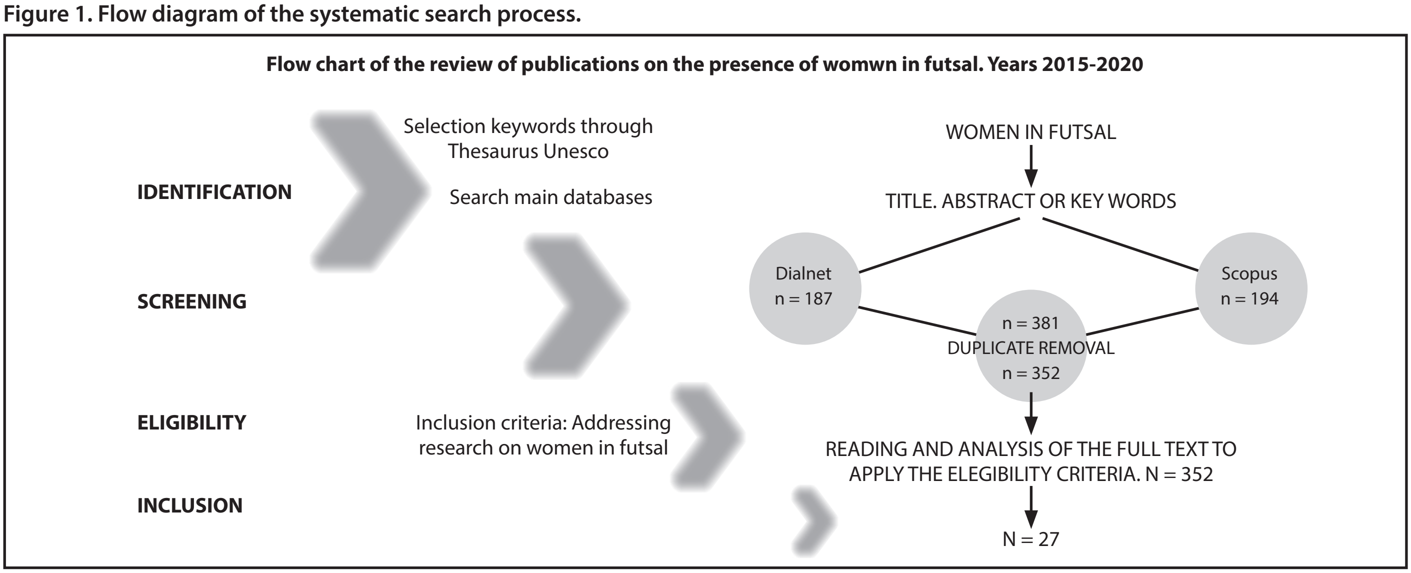
Material and method

The bibliographic review is a type of scientific article that, without being original, collects the most relevant information on a specific topic. Thus, for this review, a bibliographic search was carried out in the two most relevant international databases in this line of study. The first one, the Scopus database (Elsevier), was selected as it was a review in Social Sciences (texts in different languages). In addition, the Spanish Dialnet database was used as a complement. As keywords, the following terms were chosen from the UNESCO Theaurus (futsal, women and/or female). The inclusion criteria used in the review were the following:

- Articles published from January 1, 2015 to August 15, 2020.
- Articles that address any type of research related to futsal in the international context, incorporating experimental, descriptive, quasi-experimental studies and / or case studies.
- Articles that are published in English, Portuguese or Spanish.
- That the study analyse any variable related to women and futsal.

A total of 381 articles were found, but after applying the indicated selection criteria, the search brought together a total of 27 documents for analysis. Likewise, the work schedule for the search for information had four different phases, as can be seen below and in the flow diagram represented graphically in Figure 1.

Figure 1. Flow diagram of the systematic search process.



- 1st Phase: Search and selection of descriptors through the UNESCO Thesaurus.
- 2nd Phase: Detailed search in the scientific databases Scopus and Dialnet, using the inclusion criteria described above.
- 3rd Phase: Analysis of the content of the articles and classification by subject.
- 4th Phase: Categorization of articles and preparation of the manuscript: systematic review.

Once the 27 definitive articles had been selected, a detailed reading of all the articles was performed individually and a first categorization was made. The second phase was the analysis of the different articles and the specification of the three definitive categories. As a result of this deductive procedure, triangulating the information, the final classification of the articles was carried out in the three mentioned categories.

Results

Once the flow chart of the systematic review of publications on the presence of women in futsal had been made, the result was 27 publications. All of them were included in a categorization process by subject, finally finding three categories of analysis of the scientific literature (Table 1).

Table 1. Synthesis of the studies found on presence of women in futsal.

Journal	Article title	Authors	Year	The purpose of the study	Results and conclusions
Research related to conditioning factors of training and competition in women					
Biol Sport	Aerobic fitness and performance in elite female futsal players	Barbero-Alvarez *et al.*	2015	The aim of this study was to determine aerobic fitness in elite female futsal players using laboratory and field testing.	Peak heart rare and post-exercise blood lactate concentrations were not significantly different between tests. Elite female futsal players possess moderate aerobic fitness.
J Exerc Physiol Online	Comparison of psychophysiological responses in game simulation and different training sessions in female futsal athletes	Barth *et al.*	2016	The purpose of this study was to compare the different modes to quantifying the training load in small-sided game (SSG), repeated sprint ability (RSA), and simulated match (SM).	The results demonstrate that sessions with SM and SSG show similar psychological and physiological responses, but lower than observed in RSA training sessions.
Biol Sport	Evaluation of the external and internal workload in female futsal players	Beato *et al.*	2017	The aim of this study was to quantify locomotor and mechanical activities performed during a non-competitive female futsal match, measuring the differences between the first and second half.	Female futsal players decreased the workload in the second half compared to the first one during this non-competitive match. It was found that fatigue impairs the performance in the second part of the game.
Theory and Practice of Physical Culture	Innovative approach in modeling of motor training of women"s futsal teams	Chernysheva *et al.*	2015	The purpose of the present research was to simulate motor training of women"s futsal national team on the basis of an assessment of the functional state of the neuromuscular system.	Simulation of situations of competitive activity in training conditions makes it possible to improve the abilities of female football players to quickly perceive and adequately assess the current game situation, to make a decision depending on the situation with regard to individual characteristics of the functional state of the neuromuscular system and motor fitness.
SpringerPlus	Profile of 1-month training load in male and female football and futsal players	Clemente & Nikolaidis	2016	The aim of this study was to analyse the variance of training load between male and female football and futsal players.	In this study it was possible to verify that female players spent more time in high intensity zones and that futsal training sessions are more intense than football sessions.
Human Movement	Heart rate variations between training days and types of exercise in men and women futsal and soccer players	Clemente *et al.*	2018	The aim of the study was to compare the heart rate (HR) responses of women and men soccer and futsal players during a 4-week period of training.	The tactical tasks and match were the activities that contributed to increases in heart rare max.
RBFF-Revista Brasileira de Futsal e Futebol	Effecto de la periodización con cargas selectivas sobre la incidência de lesiones en un equipo de futsal femenino durante temporada competitiva	Ruppel da Rocha & Delia Venera	2015	This study evaluated the effect of selective loads periodization on incidence of injuries in professional female Futsal players during competitive season.	Selective loads periodization is adequate and attends the requirements of the sport decreasing the incidence of injuries during competitive season in female Futsal players.

(continuation)

Journal	Article title	Authors	Year	The purpose of the study	Results and conclusions
RBFF-Revista Brasileira de Futsal e Futebol	Incidência local de finalizações e Gols efetivados em um campeonato de Futsal feminino	Galvão de Miranda *et al.*	2019	The objective was to identify and quantify the local incidence of finals and goals scored in a women's futsal championship through an analytical performance system.	The regions closest to the opponent's goal had the highest number of finals and goals, so the modification of the defensive systems of those regions is necessary to avoid possible negative results for the teams.
The Anthropologist	Effects of plyometric training on anaerobic capacity and motor skills in female futsal players	Karavelioglu *et al.*	2016	This study was conducted to define the effects of an 8-week plyometric training program on anaerobic capacity.	A statistically significant difference was observed in the following factors among the female futsal players of leg power, absolute peak power, absolute mean power, vertical jump and speed.
Journal of Physical Education	Physiological and neuromuscular responses during the game in female futsal players	Kassiano *et al.*	2019	The present study tested whether there are differences in physiological and neuromuscular responses in futsal athletes during a friendly game.	There was a substantial increase in lactate from the moment before the start of the game to the end of the first.
The Journal of Strength & Conditioning Research	Comparative effects of two interval shuttle-run training modes on physiological and performance adaptations in female professional futsal players.	Teixeira *et al.*	2019	The purpose of this study was to analyze the effects of 2 shuttle-run interval training (SRIT) models with 1 and 3 directional changes per running bout on the aerobic and anaerobic performances of elite female futsal players.	In elite female futsal players, SRIT15×15 is a promising strategy to enhance performance-related physical fitness attributes in a short-term period during the preseason.
Sportis: Revista Técnico-Científica del Deporte Escolar, Educación Física y Psicomotricidad	Análisis de la carga interna en los entrenamientos de fútbol sala femenino de 1ª división nacional	Pascual Verdú *et al.*	2016	The aim of this study is to analyze the heart rate (HR) and the rating perception of effort (RPE) in training women futsal players from the first division team of the Spanish league.	Having significant differences in the results of maximum heart rate between technical-tactical sessions and modified games and between the physiological and technical-tactical sessions. The results showed that the modified games session obtains values of heart rate and the rating perception of effort greater than the technical-tactical and physiological work sessions.
Research related to injuries and other psychological variables in women					
Malays Orthop J.	Incidence of football and futsal injuries among youth in Malaysian Games 2018	Ahmad-Shushami & Abdul-Karim	2020	The purpose of the study was to analyse the incidence, circumstances, and characteristics of football and futsal injuries during the Malaysian Games of 2018.	A total of 48 injuries were reported from 26 football matches, equivalent to 64.64 injuries per 1000 match hours. The rate of injury in women futsal players was higher compared to men.
**Science & Sports*	*Short term creatine loading without weight gain improves sprint, agility and leg strength performance in female futsal players	*Atakan *et al.*	2019	*The main aim of this study is to identify the effects of short-term creatine supplementation on leg strength, velocity and agility in young female futsal players.	*Creatine supplementation significantly improved 10 m, 20 m and 30 m speed performances, leg strength and agility in female futsal players.
RBFF-Revista Brasileira de Futsal e Futebol	Prevalência e perfil de lesões esportivas em atletas de Futsal feminino nos jogos universitários brasileiros	Martins de Souza Filho *et al.*	2018	The aim of this study was to analyze the profile of athletic injuries in female athletes of the College Premier Futsal League during the Brazilian college sports competitions 2014.	Non-contact lesions with other athletes presented higher prevalence than lesions associated with contact. There was prevalence of single-record injuries when compared to injury re-occurrences. The prevalence of injuries per match showed high positive correlation with the day of the competition, a statistically significant result.
Int J Sports Med	Epidemiology of injuries in elite female futsal players: a prospective cohort study	Lago *et al.*	2020	The aim of this study was to analyze the injury incidence, characteristics and burden among a cohort of elite female futsal players.	The quadriceps and ankle were the regions where most injuries occurred. Contact injuries were more common during matches than training, and usually happened at the end of the season. Elite female futsal players are exposed to a substantial injury risk, especially on ankle and quadriceps with moderate severity, occurring at the end of the sessions, especially during matches.

(continuation)

Journal	Article title	Authors	Year	The purpose of the study	Results and conclusions
Sustainability	Healthy practice of female soccer and futsal: identifying sources of stress, anxiety and depression	Olmedilla *et al.*	2018	The aim of this study was to examine the post-injury psychological impact looking to avoid sources of health issues.	The female non-injured players presented values in anxiety higher than those corresponding to the non-injured male players.
Revista Brasileira de Medicina Do Esporte	Propriocepção e reforço muscular na estabilidade do tornozelo em atletas de futsal feminino.	Oscar Ribas *et al.*	2017	To compare the effects of proprioceptive training and muscle strengthening on the stability of the ankle joint in indoor soccer athletes through the Star Excursion Balance Test.	Both proprioceptive training and muscle strengthening training obtained statistically significant results and demonstrated good stability of the ankle joint.
PeerJ.	Injury incidence, characteristics and burden among female sub-elite futsal players: a prospective study with three-year follow-up.	Ruiz-Pérez *et al.*	2019	The main purpose of the current study was to analyze the injury incidence, characteristics and burden among sub-elite female futsal players.	The injuries with the highest injury burden were those that occurred at the knee, followed by quadriceps and hamstring strains.
Asian J Sports Med	Studying the Perceptive and Cognitive Function Under the Stress of Match in Female Futsal Players.	Sepahvand *et al.*	2017	The main purpose of this study was to analyze the effect of match-related stress on cognitive performance factors before and after matches among female futsal players.	The results indicated that in female futsal players, cortisol concentration in plasma was much higher before the match, compared with its concentration after the match.
Other topics investigated*					
RBNE-Revista Brasileira De Nutrição Esportiva	Estado nutricional e perfil alimentar de uma equipe escolar de Futsal feminino no município de Caxias do Sul-RS	Batalha *et al.*	2019	Evaluate the nutritional status and food profile of a school team of futsal players.	The results showed that the team is eutrophic and, according to the waist circumference, is not at risk for cardiovascular diseases. The percentage of fat is adequate and the athletes have good eating habits, although the associations between the variables studied were not statistically significant.
RBFF-Revista Brasileira de Futsal e Futebol	A mulher em quadra: evidências contemporâneas do contato inicial com futsal	Costa *et al.*	2018	This study aimed to highlight the beginning of the relationship between women and playing (futsal mode).	It was possible to conclude that female sportive initiation usually takes place in informal spaces and evolves into formal education late, their experience in the modality is stimulated by family and friends and the participation of these girls in competitions takes place at an opportune moment.
RBNE-Revista Brasileira De Nutrição Esportiva	Avaliação de hábitos alimentares de uma equipe de Futsal feminino	Barbosa *et al.*	2019	Evaluate the eating habits of a female futsal team.	Most athletes of the female futsal team, make intake above or below the daily recommendations for athletes, the data in the tables show in detail the total daily energy value as well as the amounts of macronutrients consumed.
RBFF-Revista Brasileira de Futsal e Futebol	Caracterização do perfil dos treinadores de futsal feminino de equipes que disputam os jogos abertos de Pelotas	de Freitas Vargas *et al.*	2017	The aim of this study was to characterize the profile of women's futsal coaches of teams that competed in the Pelotas open games.	The main difficulties cited for working with women's futsal were lack of financial support, sponsorship, base category teams, prejudice of families and a few competitions.
Revista Brasileira de Medicina do Esporte	Relative age in female futsal athletes: implications on anthropometric profile and starter status.	Aires Ferreira *et al.*	2020	To determine the effect of relative age (ERA) on competitive female futsal athletes, and its influence on anthropometric profile and starter status.	There was no ERA in distribution, anthropometric profile, or starter status between athletes born from January to June and those born between July and December. On the other hand, those born in the first months of the year showed longer practice times than those born in the latter months of the year.

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Journal	Article title	Authors	Year	The purpose of the study	Results and conclusions
RBFF-Revista Brasileira de Futsal e Futebol	Efeitos de um programa periodizado de futsal na aptidão física de estudantes femininas de 13 e 14 anos de idade.	Fiorante & Pellegrinoti	2018	The objective of this study is to analyze the effects on the physical fitness of female students of full-time school from a periodic futsal program	The intervention group showed a significant difference in abdominal resistance, square test and 6-minute walk / walk tests in relation to the control group
Motriz	Brazilian women elite futsal players' career development: diversified experiences and late sport specialization	Mascarin *et al*.	2019	To investigate elite women sports career development can be a way to better understand how gender issues and specific women sport practice conditions have influenced athletes' life and personal experiences, also subside reflections on policies and pedagogic intervention on the sport	Interviewed players had their first sports experiences on a variety of practices during sport initiation in childhood

* Repeated studies in the different categories

As can be seen in Table 1, from 2015 to 2020 the category of Research related to conditioning factors of training and competition in women has gathered a total of 12 studies. The category of Investigations related to injuries and other psychological variables in women has had a total of 8 studies and, finally, the category of other topics studied has brought together a total of 8 studies.

Discussion

Research related to conditioning factors of training and competition in women

For Ruppel da Rocha and Delia Venera[14], aerobic and muscular endurance, lower limb flexibility, muscular power, agility / speed and submaximal strength were developed during the preparatory period; in the competitive period, the technical and tactical components had greater emphasis and the physical capacities were maintained, with the total of injuries being 17%. Thus, periodization with selective loads is adequate and meets the demands imposed by the modality, reducing the incidence of injuries during the competitive season of female Futsal athletes[14]. The analysis of futsal in women provides useful information on their external load demands[15]. These authors Beato *et al*.[15] indicated that female futsal players decreased the workload in the second half compared to the first during a non-competitive match and found that fatigue impaired performance in the second half of the game. The results of another research Pascual Verdú *et al*.[16] showed that the modified match session obtains values for Heart Rate (HR) and subjective perception of effort greater than the technical-tactical and work sessions physical training of a female futsal team of the first national division. Likewise, for Clemente *et al*.[17] the tactical tasks and the match were the activities that contributed to the largest increases in maximum HR. However, Barth *et al*.[18] found no differences in maximum HR and only found differences in internal load between Small Sided Games and simulated matches. The results of these researchers[19] show that the sessions with simulated match and Small Sided Game show similar psychological and physiological responses, but lower than those observed in training sessions with repeated sprinting. Likewise, according to Barbero-Alvarez *et al*.[9], the peak HR and blood lactate concentrations after exercise were not significantly different between the tests in elite futsal players who have moderate aerobic fitness. Kassiano *et al*.[19] showed that although blood lactate increased in female futsal players, their performance was not suppressed during and immediately after a friendly game, suggesting that the neuromuscular system can be restored immediately after the game end.

Karavelioglu *et al*.[20] defined the effects of an 8-week plyometric training program on anaerobic capacity, leg strength, vertical jump, and speed values in women and observed a statistically significant difference in leg power, absolute peak power, absolute average power, vertical jump and speed. For their part, Teixeira *et al*.[21] noted that in elite women's futsal, shuttle running interval training is a promising strategy to improve performance-related physical fitness attributes over a 5-week period during preseason, due to a better effect on aerobic and anaerobic qualities. Following Chernysheva *et al*.[10] the simulation of situations of competitive activity in training conditions allows improving the capacities of futsal players to quickly perceive and adequately evaluate the current situation of the game, to make a decision based on the situation in terms of individual characteristics of the game functional status of the neuromuscular system and motor fitness. An improved central movement regulation mechanisms in girls contributes to effective physical performance when playing sports.

The central sectors of the field have the highest effectiveness rates. Therefore, the quadrants closest to the rival goal had the highest number of shots and goals scored, so it is necessary to modify the defensive systems of these regions to avoid possible negative results for the teams. Regarding the analytical performance system, the scout proved to be useful in analyzing various fundamentals of the sport, including the completions and the effective goals in a women's futsal championship[22]. In another study[23] it was found that female players spent more time than male players in high-intensity areas and that futsal training sessions are more intense than soccer sessions.

Research related to injuries and other psychological variables in women

Injuries are one of the worst scenarios for an athlete and a team[24]. Futsal is a team sport characterized by fast movements and high intensity, with frequent changes of direction of athletes, which predisposes the lower limb to injuries mainly in the ankle joint[25]. Following these lines, other authors[26] pointed out that the characteristics of Futsal require players to perform frequent episodes of high intensity activity with limited rest periods that are not enough for a full recovery.

The main objective of another study[27] was to analyse the incidence, characteristics and burden of injuries among women of the futsal sub-elite. Thus, the most common type of injury was muscle / tendon followed by joint (not bone) and ligament. The injuries with the highest injury load and that required the longest recovery time were those that occurred in the knee, followed by the quadriceps and hamstrings. On the other hand, in another study[24] a total of 90 injuries were recorded, with 60.6% of the players suffering some type of injury. For these authors[24], moderate or less severe injuries were the most frequent and they found that the majority of injuries occurred in the quadriceps and ankle. Following these contributions[3] they observed a higher prevalence of injuries in the lower limbs, which are musculotendinous in the ankle and thigh. According to Oscar Ribas *et al.*[25] both proprioceptive training and muscle strengthening training obtained statistically significant results in the ankle joint, improving stability. For other authors[28] the injury rate in women who practice futsal was higher compared to men.

Most of the injuries had a non-contact mechanism (93%), with the lower extremity being the most frequently injured anatomical region[27]. However, the results of another investigation[3] indicated a prevalence of 2.16 injuries per game, with non-contact injuries being more frequent than injuries associated with contact with other players. Likewise, according to Lago *et al.*[24] contact injuries were more common during matches than in training sessions and generally occurred more frequently at the end of the season in elite women's futsal competitions. On the other hand, for Ruiz-Pérez *et al.*[27] the first weeks of competition after preseason and shortly after the Christmas holidays were the times when the most injuries occurred. Therefore, futsal is presented as a risky sport with a high frequency of injuries, so it is necessary to carry out studies that address the factors related to this occurrence in order to guide future studies aimed at preventing new injuries and its recurrences[3]. To reduce the overall injury burden, efforts should be directed to the design, implementation, and evaluation of preventive measures that address the most common diagnoses, namely, muscle/ tendon and ligament injuries[27].

On the other hand, another research[29] examined the psychological impact after injury and for this they analysed the differences in levels of stress, anxiety and depression among players who they had suffered at least one injury during the season. The stress levels of uninjured players are higher than those of injured players. Compared with men, the uninjured female players presented higher anxiety values than those corresponding to the uninjured male players. Thus, sports injury affects mental health problems such as anxiety and stress, and differently in terms of gender[29]. Following this line, Sepahvand *et al.*[30] indicated that stress negatively affects cognitive function in female futsal players, however, the effect of acute mental stress is not well understood. The results of these authors[30] indicated that in women practicing futsal, the plasma cortisol concentration was much higher before the game, compared to its concentration after the game. It should also be noted that general health, sustained attention and response speed were higher after the match.

Other topics investigated on women and futsal

The results of Fiorante and Pellegrinoti[31] showed that the dermatoglyphic profile of high-performance futsal athletes differs significantly from the profile of the non-athlete population. The results of Batalha *et al.*[2] showed that the equipment is eutrophic and, based on waist circumference, it is not at risk of cardiovascular disease. The percentage of fat is adequate and the athletes have good eating habits and showed the importance of adequate and balanced nutrition guidelines to improve the physical performance and health of the players[2]. For Barbosa *et al.*[32] most of the players of an elite women's futsal team ingest above or below the daily recommendations for these athletes. Data obtained by other authors[26] indicate that low-dose creatine supplementation for 7 days may be an effective approach to improve exercise capacity in women who practice futsal without an associated increase in body weight.

According to Aires Ferreira *et al.*[33], although the relative age revealed longer practice times that favour women born in the first quartile of the year, it did not influence the starter status, the distribution in the teams, or any advantage in the anthropometric profile. On the other hand, Costa *et al.*[12] indicated that female sports initiation tends to occur in informal spaces and evolves towards late formal education, and their experience in the modality is stimulated by family and friends. Following these lines, Bevilaqua Mascarin *et al.*[7] indicated that the interviewed players had their first sporting experiences during childhood. Also, the beginning of systematic practice of specialization in futsal occurred later than in men due to the lack of competitions for women and the fact that futsal and other "kicking ball games" are considered more appropriate for men[7]. Likewise, the main difficulties cited by other authors[1] to work in women's futsal were the lack of financial support, sponsorships, grassroots teams, prejudices from families and the few existing competitions.

Conclusions

After the analysis of the 27 definitive articles for this systematic review of research on the presence of women in Futsal from 2015 to 2020, it is concluded that: Research focused on women in futsal is more developed and in-depth than that of years ago, both in quantity and quality. As for the topics that have shown the greatest focus of interest among researchers, they have been studies on the conditioning factors of training, competition and injuries. On the contrary, the lack of studies related to the psychosocial field linked to the branch of sport psychology has become evident, with little research related to the emotional and mental performance or mental fatigue of the players. There has also been a shortage of studies that address the training and detection of talent in high performance in women futsal.

Practical applications and future research

This research may be of interest to professionals in technical bodies, physicians, physiotherapists and psychologists. In a particular way, they are also relevant for all researchers who dedicate themselves to the study of futsal, since with this review they can learn first-hand about the topics most studied in recent years, and thus start new research projects or have clearer prospects and application needs of new research for the future.

The analysis of the different studies related to the presence of the figure of women in this sport helps to identify the diversity of lines of research related to the topic addressed and the degree of specificity thereof, giving the scientific community a global vision of the relevance and amount of research that has been published to date. For this reason, this review has the scientific evidence summarized in a global way, as well as a valuable compilation of the references available to the different professionals who study this field.

It is necessary to cover female futsal with a greater scientific contribution in all the topics investigated, given the great boom, extension and popularity that the figure of women has been acquiring within this sport in particular. With a view to future work carried out in futsal, it is advisable to provide studies related to the field of sports psychology, sociology and pedagogy, to learn more about the emotional, psychic and social relationship management demands that occur in futsal. They could contribute to the improvement of this sport and to greater sporting performance

Conflict of interest

The author do not declare a conflict of interest.

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Original article

Return to Sport, integrating the process from conventional rehabilitation up to reconditioning: a narrative review

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Summary

Introduction: The process of return to sport after injury, has traditionally been approached in 2 separate stages; first the athlete is treated the medical service through conventional rehabilitation processes and is then referred to the sports team (coach and / or physical trainer) who complete the return to the sport activity. This approach may lack communication and coordination between both teams and may be insufficient for the demands of the current sports environment, causing longer processes of return to sport and greater risk of re-injury. The objective of this manuscript is to document the current models of return to sport, its stages, objectives and contents.
Material and method: A comprehensive review of publications was carried out, including observational studies, clinical trials, reviews, consensus, systematic reviews and meta-analysis, related to treatment, rehabilitation, readaptation and return to sport.
Results: The description of a model of return to sports of gradual progression that includes 3 stages was found: return to participation, readaptation to sport and return to maximum sports performance. The stage of return to participation aims to eliminate the symptoms and regain the functionality of the athlete in their non-sports activities, through conventional rehabilitation processes. The stage of readaptation to sport aims to achieve asymptomatic performance of training and competition activities, through the rehabilitation of deficiencies caused by the injury and the maintenance and / or development of motor skills with modified training. The stage of return to maximum sports performance includes specific sports training to reach the level of performance prior to the injury.
Conclusions: This model could be associated with greater success in returning to sports activity and lower risk of recurrence of the injury.

Key words:
Injury. Sport. Rehabilitation. Return to play.

Retorno al deporte, integrando el proceso desde la rehabilitación convencional a la readaptación deportiva: revisión narrativa

Resumen

Introducción: El proceso de retorno al deporte posterior a una lesión, ha sido abordado tradicionalmente en 2 etapas separadas: primero el atleta es tratado por el servicio médico mediante procesos de rehabilitación convencional y posteriormente es referido al equipo deportivo (entrenador y/o preparador físico) quienes completan el regreso a la actividad deportiva. Este abordaje puede carecer de comunicación y coordinación entre ambos equipos y tal vez es insuficiente para las demandas del entorno deportivo actual, originando procesos más largos de retorno al deporte y mayor riesgo de re-lesión. El objetivo de este manuscrito es documentar los modelos actuales de retorno al deporte, sus etapas, objetivos y contenidos.
Material y método: Se realizó una revisión exhaustiva de publicaciones que incluyó estudios observacionales, ensayos clínicos, revisiones, consensos, revisiones sistemáticas y meta análisis, relacionadas con el tratamiento, rehabilitación, readaptación y retorno a la actividad deportiva.
Resultados: Se encontró la descripción de un modelo de retorno a la actividad deportiva de progresión gradual que incluye 3 etapas: retorno a la participación, readaptación al deporte y retorno al máximo de rendimiento deportivo. La etapa de retorno a la participación tiene como objetivo eliminar la sintomatología y recobrar la funcionalidad del atleta en sus actividades no deportivas, mediante procesos de rehabilitación convencional. La etapa de readaptación al deporte tiene el objetivo de alcanzar la realización asintomática de las actividades de entrenamiento y competición, mediante la rehabilitación de las deficiencias originadas por la lesión y el mantenimiento y/o desarrollo de las capacidades motoras con entrenamiento modificado. La etapa de retorno al máximo rendimiento deportivo incluye el entrenamiento deportivo específico para alcanzar el nivel de rendimiento previo a la lesión.
Conclusiones: Este modelo, podría estar asociado a mayor éxito en el retorno a la actividad deportiva y menor riesgo de presentar reincidencia de la lesión.

Palabras clave:
Lesión. Deporte. Rehabilitación. Retorno al juego.

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Introduction

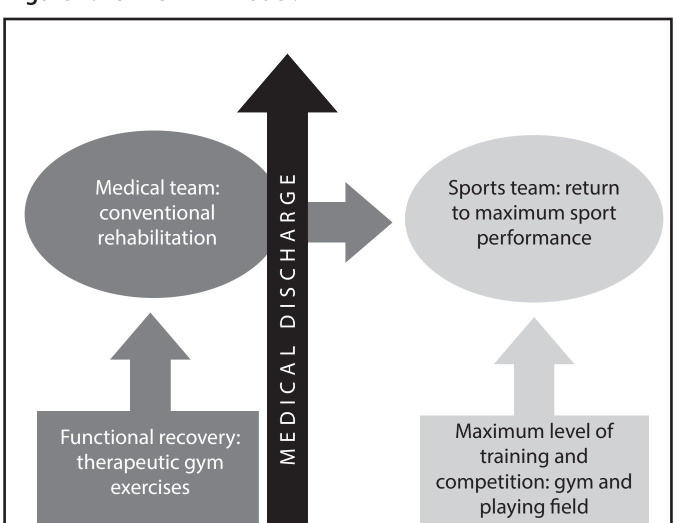
A sports injury is defined as any physical or medical condition that may occur during participation in a sport or training activity and that results in an inability to participate in competitive or training activities and requires medical diagnosis and treatment[1,2].

The process to return to sporting activity following an injury is known as Return to Sport (RTS) or Return to Play (RTP)[3]. This is a complex process that must take account of the biological-structural characteristics of the injury (type of injured tissue, extent of the injury, duration of the injury, signs and symptoms and characteristics of the injury reported in imaging studies), history of previous injuries and the athlete's state of health, functional losses generated by the injury (limitation of mobility, muscle weakness and imbalance, strength alterations, loss of balance, alterations in physical-functional tests), the factors relating to the sport in question (level of participation prior to the injury, competitive category or level, type of sport, position or test in the sport, stage of the season) and related personal, psychosocial and environmental factors (gender, age, race, non-sporting activities, job, psychological characteristics, family and/or social factors, external pressures, conflicts of interest, etc.)[3-5].

The RTP processes have traditionally been conducted in 2 separate stages: firstly, through medical treatment based on the conventional rehabilitation processes to subsequently be referred to the sports team (trainer and/or fitness coach) who complete the Return to Performance process[6] (Figure 1). However, this approach involved little communication between both teams and, on many occasions, proved to be insufficient for the demands of the current sports environment, given that it involved longer RTP processes with a high risk of re-injury and inability to return to the pre-injury level of performance[6].

Therefore, this review aims to document the models currently proposed to conduct the RTP processes, to indicate the stages into which this process is divided and to describe the goals and contents of each one.

Figure 1. Former RTP model.



Material and method

An exhaustive review of the literature published up to 30 March 2021 was conducted using the databases of PubMed, PeDro, Dialnet, and Google Scholar. This comprised observational studies, clinical trials, reviews of the literature, consensus statements, systematic reviews and meta-analyses that included information on strategies and interventions that are currently used in the treatment, rehabilitation and reconditioning to return to sport following injury, published in English or Spanish. The search strategy of the articles included was divided into 2 stages. In the first stage, documents were retrieved using the following search terms: "return to play" or "sports rehabilitation" or "sports reconditioning" and "sport injury" in order to identify those articles documenting the RTP process and defining the stages involved. Secondly, a direct search was made on the topics mentioned in the previously identified articles, including the analysis of the bibliography referenced in the same, for the purpose of supporting the information on the goals and contents of each of the RTP stages.

Results

RTP integrated models

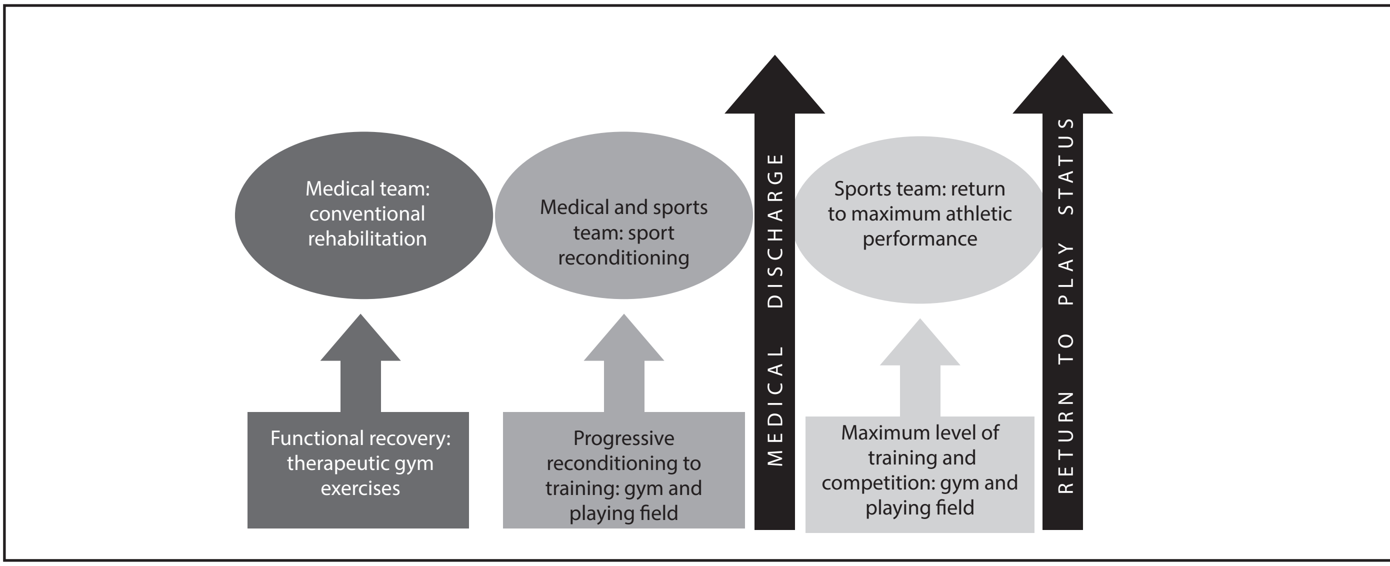
The needs and demands of today's sport environment make it necessary to have more efficient and effective RTP protocols. Buckthorpe *et al.*[6] highlight the need to include a "transition stage" to form a bridge between conventional clinical rehabilitation and sports training and that must take a multi-disciplinary approach, emphasising the involvement of the medical team with specialist training. Ardern *et al.*[4] proposed an RTP model that contemplates 3 stages that form a therapeutic continuum: Return to Participation, Return to Sport and Return to Performance. The Return to Sport stage has also been termed On-field Rehabilitation[6] or Sports Reconditioning[7]. Figure 2 is a schematic of the current RTP model.

Return to Participation stage

Within the RTP model proposed by Ardern *et al.*[4], the first stage is the Return to Participation. This stage is normally coordinated by the medical team and is directed at establishing a diagnosis and prognosis of the injury and starting the treatment and rehabilitationof the injury as soon as possible.

During this stage, the injured athlete participates in the conventional clinical rehabilitation process and also takes part in modified or restricted training sessions. The contents are focussed on recovering the functionality level in order to perform the activities of daily living with no symptoms and to maintain one's physical condition as far as possible with no risk of greater injury[4,6].

Figure 2. Current RTP model.



The approach to this initial phase aims to resolve the biological processes associated with the injury, including inflammatory and tissue repair mechanisms. This stage is therefore governed by biological and functional needs rather than specific times[8]. In this initial stage, the following goals must be ensured:

– Eliminate or reduce the pain, inflammation, effusion or oedema[9].
– Prevent greater damage[9].
– Limit the damaging effects of disuse or prolonged rest[9].

These goals can be met through the application of a number of strategies. Protection and rest following injury are directed at avoiding the mechanical overload of the tissue, which could aggravate the injury[8,9]. The prescription of non-steroidal anti-inflammatory drugs (NSAIDs) is common practice during this stage in order to control the pain and/or modulate the inflammatory process. However, their use is controversial in chronic phases of the injury or for prolonged use in muscular injuries[10]. The use of various physical means[11-15] is also a common treatment strategy in this phase. Likewise, intervention treatments through the infiltration of substances such as Platelet Rich Plasma, Hyaluronic Acid and Hypertonic Dextrose are becoming increasingly more common in the treatment of sports injuries[16,17], reporting favourable effects in addressing muscle injuries[18] and chronic tendinopathies[19-21]. In fact they represent an alternative to infiltration with corticosteroids which is still controversial for the treatment of some injuries due to the damaging effects that these can generate in tissue[17,22].

Kinesiotherapy programs, based on early mobility and isometric strengthening, are a fundamental part of this stage[23]. The application of an optimal load to the affected site limits any undesirable effects of disuse and seeks a positive effect in the injured tissue reorganisation and healing[9,23]. Isometric strengthening[24] and neuromuscular stimulation[25,26] are effective therapeutic interventions to prevent arthrogenic muscle inhibition, muscular atrophy and to maintain the strength level following sports injuries[24-26]. It is feasible to perform such interventions right from the early stages of the injury.

On the other hand, from this stage onwards an optimal modified or adapted training load should be established, one which addresses the uninjured body parts and is able to prevent physical deconditioning without creating greater damage to the injured tissue. With this aim in mind, strategies can be used such as hydrotherapy to promote activities that unload the body weight[27], strengthen the muscles not involved in the injured part of the body[9] and allow for cross training, which is defined as the use of an activity or motor movement that involves less load for the injured part while maintaining physical performance[28,29].

Some functional-clinical evolution criteria that the athlete must meet in order to progress to the following stage, could be the following:

– Adequate level in the process involving the repair, remodelling and stage of maturation of the damaged tissue, with no injury data in imaging studies[30-32].
– Asymptomatic physical examination: localized palpation with no pain or very slight pain (<3 on the Visual Analogue Scale), full range of motion and with no pain, negative clinical tests and good joint stability[30,31].
– Symmetrical pain-free muscle strength. It has been recommended that, at the end of this stage, the difference in strength between the injured and uninjured limbs must be less than 20%[30,33], which can be determined with hand-held isometric dynamometers that have been validated for the assessment of the muscles of the lower limbs, being a simple low-risk assessment that makes it possible to objectively determine the level of strength[34]. A further proposal is

to achieve a minimum level of strength that permits the correct and asymptomatic movement of a load equivalent to 50% of the body weight in the single-leg press exercise[33].

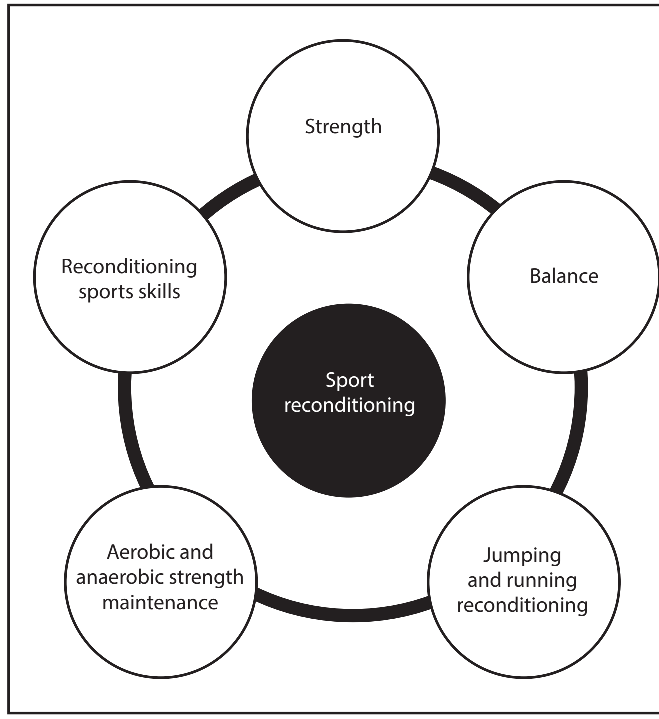
- Walking with normal, asymptomatic patterns; abnormal walking patterns have been associated with muscle weakness, reduced functional performance and may be exacerbated when the patient starts to run. It is therefore essential to safely re-establish normal walking at an early stage prior to the start of the reconditioning process[33]. It has been suggested that the injured athlete should be able to walk quickly for 10 minutes with a normal, pain-free mechanical pattern before commencing the Return to Performance stage[30].
- Correct, asymptomatic performance of the bilateral squat, given that this exercise represents a basic motor pattern for the development of other motor tasks and it is highly recommendable to restore this motor pattern right from the early stages[33]. Some tests, such as the overhead squat, have been validated and are useful to identify abnormal patterns of motion that predispose to an injury / re-injury[35].

Return to Sport / Sports Reconditioning stage

The Return to Sport or Sports Reconditioning stage represents a transition period between Return to Participation and Return to Performance. This stage is not performed in the physical therapy booths and/or in the therapeutic gym where conventional rehabilitation is normally done. Instead, it must be performed in the "physical fitness gymnasium" and on the "playing field"[6]. It must include the processes for reconditioning to training and competition. Therefore, "fieldwork" is an essential part given that, here, the athlete starts with a combination of activities (rehabilitation and modified training) focussing on progressing towards the asymptomatic performance of the activities forming part of the athlete's daily training and specific sports activity[6,30]. The sessions on the "playing field" are alternated with sessions in the "physical conditioning gym" to train strength, stability, flexibility and endurance, specifically adapted to the shortcomings of the athlete and to the type of injury[30]. It is important to emphasise the fact that, during this stage, the participation and supervision of the doctor coordinating the rehabilitation process is necessary. On successful completion of this stage, this doctor will then give the medical discharge[6].

The Sports Reconditioning stage includes the rehabilitation of the shortcomings that are a product of the injury, as well as the maintenance and/or development of motor skills through modified physical training that primarily involves the uninjured body parts[9,30]. The levels of intervention and progress must be guided by the clinical-functional evolution until the athlete's injury is completely asymptomatic and there are no training restrictions[30]. The potential components of this stage are shown in Figure 3.

Figure 3. Components of the Sports Reconditioning stage.



Muscle strength reconditioning

Muscle strength represents one of the main motor skills to be developed and standardised with regard to returning to sport following injury[30,36]. It has been reported that muscle fatigue, the alteration of muscle activation over time, muscle imbalances between dominant and non-dominant limbs, alterations in muscle stiffness and lumbar abdominal strength defects are neuromuscular factors that could predispose to injury[37]. During the reconditioning stage, the degree of strength of the muscles related to the injured structure must be objectively assessed. To do so, the hand-held isometric dynamometer can be used[34,38], or isokinetics, either in an open kinetic chain[39,40] or in a closed kinetic chain[41] or even in exercises with free weights such as the single leg press, leg extension or single leg flexion[33,42]. These tests make it possible to analyse the level of strength in relation to a pre-established reference value[42], to compare the muscles of the injured limb with those of the uninjured one[42,43] or to evaluate the agonist-antagonist ratio[44]. It has been suggested that, for isokinetic evaluations, at the end of the Reconditioning stage, athletes must have a difference of less than 10-15% when comparing the muscle strength of the injured limb with that of the uninjured one[43]. When isokinetic evaluation is not possible, consideration could be given to the single-leg press test as a functional test to assess the muscle strength levels in the injured limb[33]. In the comparison between agonist and antagonist muscles, the strength relationship varies according to the muscle group involved and the contraction regime in which the assessment is being made. For example, for open-chain isokinetic evaluations, it has been suggested that the ratio between the hamstrings (concentric): quadriceps (concentric) and the ratio between hamstrings (eccentric): quadriceps (concentric) must be greater than 0.6 and 1.0 respectively[44].

During the reconditioning stage, the dynamic strength program progresses from a partial joint range to a total joint range, according to the mechanical stress phase and level to which the injured structure is subject during the joint motion[23]. Although during sports training there is a proposal for the use of maximum repetition as a progression criterion for load intensity, during the reconditioning stage this criterion may not be applied in a similar fashion, given that the injured tissue is still in the repair-regeneration or remodelling process[45]. Therefore, the load intensity must be guided by the symptomatic response 30 and other variables such as the perception of effort [45]. It has been recommended that, during the reconditioning stage, the effects of the strengthening program should perhaps be focused on the improvement of resistance and muscle atrophy[45]. This can be achieved through the use of Roberston's OMNI RES scale that rates the perceived muscle effort at the end of the series and suggests using loads that make it possible to use series of 12 to 20 repetitions in order to improve muscle resistance and series of 8 to 12 repetitions in order to improve muscle strength and atrophy, with a perceived effort of more than 6 in order to guarantee muscle adaptations[46]. This strategy permits a balance between the safety and effectiveness of the program, in order to achieve greater benefits with no undesirable effects. When the injured structure is at advanced stages of remodelling or maturation, the strengthening loads could perhaps be guided by the conventional maximum repetition.

Balance reconditioning

Balance is defined as the ability to maintain the centre of gravity within the base of support with no loss of equilibrium[47]. The multi-intervention neuromuscular training programs that included balance, lumbar abdominal strengthening, limb strengthening, jumps, etc. may reduce the risk of injuries and improve subsequent functionality for knee and ankle injuries[48,49]. It is important to start with the assessment of balance and dynamic posture control. A number of tests have been validated and used for this purpose, such as the Y Balance Test[50], the Star Balance Test[50] and the unilateral squat test[51,52]. The unilateral squat is a motor action that forms the basis of many sports movements and, in order to perform it, the athlete requires balance, neuromuscular control and the strength required to support and move all the body weight[33]. The asymptomatic and qualitatively correct performance of this test is required in order to progress in the reconditioning process[33]. Balance training can be started once the athlete is able to perform a pain-free unilateral squat with a complete load on the injured limb. It has been proposed to start with that the static balance training, progressing from two-leg to single-leg support, from work with visual information to the suppression of visual information, from stable surfaces to sloping or unstable surfaces, seeking to get close to postures that are similar to the sports gesture and/or that retain the injury mechanisms[53,54]. Subsequently, the athlete must progress to activities that challenge dynamic balance, starting with low-speed - low-load activities and progressing to high-speed - high-load activities[53,54].

Jump reconditioning and the plyometric movement

Given that jumping is a high-speed, high-impact mechanical gesture that is an essential component of high-intensity sport activities such as running, braking, changing direction, reconditioning must take place before starting high-intensity training and competitive activity[33,55]. Jumping can be divided into 2 phases: an "impulse" phase where the muscles act concentrically, generating the necessary force for take-off and a "landing" phase where the muscles act eccentrically, generating the necessary shock-absorbing force. The combination of these phases through a short period of time, make up the plyometric movement[56]. The evaluation of this gesture is fundamental in the reconditioning stage and, for this purpose, use has been made of a number of tests such as the "Hop Jump test"[57], "Vertical Single Jump test"[58], "Drop Jump test"[50], "Drop Single Jump test"[59] and "Tuck Jump test"[50], that have been validated and used in the prevention of injuries and the return to sport.

To start the two-leg jump reconditioning process, the following criteria have been proposed: absence of pain, inflammation and oedema[56], complete, pain-free ranges of motion[56], symmetrical pain-free muscle strength with a contralateral difference of less than 20%[33,56], qualitatively correct and asymptomatic performance of the unilateral squat[33,56] and ability to asymptomatically perform a repetition of a single leg press with a load equivalent to 100% of the body weight[33]. Additionally, in the case of the reconditioning of the single leg jump, it has been suggested that the athlete should first be able to asymptomatically perform a repetition of a single leg press with a load equivalent to 150% of the body weight[33].

It has been suggested that the progression in the reconditioning process should start with low-intensity exercises such as "box jump ups" with emphasis on the impulse phase while minimising the landing phase, to subsequently progress to exercises of greater intensity such as "box drops" with emphasis on the landing phase[33]; Van Lieshout *et al.*[60] determined that exercises such as "box jump ups" and "box drops" generate less joint load on the hip, knee and ankle than other types of exercises such as the countermovement jump, vertical jumps with knee flexion and drop jump. Following reconditioning of the impulse and landing phases, it has been suggested to start the reconditioning of the plyometric movement with exercises such as the "box to box jump"[33]. This process must initially be performed for two-leg jumps and subsequently single-leg jumps[33] and to progress from single jumps to consecutive jumps[55,56]. It has been proposed that, at the end of the reconditioning stage, the athlete must be able to achieve a performance greater than 90% with the injured limb (compared to the uninjured one) in functional jump tests such as the single-leg horizontal or vertical jump and/or consecutive jump tests such as the triple jump where the movement must also be asymptomatic and qualitatively correct[57,61].

Reconditioning of the running motor skill

Running is the most frequently used movement in sport and, in biomechanical terms, it is considered to be a series of jumps[62]. The reconditioning of running is a fundamental step in order to continue with the rest of the reconditioning process[33] and, in general, it takes place on the "playing field"[6] although, in the initial stages, it could equally be performed on a treadmill[33]. A few criteria suggested for the start of the low-intensity running reconditioning process are: absence of pain, inflammation and oedema[63], full and pain-free ranges of motion[63], quadriceps muscle strength with a contralateral difference of less than 20%[63], performance of a qualitatively correct and asymptomatic unilateral squat[30,33,63] and ability to asymptomatically perform a single-leg press repetition with a load equivalent to 125% of the body weight[33]. It has been recommended to start the running reconditioning at speeds of around 8 km/h[33] and progress by increasing the running volume up to 20 minutes with no exacerbation of symptoms[43]. From then onwards, the running speed can be progressively increased, ensuring that this increase is in keeping with the clinical response[30].

The reconditioning of sprinting (>25 km/h)[42] will follow a different process. Given that sprinting is considered to be a series of jumps[62], it is necessary to have completed the reconditioning of the single-leg plyometric movement before starting the reconditioning of sprinting (performance greater than 85% with the injured limb compared to the uninjured one in the single-leg horizontal jump[63], as well as having achieved a contralateral difference of less than 10% in the quadriceps muscle strength[33] and ability to asymptomatically perform a single-leg press repetition with a load equivalent to 125% of the body weight[33]. The reconditioning process could perhaps start with the performance of running drills made with a high frequency of movement in 20-40 metre sections, simulating a sprint but with a shorter stride, involving less muscle stress and joint load[64]. Once this is achieved asymptomatically, sprinting can start, equally in short sections of around 20-240 metres, where the speed shall be progressively increased, guided by the patient's symptomatology[30,43], until the maximum sprinting speed has been reached asymptomatically.

Once reconditioning has been achieved for the maximum linear sprinting speed, then, agility work can start. This is defined as the ability to decelerate, accelerate and make changes of direction at the greatest possible speed and with the least loss of intensity[65] and represents one of the final components in the reconditioning process[33]. Given that agility exercises require high levels of strength, neuromuscular control and reactive ability, a few criteria have been suggested for the start of the agility reconditioning process: quadriceps muscle strength with a contralateral difference of less than 10%[33], ability to asymptomatically perform a single-leg press repetition with a load equivalent to 200% of the body weight[33] and the successful reconditioning of the plyometric movement. Exercises can be included such as the "agility ladder", "carioca drills", running backwards and sideways, accelerations-decelerations, turns, changes in direction, etc.[43,66], with a gradual increase in speed and symptomatic control. Progress can be assessed with agility tests that include movements similar to those used in the sport in question, such as the "Edgren Side Step Test", "T-Test" and "Illinois Agility Test"[65]. These tests often represent a criterion to start sport-specific training and competition activities[33,67].

Maintenance of the physical condition

EMaintenance of the physical condition must be a priority component of the sports rehabilitation and reconditioning processes. Maintenance of aerobic strength must be made at all stages of the process. Cross training has been used for this[28,29]. For injuries to a lower limb, activities such as deep water running"[27] and/or an arm ergometer[68] can be used from very early stages when the injured structure requires complete unloading. In keeping with the type of injury or when the complete unloading of the injured structure is not necessary, other activities such as the ergometric or elliptical bike are also effective in maintaining and even improving an injured athlete's aerobic capacity[28,29]. On the other hand, the uninjured structures must be trained as normal in order to maintain or even improve the muscular strength levels, independently of the therapeutic work to strengthen the injured structure[9,45]. It may also be possible to train anaerobic strength through cross training, for which the same ergometers can be used, provided that the injured body structure, the type of injury and the stage of recovery from the injury permit this.

Reconditioning athletic skills

The reconditioning of the sport-specific motor skills and their technical aspects must be introduced from the start of the reconditioning stage. This should be started at low-speed, emphasising correct execution, given that this will promote the acquisition and consolidation of the correct movement patterns, preparing the athlete for the subsequent phases in which the movements will be made at greater speed, including complex, multi-directional and reactive movements, including sports implements, challenges related to the sport context and the participation of adversaries[30,33].

Duration and criteria of the reconditioning stage

The duration of this stage will depend on the type of injury and its specific context.

The progress and safety of the programme must be based on clinical data and must be closely monitored throughout its duration, considering data on the overloading of the tissue under repair, the appearance of pain, oedema or inflammation[30]. The following criteria should be taken into account in order to conclude this stage and start the Return to Performance stage:

- Injured tissue healing process successfully completed, with no signs and symptoms when performing the activities characteristic of this stage.
- Symmetrical muscle strength of the lower limb, with a contralateral difference of less than 10% when comparing the injured limb to the uninjured one[33,61] and restored agonist-antagonist muscle

balance[43]. Ability to asymptomatically perform a repetition of a single leg press with a load equivalent to 200% of the body weight[33].

- Qualitatively correct plyometric movement and with a performance in functional jump tests of 90% when comparing the injured limb to the uninjured one[57,61].
- Ability to asymptomatically perform a linear, multi-directional sprint[30] and good quality, asymptomatic agility tes[t33,67].
- Correct, asymptomatic technical execution of the sports movement[30,33].

Return to Performance stage

This should be started once the Return to Participation and Return to Sport (reconditioning) stages have been completed successfully. At this point in the process, the athlete has recovered from the injury and has been given the "medical discharge" but has not yet reached the levels of physical, technical and tactical preparation to reach the maximum performance level[4,6] and to guarantee an adequate return with less risk of re-injury[6]. The athlete has therefore not yet been given the go ahead to "return to play".

The goals for this stage are:

- Achieve the levels of physical, technical and tactical preparation that allow the athlete to achieve the maximum performance level[4,6].
- Reduce the risk of re-injury, which will be increased *per se*[4,31].

For this purpose, the sports training programmes will be the main component of this stage. These programmes must be prepared and supervised by the sports team (trainer/fitness coach) which will act on the playing field and in the physical conditioning gym[6,7]. However, the medical team must continue to be involved, with the focus on reducing the risk of re-injury, as well as actively taking part in the medical control of the sport training[69].

During this stage, the athlete plays an unrestricted part in all the activities involved in their normal sports training, in line with the methodology put forward by the trainer[6,7]. Furthermore, the athlete can take part in pre-competition activities, low-demand or short-duration competitive matches, progressing to achieve or exceed the pre-injury performance level. At this point, the athlete shall be given the "return to play" status, considering the RTP process to have successfully concluded[6].

Conclusions

Return to Sport must be a continuum, addressed by a multidisciplinary team involving a range of professionals having the training and expertise in dealing with sports injuries. It must contemplate all factors (biological-structural, functional, sports, personal, psychosocial and environmental) that may influence the Return to Sport. A 3-stage model that includes Return to Participation, Return to Sport, and Return to Performance, could be a feasible proposal that could be associated with greater success in the return to sporting activity, less risk of re-injury and a greater possibility of achieving the pre-injury performance level.

Conflict of interest

The authors have no conflict of interest at all.

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Original article

Impact of airflow on body cooling in exercise: an exploratory study

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Summary

Objective: To analyze the body heat dissipation by thermography during indoor running treadmill with different airflow conditions.
Materials and method: Nine male participants (23.0±2.5 years old) underwent three 45-minute moderate-intensity running sessions (60-70% reserve heart rate) on a treadmill. At each session, a different experimental condition was applied in a cros-sover design: without airflow (NF), and with low (LF) and high airflow (HF) generated by a fun. Thermograms were obtained with a thermal camera before exercise, during (every 10 minutes), and after exercise. Skin temperature (Tsk) was measured on regions of interest of the upper body: pectoral, brachial biceps, and upper back. A repeated measures ANOVA was used to compare Tsk over time and between conditions, considering $p<0.05$ as statistically significant.
Results: In pectoral and brachial biceps, LF and HF conditions provided greater reductions in Tsk at all moments when compared to the NF ($p<0.05$). There was a higher reduction in Tsk to the HF vs LF in biceps at 30, 40, and 45 min during exercise ($p<0.05$). In the upper back, Tsk remained below baseline at all moments during exercise only in the HF condition ($p<0.05$). In NF and LF conditions, Tsk returned to baseline at 30 min during exercise ($p>0.05$).
Conclusion: The frontal wind flow enhances body heat dissipation during moderate-intensity running in the pectoral, brachial biceps, and upper back, with a direct relationship of flow speed and Tsk reduction during exercise.

Key words:
Thermography. Convection. Exercise. Body temperature regulation.

Impacto del flujo de aire en el enfriamiento del cuerpo en el ejercicio: un estudio exploratorio

Resumen

Objetivo: Analizar el disipación del calor corporal mediante termografía en ejercicio de carrera en tapiz con diferentes condiciones de flujo de aire.
Material y método: Nueve hombres (23,0±2,5 años) se sometieron a tres sesiones de 45 minutos de carrera de intensidad moderada (60-70% frecuencia cardíaca de reserva) en tapiz, bajo tres condiciones diferentes en un diseño cruzado: sin flujo de aire (NF) y con flujo de aire bajo (LF) y alto (HF) generado por un ventilador. Los termogramas se obtuvieron con una cámara térmica antes del ejercicio, durante y después del ejercicio, midiéndose la temperatura de la piel (Tp) en las regiones de interés del pectorales, bíceps braquiales y parte superior de la espalda. Se utilizó un ANOVA de medidas repetidas para comparar Tp en función del tiempo y entre condiciones, considerando $p<0,05$ como estadísticamente significativo.
Resultados: En los pectorales y bíceps braquiales, las condiciones LF y HF redujeron en todo momento la Tp comparadas con NF ($p<0,05$). La reducción de Tp fue mayor con HF que con LF en bíceps a los 30, 40 y 45 min ($p<0,05$). En la espalda superior, la Tp se mantuvo siempre por debajo de la línea base durante el ejercicio solo en la condición HF ($p<0,05$). En condiciones de NF y LF la Tp volvió a valores de referencia a los 30 min de ejercicio ($p>0,05$).
Conclusiones: El flujo de viento frontal mejora la disipación del calor corporal en pectorales, bíceps braquiales y parte superior de la espalda durante la carrera de intensidad moderada, con una relación directa de la velocidad del flujo y la reducción de la Tp durante el ejercicio.

Palabras clave:
Termografia. Convección. Ejercicio. Regulación de la temperatura corporal.

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Introduction

Physical exercise is characterized by high levels of internal heat metabolic production due to muscular metabolism, which must be dissipated from the body surface to the environment to prevent dangerous elevations in internal temperature. Heat dissipation occurs through the physical processes of conduction, convection, radiation, and evaporation[1]. When body temperature is controlled by evaporation of sweat, caution is needed to avoid a high degree of dehydration. This condition may impair performance and health. In extreme conditions, dehydration can lead to death[2].

Since the airflow removes heat from the body surface, the presence of wind during exercise may assist convective heat loss[3], reducing the risk of dehydration. Several studies have searched for the effects of cooling before and during exercise by using cold necklaces[4], cold vests[5], and head ventilators with or without water misting[6]. Stevens and collaborators[7] reported that cooling during exercise (mid-cooling) appears largely irrelevant to core temperature reduction but may be of greater relevance in the behavior of the cardiovascular and central nervous system and some psychophysiological factors, mainly in hot environments.

Moreover, the effect of airflow at different temperatures on the face has been a quite important topic in the literature for many years. Effects of face cooling have been reported on metabolism[8], heart rate (HR)[9], rate of perceived exertion (RPE)[10], and energy expenditure[11]; however, there is a lack of studies searching on the effect of whole-body cooling by an airflow generated with a fun. Infrared thermography (IRT) is a non-invasive tool to measure the body surface radiation temperature in real time[12]. Although several studies have used IRT for monitoring thermoregulatory adjustments on the body surface during different types of exercise[13-17], the impact of wind on the cooling capacity of the skin has not yet been studied by IRT.

The practice of indoor physical activity on a treadmill promotes a greater difficulty of convective heat loss when compared to outdoor running. Thus, the use of a fan can facilitate heat exchange through convection. Observing the skin temperature (Tsk) response during exercise with and without airflow can help to understand the importance of convection on thermoregulation. Moreover, this study can assist in the layout of spaces or in planning ventilation strategies to improve thermoregulation during exercise. Therefore, this study analyzed the body heat dissipation by thermography during indoor running treadmill with different airflow conditions.

Material and method

Participants

This study included nine healthy and physically active men, used to train on a treadmill (age 23.0 ± 2.5 years old, VO_{2max} 49.4 ± 4.3 ml $(kg.min)^{-1}$, height 174.1 ± 3.2 cm, body mass 70.6 ± 4.6 kg, body fat 11.1 ± 4.7%). All participants presented negative responses to all questions from the PAR-Q[18] and below-average coronary risk[19]. Several influencing factors in Tsk [20] were considered as exclusion criteria: smoking, musculoskeletal injuries, burns on the skin; pain symptoms; fever in the last week; treatments using creams, ointments or lotions; consumption of antipyretics and/or diuretics, or any food supplement. This study was assessed by the Local Committee of Ethics in Research and conducted following ethical principles of the Declaration of Helsinki and Resolution 466/2012 of the National Health Council. Participants provided written informed consent to participate in the study.

Experimental design

In this crossover study, participants underwent three equal moderate-intensity indoor running sessions, with 2 to 7 interval days between them. In each session, a different frontal wind speed was randomly applied via fan: low flow (LF: - 1.8 m/s), high flow (HF: - 3.0 m/s), and a control condition without airflow (NF: - 0 m/s). To analyze the impact of airflow on body heat dissipation, the upper-body Tsk was measured from thermograms taken before, during, and after exercise.

Procedures

To mitigate circadian variations[21], each participant was evaluated on the same time day. On the first day, all subjects underwent a maximal treadmill test using the Bruce protocol[22] to obtain both the predicted-VO_{2max} and maximum HR (Polar®, F1+). At least two days after the test, the participants returned to the laboratory to establish the running speed of the exercise protocol for the following training HR zones: 40-50%, 50-60%, and 60-70% of reserve HR. Exercise intensity was determined according to Karvonen equation, which considers a percentage of the reserve HR to calculate exercise intensity: $[(HR_{TRAINING} = HR_{MAXIMUM} - HR_{RESTING}) \times \%\ \text{of intensity} + (HR_{RESTING})]$[23]. The maximum HR obtained in the Bruce test was used in the Karvonen equation, along with the resting HR determined after 5 minutes of lying rest (Polar®, F1+).

On the third, fourth and fifth days of collection, the running session lasting 45 minutes was applied on a treadmill (Embreex®, 565 TX-1), divided as follows: 10 minutes of warm-up (5 minutes: 40-50% of $HR_{RESERVE}$ at 6.6 ± 0.6 km/h, and 5 minutes: 50-60% of $HR_{RESERVE}$ at 7.2 ± 0.8 km/h), a main part of 30 minutes (60-70% of $HR_{RESERVE}$ at 8.0 ± 1.0 km/h), 5 minutes of active recovery (walking at <50% of $HR_{RESERVE}$) and 5 minutes of passive recovery (standing on the treadmill). The distance covered during both the warm-up and the main part of the exercise was 571.3±62.6 m and 4000±519.6 m, respectively. HR was recorded every 2 minutes, and RPE was reported every 10 minutes on the Borg 6-20 scale[24]. To produce the wind, a 3-propeller fan (Arno®, Versatile) was positioned on the floor, one meter from the volunteer, and in front of the treadmill. The airflow was positioned from bottom to top towards the anterior upper body. The fan was turned off after completion of the exercise. Wind speed was monitored with a digital anemometer (Instrutherm, AD-250). Fan position is presented in Figure 1.

In each session, 3 ml of water per kilogram of body mass was administered every 15 minutes of exercise as a hydration protocol[25]. Participants were weighed at the beginning and immediately after sessions to assess hydration status[2].

The Thermographic Imaging of Sport and Exercise Medicine consensus statement was followed[26]. The temperature and humidity of

Figure 1. Fan position.

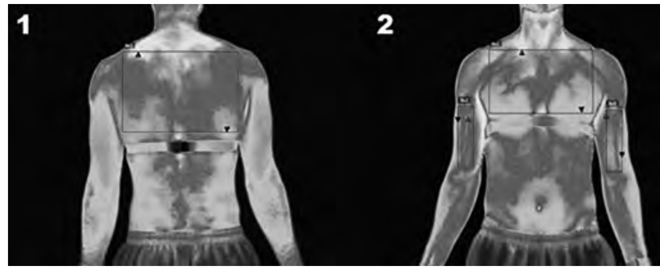
Table 1. Rate of perceived exertion during each experimental condition.

		Exercise protocol			
		Warm-up		Main part	
	Condition	10 min	20 min	30 min	40 min
Rate of perceived exertion (6-20)	Windless	10.4 ± 1.6	12.3 ± 1.7	12.7 ± 2.1	13.3 ± 1.5
	Low flow	10.3 ± 1.4	11.8 ± 1.8	12.5 ± 2.0	12.9 ± 2.3
	High flow	10.8 ± 1.2	12.4 ± 2.1	13.5 ± 2.3	13.7 ± 2.3

the room were stable between conditions [NF (21.22 ± 1.15 °C, 61.33 ± 3.95 %), LF (21.17 ± 1.32 °C, 62.22 ± 4.15 %), HF (20.90 ± 1.55 °C, 60.00 ± 4.27 %)]. Environmental conditions were monitored using a portable weather station (Instrutherm®, THAL-300), which was positioned 1.8m from the floor. An acclimation of 10 minutes was performed[27]. At that time, subjects only wore shoes and shorts running, and the heart monitor; they were asked to remain upright on the treadmill, not to do sudden movements, and not to rub with their hands any part of the body. Thermograms (anterior and posterior upper body) were obtained before exercise; at 10, 20, 30, 40 min during exercise; and after 5 min of active recovery and 5 min after completion of the protocol (passive recovery). For all images, participants positioned himself in a demarcated location on the treadmill (see supplementary material).

To record thermograms, a FLIR® T420 imager was used with 2% accuracy, sensitivity ≤0.05 °C, at 7.5-13 µm infrared spectral band, 60 Hz refresh rate, autofocus, and 320 x 240 pixels. The camera was turned on 15 min before the measures to allow for sensor stabilization. It was positioned on a tripod behind the treadmill, 2 meters away from the volunteer (see supplementary material), perpendicular to the regions of interest (ROIs) (1.5 to 1.6 m away from the floor ranging in accordance with the participants' height). Thermograms were analyzed using FLIR® Tools software, version 6.4, where the Tsk on ROIs of the pectoral, brachial

Figure 2. Delimitation of the upper dorsal (1), pectoralis, and biceps brachii (2) ROI.



biceps, and upper dorsal were measured using anatomical points as reference: a) pectoral - the line of the nipple and the upper border of the sternum; b) biceps - the cubital fossa and the axillary line; c) upper dorsal - acromial edge of scapula and 1 cm above the lower scapula angle. The HR belt was out of all selected ROIs. Emissivity was set at 0.98. Figure 2 shows the demarcation of ROIs.

Statistical analysis

The average Tsk obtained from each ROI was considered for the statistical analysis. For the arms, the arithmetic mean between the right and left side was calculated as the final value for the data analysis. The normal distribution of the data was verified by the Shapiro-Wilk test. Therefore, all data are reported as means and standard deviations. To compare the RPE among the different experimental conditions, one-way ANOVA was used. A repeated-measures ANOVA was performed to analyze Tsk changes over time and to compare the Tsk intra-moment among the different conditions. When significant F values were found, Bonferroni's post hoc test was used to determine the level of significance. Sphericity was assessed by Mauchly test, and once violated, the Greenhouse-Geisser adjustment was used. The partial eta square (ηp^2) was used as a measure of effect size and classified as weak (<0.1), modest (0.1-0.29), moderate (0.3-0.5), or strong (>0.5). Statistical significance was considered at $p<0.05$. All calculations were performed in SPSS, version 25.

Results

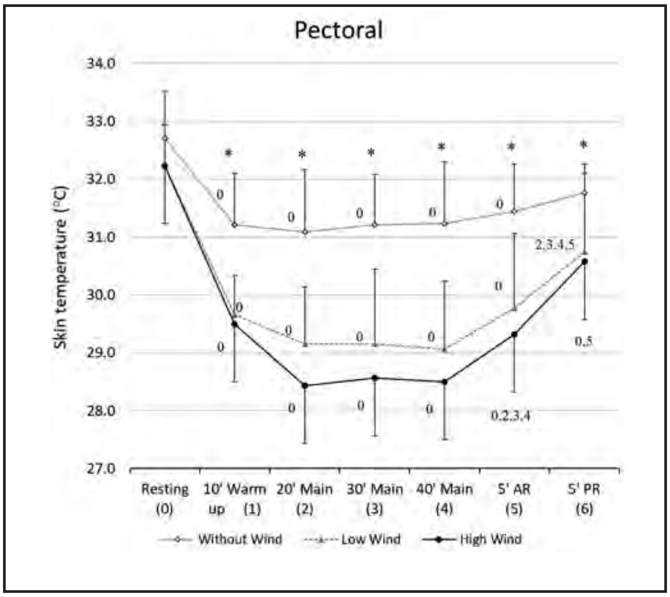
The participants' hydration status was maintained after each exercise session. Body mass changes were minimal after NF (Δ: 0.11%), LF (Δ: 0.05%), and HF (Δ: 0.16%) sessions. Regarding RPE, there was no significant difference between groups when each time point was compared (10 min, p=0.787; 20 min, p=0.728; 30 min, p=0.563; 40 min, p=0.711). Table 1 shows the rating of perceived exertion for the different protocols.

When comparing resting Tsk among the conditions, there was no significant difference: pectoral (p=0.158), upper dorsal (p=0.137), or biceps brachial (p=0.056). Next, the Tsk response of each ROI is presented.

Pectoral

Figure 3 shows the pectoral Tsk response to the experimental protocols.

Figure 3. Tsk behavior (°C) in the pectoral region.



* Significant differences between groups comparing windless condition with both windy conditions. "no.": significant differences in relation to the corresponding moment condition (see code in the X axis).

Significant differences were found in pectoral Tsk when each moment was compared between conditions (p<0.001). In all moments, both wind speeds provided greater reductions in Tsk versus NF condition [during exercise and after active recovery (p≤0.001); after passive recovery (LF *vs* NF, p=0.043; HF *vs* NF p=0.001)].

There were Tsk changes over time in the NF exercise [F=12.389; p<0.001, ηp^2=0.608]. Tsk decreased after 10 min of exercise (p=0.001) and was sustained below baseline throughout the session (p≤0.01) and after 5 min of active recovery (p=0.015). After 5 min of passive recovery, Tsk returned to baseline (p=0.078).

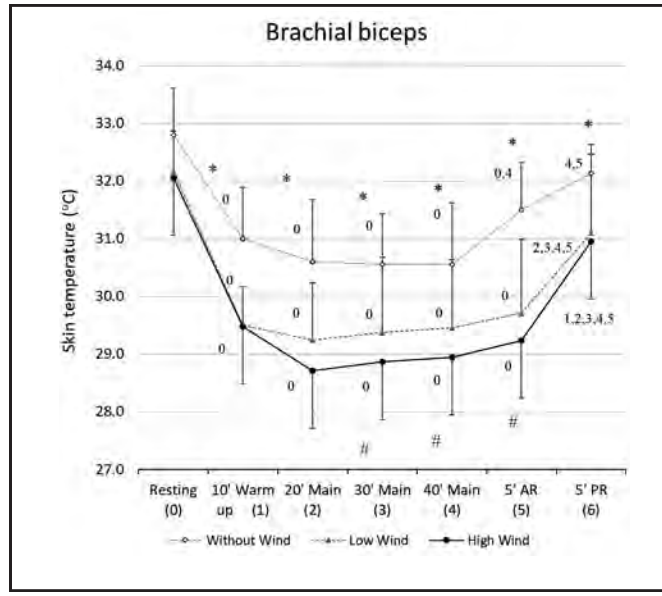
In the LF condition, Tsk changed over time [F=26.708; p<0.001, ηp^2=0.770]. Tsk decreased after 10 min of exercise (p<0.001) and was kept below baseline throughout the session (p≤0.01) and after 5 min of active recovery (p=0.015). However, after 5 min of passive recovery, Tsk returned to baseline (p=0.188). Moreover, Tsk increased after 5 min of passive recovery when compared to 20, 30, 40 min, and after active recovery (p≤0.01).

In the HF session, there were significant Tsk changes over time [F=47.980; p<0.001, ηp^2=0.857]. Tsk decreased after 10 min of exercise (p<0.001) and was kept below baseline throughout the session (p<0.001), after 5 min of active recovery (p=0.001) and after 5 min of passive recovery (p=0.007). However, after 5 min of active recovery, Tsk increased when compared to after 20, 30, and 40 min of exercise (p<0.05). Furthermore, Tsk increased after 5 min of passive recovery compared to 20, 30, 40 min of exercise, and 5 min of active recovery (p<0.001).

Brachial biceps

Figure 4 shows the biceps Tsk response to the experimental protocols.

Figure 4. Tsk behavior (°C) in the biceps region.



* Significant difference between groups in the comparison between the without wind condition (NF) vs little airflow (LF) and high flow (HF). # significant difference between groups when comparing low wind vs high wind conditions. "no.": significant differences in relation to the corresponding moment condition (see code in the X axis).

Significant differences were found in biceps Tsk when each moment was compared between conditions (p≤0.001). In all moments, both wind speeds provided greater reductions in Tsk versus NF condition (p≤0.01). Moreover, the HF versus LF condition provided a greater reduction in Tsk after 30, 40, and 5 min of active recovery (p<0.05).

There were Tsk changes over time in the NF exercise [F=54.555; p<0.001, ηp^2=0.872]. Tsk decreased after 10 min of exercise (p<0.001) and was sustained below baseline throughout the session (p≤0.001). However, after 5 min of passive recovery, Tsk returned to rest (p=0.186). Moreover, Tsk increased after 5 min of active recovery (p=0.001) and after passive recovery (p<0.001) when compared to the time of completion of the main part of the exercise (40 min). Finally, Tsk increased after 5 min of passive recovery versus after active recovery (p=0.001).

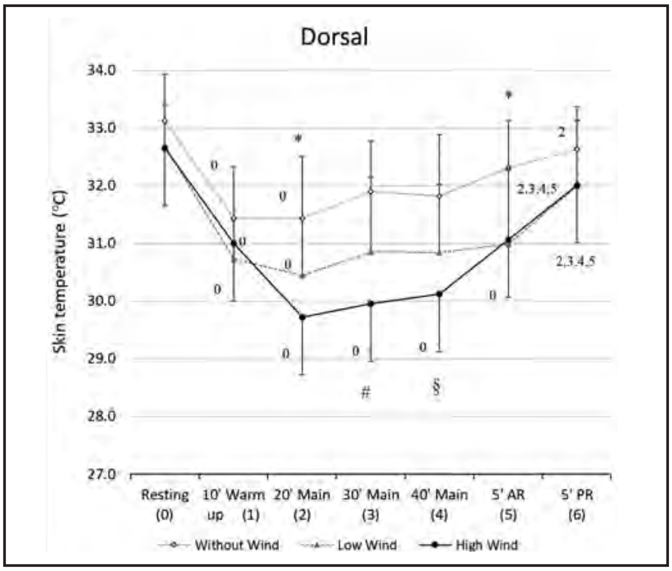
In the LF session, Tsk changed over time [F=27.943; p<0.001, ηp^2=0.777]. Tsk decreased after 10 min (p<0.001) of exercise and was kept below baseline throughout the main part of the session (p≤0.01) and after active recovery (p=0.034). However, after 5 min of passive recovery, Tsk returned to rest (p=1.0). Furthermore, Tsk increased after passive recovery when compared to after 20 (p=0.022), 30, 40 min, and active recovery (p<0.001).

In the HF session, there were significant Tsk changes across time [F=54.484; p <0.001, ηp^2=0.872]. Tsk decreased with 10 min of exercise (p=0.001) and was kept below baseline throughout the session (p<0.001) and after passive recovery (p=0.018). However, after passive recovery, Tsk increased when compared to the 10 (p=0.018), 20 (p=0.027), and other moments throughout the exercise (p<0.001).

Upper dorsal

Figure 5 shows the dorsal Tsk response to the experimental protocols.

Figure 5. Skin temperature behavior (°C) in the dorsal region.



* Significant difference between groups in the comparison between the condition without wind vs little wind and a lot of wind. # Significant difference between groups when comparing the very wind vs no wind and little wind conditions. § Significant difference between groups when comparing windless vs very windy conditions. "no": significant differences in relation to the corresponding moment condition (see code in the X axis).

Significant differences were found in dorsal Tsk when the time points (20, 30, 40 min, and active recovery) were compared between conditions ($p \leq 0.001$). Both wind speeds provided greater reductions in Tsk when compared to the NF condition at 20 min and after active recovery ($p \leq 0.01$). Moreover, the HF condition provided a greater reduction in Tsk at 30 min versus LF ($p=0.043$) and NF ($p<0.001$) conditions and at 40 min *versus* NF condition ($p<0.001$).

There were Tsk changes over time in the NF exercise [F=8.787; $p<0.001$, $\eta p^2=0.523$]. Tsk decreased after 10 ($p=0.003$) and 20 min ($p=0.038$) of exercise compared to baseline. However, Tsk returned to baseline after 30 min of exercise ($p=0.081$) and stabilized until the end of exercise ($p>0.05$). Furthermore, Tsk after passive recovery was higher than 20 min of exercise ($p=0.049$).

In the LF session, Tsk changed over time [F=8.271; $p=0.007$, $\eta p^2=0.508$]. Tsk decreased after 10 ($p=0.004$) and 20 min ($p=0.023$) of exercise versus baseline. However, Tsk returned to baseline after 30 min of exercise ($p=0.325$). Moreover, Tsk after passive recovery was higher than after 20, 30, 40 min, and 5 min of active recovery ($p<0.05$).

Finally, in exercise session HF, Tsk changed over time [F=40.406; $p<0.001$, $\eta p^2=0.835$]. Tsk decreased after 10 min of exercise ($p=0.008$) and was kept below baseline throughout the running session ($p \leq 0.001$) and after active recovery ($p=0.004$). However, after passive recovery, Tsk returned to baseline ($p=0.706$). Additionally, Tsk after passive recovery was higher compared to all moments during and after exercise ($p \leq 0.001$).

Exercise-induced Tsk reduction with and without wind

Table 2 shows the average Tsk reduction in each experimental condition.

Distribution of Tsk under experimental conditions

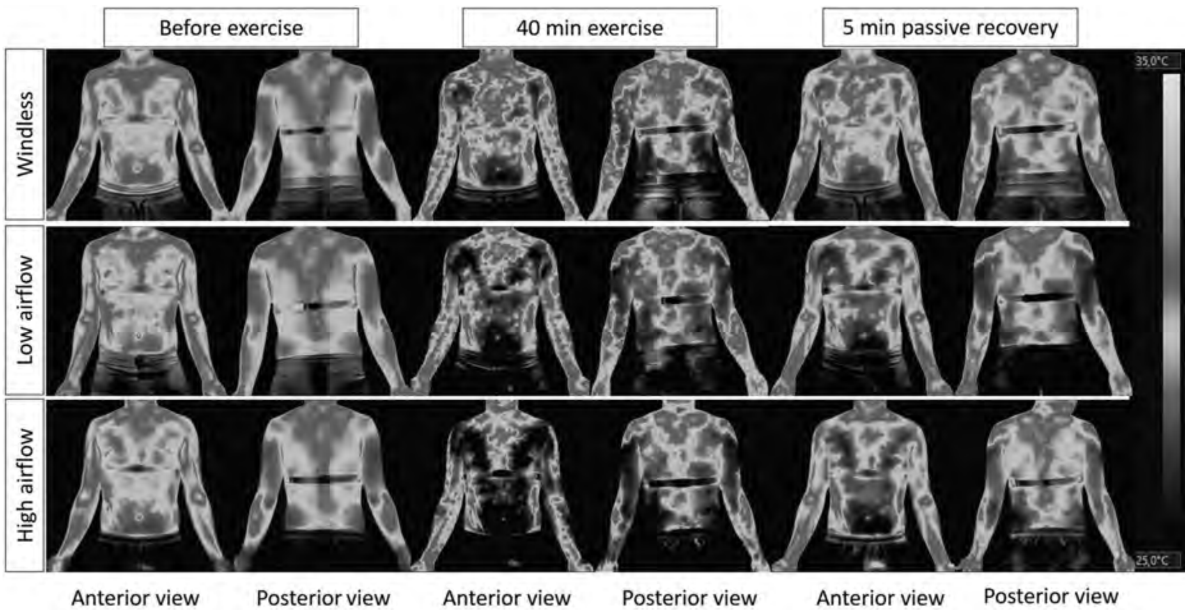
From a qualitative perspective, Figure 6 shows the Tsk distribution on the body surface for one participant before exercise, after 40 min of exercise, and after 5 minutes of passive recovery, in each experimental condition. It is possible to highlight the similarity between the pre-exercise thermograms, as well as the clear Tsk reduction, especially in the anterior region of the trunk and arms after 40 min of exercise mainly in conditions with the presence of wind. In the recovery period of the NF exercise, the thermogram became very similar to the resting thermogram, while thermal reduction remained evident under windy conditions. Characteristic hot spots are observed in the central region of the chest, back, and arms after 40 min and in recovery from exercise; this phenomenon was attenuated according to the intensity of the wind.

Table 2. Average thermal reduction (ΔT °C) at each moment compared to baseline Tsk.

			Exercise protocol					
			Warm-up	Main part			Recovery	
ROI	Condition	Basal Tsk (°C)	10 min ΔT °C	20 min ΔT °C	30 min ΔT °C	40 min ΔT °C	5 min AR ΔT °C	5 min PR ΔT °C
Pectoral	NF	32.7	-1.5	-1.6	-1.5	-1.5	-1.3	-0.9
	LF	32.2	-2.6	-3.1	-3.1	-3.2	-2.5	-1.5
	HF	32.2	-2.7	-3.8	-3.7	-3.7	-2.9	-1.6
Biceps	NF	32.8	-1.8	-2.2	-2.2	-2.2	-1.3	-0.7
	LF	32.2	-2.7	-2.9	-2.8	-2.7	-2.5	-1.1
	HF	32.0	-2.5	-3.3	-3.2	-3.1	-2.8	-1.1
Dorsal	NF	33.1	-1.7	-1.7	-1.2	-1.3	-0.8	-0.5
	LF	32.7	-2.0	-2.3	-1.8	-1.9	-1.7	-0.7
	HF	32.7	-1.7	-2.9	-2.7	-2.5	-1.6	-0.6

ROI: body region of interest; NF: windless; LF: low flow; HF: high flow; Tsk: skin temperature; AR: active recovery; PR: passive recovery; ΔT: thermal reduction compared to baseline.

Figure 6. Evolution of the anterior and posterior thermograms of a participant in the pre-exercise period, after 40 min of exercise, and after 5 min of passive recovery moments under the three experimental conditions.



Discussion

The objective of this study was to analyze the body heat dissipation during indoor running treadmill with different airflow conditions. The pre-exercise conditions among testing days were similar regarding hydration level, environmental condition, body mass, and Tsk. Moreover, the participants' RPE during exercise was statistically similar among the different protocols. Taken together, these results reinforce that the observed thermal changes were due to the different airflow conditions during exercise. Our main findings show an important impact of wind on the body surface cooling during moderate-intensity exercise on a treadmill. This effect has been visualized and quantified with thermography.

Since we analyzed inactive muscle groups during running, the exercise-induced Tsk reduction may be attributed to adrenergic cutaneous vasoconstriction, which contributes to redirecting blood flow from inactive regions to active muscles[28-31]. This adjustment may explain the Tsk reduction especially in the initial moments of windless exercise[12]. Other authors have reported Tsk reductions in inactive ROIs during exercise[15,17]. Moreover, Tsk reduction may be explained by evaporative heat loss. As exercise continues, the excess of metabolic heat needs to be transferred to the body surface, where it is dissipated to the environment through the evaporation of sweat[29,32].

When the use of the ventilator was included in the exercise session, the Tsk reduction was enhanced in all the ROIs. This behavior accelerates the body's surface cooling, facilitating thermoregulation. In the present study, it was evident how the effect of the airflow acts in removing heat from the body through convection, cooling the sweat, or even helping in its evaporation[3]. This Tsk reduction favors heat dissipation to the environment, as it increases the thermal gradient between the core and the skin, facilitating internal heat transfer to the skin[1]. Thus, our results demonstrate the efficiency of the airflow during exercise to increase heat dissipation in running exercise. The impact of the wind in the Tsk distribution on the body surface of a participant can be seen in Figure 6.

In the chest, the different wind speeds comparably potentiated the Tsk reduction at all moments in comparison to the condition NF. Therefore, in pectorals, a low wind speed was sufficient to maximize the release of body heat. However, the higher wind speed contributed to the maintenance of the thermal reduction after the end of the exercise, since Tsk did not return to the rest value after passive recovery only in HF condition (Figure 3).

The greatest Tsk drops in comparison with the NF condition were found in the chest. Reductions of ≈1.5 °C during the NF exercise were maximized by airflow, reaching values greater than 3 °C with LF and ≈ 4 °C with HF (Table 2). A probable explanation is that the chest received a greater flow of wind due to its large contact surface in comparison to the biceps; compared to the dorsal ROI, the chest (but not the dorsal) received direct wind during exercise.

In the biceps, the wind flow potentiated the reduction in Tsk throughout the exercise session in comparison to the NF condition. The greatest thermal reduction during the NF exercise was 2.2 °C, while in the LF and HF conditions, the thermal reduction reached values of 2.9 °C and 3.3 °C, respectively. Moreover, the higher wind speed induced Tsk reductions of greater magnitude compared to the LF condition at 30 and 40 min of exercise, and after 5 min of active recovery (Δ Tsk ≈ 0.4 °C between HF and LF) (Table 2). As with the chest, the increased participation of the convection mechanism promoted by the higher wind speed could have been important to keep the Tsk reduced longer time in the biceps after exercise.

The dorsal region did not receive direct wind. Even so, the exercise conditions with wind were effective in reducing Tsk (Figure 5) but in a less accentuated way than in the other ROIs. While the Tsk reduction in the NF exercise was 1.2 to 1.7 °C in the main part of the exercise, under wind conditions, this reduction varied from 1.8 - 2.3 °C with LF and 1.7 - 2.9 °C with HF (Table 2). These results confirm that even though the dorsal region had not received frontal airflow, the back is an important heat exchange region for the human body since it has more eccrine sweat glands compared to other regions[33,34]. The greater potential for sweat production in the dorsal ROI can increase the convective heat loss when there is wind flow in the environment.

The dorsal ROI showed a non-linear behaviour of Tsk after the end of the warm-up. However, the return of Tsk to baseline was after 30 min of exercise in the NF and LF conditions, while the thermal reduction in the HF condition was preserved throughout the training session, returning to baseline only after 5 min of passive recovery. These findings indicate that even with indirect airflow, the speed of the wind influences the cooling of this region, increasing its potential for heat loss.

In the post-exercise recovery period, there was a gradual increase in Tsk even in the presence of airflow. This response probably occurred due to the lower intensity after the end of the main part of the exercise. It has been shown that the reduction in Tsk during exercise is proportional to the increase in intensity[16]. Therefore, from the moment that the intensity was reduced in the recovery period, the thermal reduction previously achieved was attenuated. Moreover, after active recovery, the fun was off, which increased the Tsk after 5 minutes of passive rest. These results reinforce the relevance of wind flow on skin cooling during exercise.

Currently, many gyms have installed aerobic rooms, where several fans can be arranged to allow airflow to reach the maximum of the skin areas of the athlete. On the other hand, some treadmill models already have a fan attached, helping thermoregulation during exercise. Considering the duration of exercise (45 min) in our study, it was observed that the wind plays a fundamental role in body thermoregulation by increasing the participation of the convection mechanism, making it evident that simple fans are sufficient to enhance the body surface cooling during the exercise period.

A limitation of the study is the absence of other techniques to assess hydration status after exercise. However, since changes in the participants' body weight were lower than 2%, we assume that the hydration protocol ensured a euhydration condition and avoided interference in thermoregulatory responses. The pioneering nature of our study was to quantify, by IRT, the impact of the wind on Tsk, something that has not yet been accomplished. We demonstrate the magnitude of body surface cooling during exercise with and without any airflow, confirming that convection increases the potential for heat exchange[3]. To replicate our study with highly trained runners is interesting since the effect of systematic training on the thermoregulation of experienced runners could provide different results. Future studies should investigate whether airflow-induced body cooling could translate into a better exercise performance, including female participants since gender influences thermoregulatory processes[35].

Conclusion

The airflow during moderate-intensity treadmill running enhance the heat dissipation from the upper body surface to the environment in physically active men. In the chest, reduced wind speed is sufficient to increase the release of heat. In the brachial biceps, the higher wind speed induces thermal reductions of greater magnitude. In the upper dorsal region, the higher wind speed is effective in increasing the release of heat and keeping Tsk reduced during exercise.

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Conflict of interest

The authors do not declare a conflict of interest.

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Original article

Validity of a novel inertial measurement unit to track barbell velocity

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Summary

The objective of this work is to analyze the reliability and validity of the new inertial measurement unit (IMU) PUSH™ Band 2.0 to measure barbell velocity. Six healthy males (24.83±3.71years; 69.88±8.36kg; 175.92±4.5cm) participated in this study and performed several sets on the bench press. Barbell concentric mean (MV) and peak (PV) velocity were recorded with a LT and the IMU. Pearson correlation coefficient shows a very high relationship for MV (r = 0.97; SEE: 0.08 m/s; 95%CI: 0.95-0.98; p< 0.001) and PV (r = 0.97; SEE: 0.13 m/s; 95%CI: 0.96-0.98; p< 0.001). There was a very high agreement for the values of MV and PV (MV: ICC = 0.945, CI = 0.834–0.974, α = 0.981; PV: ICC = 0.926, CI = 0.708–0.969, α = 0.977). Paired sample t-test revealed systematic bias for MV (p< 0.001; mean difference between instruments = 0.06 ± 0.09 m/s) and PV (p< 0.001; mean difference between instruments = 0.15 ± 0.18 m/s). Bland-Altman plots showed almost trivial and moderate relationships for MV (r^2 = 0.1) and PV (r^2 = 0.37). In conclusion, the PUSH™ Band 2.0 was proven to be a valid alternative for measuring barbell velocity in the bench press.

Key words:
Resistance training. Movement velocity. Bench press. Monitoring. Technology. Validation

Validación de un nuevo sensor inercial para medir la velocidad de ejecución

Resumen

El objetivo de este trabajo es analizar la fiabilidad y validez de la nueva unidad de medición inercial (IMU) PUSH™ Band 2.0 para medir la velocidad de la barra. Seis hombres sanos (24.83 ± 3.71 años; 69.88 ± 8.36 kg; 175.92 ± 4.5 cm) participaron en este estudio y realizaron varias series en el press de banca. La velocidad concéntrica de barra (MV) y la velocidad pico (PV) se registraron con un LT y la IMU. El coeficiente de correlación de Pearson muestra una relación muy alta para MV (r = 0.97; SEE: 0.08 m/s; IC 95%: 0.95-0.98; p <0.001) y PV (r = 0.97; SEE: 0.13 m/s; 95% IC: 0,96-0,98; p <0,001). Hubo un acuerdo muy alto para los valores de MV y PV (MV: ICC = 0.945, CI = 0.834–0.974, α = 0.981; PV: ICC = 0.926, CI = 0.708–0.969, α = 0.977). La prueba t de muestras relacionadas reveló un sesgo sistemático para MV (p <0.001; diferencia media entre instrumentos = 0.06 ± 0.09 m/s) y PV (p <0.001; diferencia media entre instrumentos = 0.15 ± 0.18 m/s). Las gráficas de Bland-Altman mostraron relaciones casi triviales y moderadas para VM (r^2 = 0.1) y VP (r^2 = 0.37). En conclusión, se demostró que PUSH™ Band 2.0 es una alternativa válida para medir la velocidad de la barra en el press de banca.

Palabras clave:
Entrenamiento de fuerza. Velocidad de ejecución. Press de banca. Monitorización. Tecnología. Validación.

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Introduction

Accurately controlling and prescribing the training load in resistance training is vital to achieve the desired adaptations[1]. Specifically, adequate control of intensity has been shown to be a key factor in the improvement of muscular strength[2-6] which is a determining factor of sports performance[3,7,8].

Traditionally the intensity of resistance training has been prescribed through percentages of the 1RM (maximum load with which only one repetition can be performed) or through the XRM (maximum number of repetitions that can be performed with a given load)[1,9-11]. However, in recent years it has been found that movement velocity is the most accurate and safe variable to control and prescribe intensity in resistance training[12-14] allowing to estimate the 1RM through the load-velocity relationship without performing an RM or XRM test.

To measure the movement velocity there are different instruments such as linear transducers (LT), accelerometers, advanced video analysis systems or mobile applications[15-19]. Linear transducers have been considered as "gold standards", but these devices present two important drawbacks: a) they are relatively expensive for most users; and b) it is necessary to connect the device to the bar with a cable which makes them impractical for daily use. For these reasons, in recent years the reliability and validity of cheaper alternatives such as different models of accelerometers and mobile applications have been proven, several of them demonstrating being valid for measuring barbell velocity[15-17].

Actually, new alternatives are being presented to measure barbell velocity and different brands try to improve the performance of their products. We hypothesize that the new models of inertial measurement units (IMUs) PUSH™ Band 2.0 should offer better results than previous models, and being a better alternative to LT. For this reason the objective of this work is to analyze the reliability and validity of the new IMU PUSH™ Band 2.0 for measuring barbell velocity in the bench press exercise. We hypothesize that this device will have greater results in terms of validity than previous IMUs.

Material and method

Participants

Six healthy males (24.83±3.71 years; 69.88±8.36 kg; 175.92±4.5 cm; RM 80.83 ± 21.13 kg; VRM 0.17 ± 0.04 m/s) selected incidentally took part in this study, all of them had at least 1 year of experience in resistance training and in particular in the bench press exercise. None of the participants had physical limitations, health problems or injuries at the time of the test. None of the participants were taking drugs, medications or other substances that could alter their physical performance. Written informed consent was obtained from each participant; the study protocol was approved by the ethics committee at the institutional review board and complied with the Declaration of Helsinki for Human Experimentation.

Procedures

Participants performed several sets on the bench press exercise starting with a load of 20 kg and progressively increasing the weight by 10 kg until a velocity ≈0,3 m/s was reached, then one last set was performed with an increase of weight of only 5 kg (if participants did not feel capable of performing this last series they were allowed to finish the protocol in the previous series) , therefore, they do not performed the same number of reps. Barbell mean velocity was being recorded with the Smartcoach Power Encoder (Smartcoach Europe, Stockholm, Sweden) LT and the PUSH™ Band 2.0 IMU (PUSH Inc., Toronto, Canada). Each subject performed 2 sets of 3 repetitions with 20, 30 and 40 kg loads, and then performed 2 sets of 2 repetitions with the 50 kg load and 2 sets of 1 repetition with the remaining loads. A total of 140 repetitions were performed and 13 repetitions were discarded because the LT could not measure them correctly. Finally a total of 127 repetitions were analyzed. Concentric mean (MV) and peak velocities (PV) of the resultant 127 repetitions measured with both instruments were compared for reliability and validity purposes. Before the data acquisition anthropometric measurements were taken from all subjects using a digital stadiometer with scale (SECA 220, SECA, Germany).

Incremental bench press test

The warm-up consisted of 5 minutes of joint mobility and 3 sets of 10, 8 and 5 repetitions (2 minutes of rest between sets) with loads of 20, 30, and 40 kg respectively. The initial load of the test was established in 20 kg and increments of 10 kg were made until reaching a MV ≈0.3m/s, then the load was increased 5 kg for one last set or the test was stopped if the subjects did not feel capable of continuing the test. Subjects performed 2 sets of 3 repetitions with loads form 20 to 40 kg and 2 sets of 2 repetitions with the 50 kg load, for the remaining loads (>50 kg) each subject performed 2 sets of 1 repetition. Rest between set was 3 minutes except for the last increment of 5 kg for which the rest was 5 minutes. The test was carried out in a Smith machine. The subjects were placed in the supine position on a flat bench, with the feet fully supported on the floor and with the hands placed on the bar with a self-selected grip-width. The placement on the bench was adjusted so that the vertical projection of the bar corresponded with the intermammary line of each subject. Subjects were required to perform a pause of ≈1 to 1,5 s between the eccentric and concentric phases when the bar contacted their chest with the purpose of minimizing the effect of the stretch-shortening cycle (SSC) and the contribution of elastic energy to the movement to increase the reliability of the measures[20]. The subjects were instructed to perform the concentric phase at the maximum possible velocity in each repetition.

Instruments

Linear transducer: The Smartcoach Power Encoder LT (Smartcoach Europe, Stockholm, Sweden) was used as the "gold standard" for measuring barbell mean velocity. The Smartcoach LT cable was attached to the barbell following the criteria described by the manufacturer (the cable needs to be aligned with the vertical axis). Then, the LT was connected to the Smartcoach software 5.3.3.6 installed on a personal computer running the Windows 10 operating system. Mean velocity values in $m \cdot s^{-1}$ were recorded for each repetition in the aforementioned software. The LT had a sampling frequency of 1000 Hz.

Inertial Sensor: The the PUSH™ Band 2.0 IMU (PUSH Inc., Toronto, Canada) was attached to the barbell by means of the manufacturer Velcro cover following manufacturer criteria. IS was linked to an IOS PUSH App v. 4.1.2 via Bluetooth connection. Mean velocity values in m · s-1 were recorded for each repetition in the aforementioned App. The PUSH™ Band 2.0 consists of a 3-D accelerometer and a 3-D gyroscope that provides 6 degrees of freedom with a sampling rate of 1000 Hz.

Statistical analysis

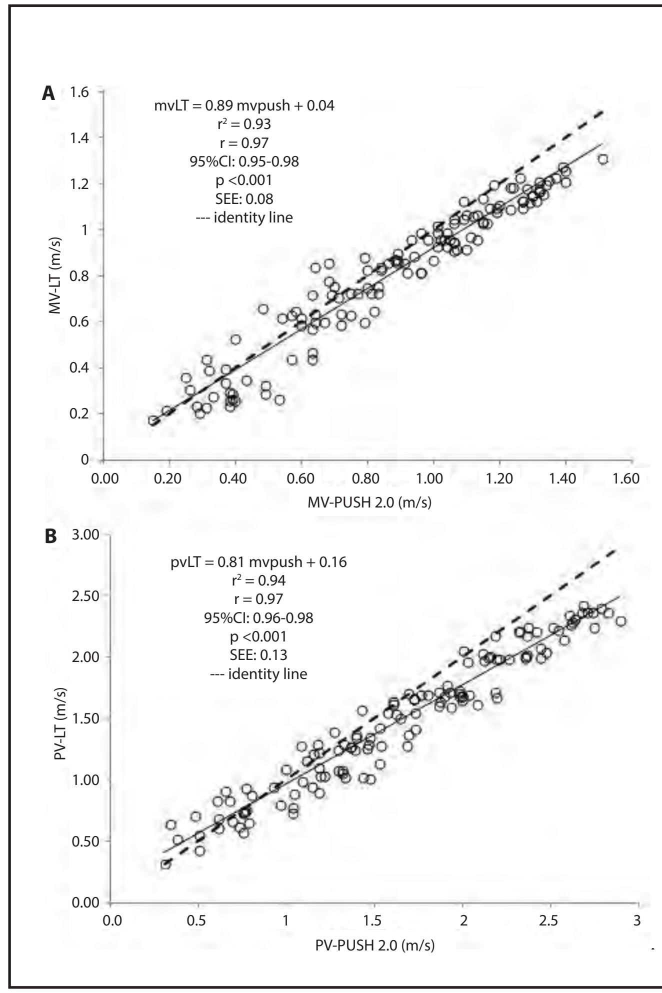
Concurrent validity of the IMU was tested using Pearson's product-moment correlation coefficient (r) with 95% confident intervals (CI) via bootstrapping (n=1000). To analyze the level of agreement (reliability) between the IMU and the LT, the intraclass correlation coefficient (ICC 2.1) with 95% CI and Cronbach's alpha were used. In addition, Paired sample t-test and Bland-Altman plots were used to identify potential systematic bias by reporting mean bias, standard deviations and the analysis of the regression line of the Bland-Altman plots. The criteria for interpreting the magnitude of the *r* coefficients were: *trivial* (0.00–0.09), *small* (0.10–0.29), *moderate* (0.30–0.49), *large* (0.50–0.69), *very large* (0.70–0.89), *nearly perfect* (0.90–0.99) and *perfect* (1.00)[21]. Level of significance was set at 0.05 and all the analysis were performed using IBM® SPSS® Statistics 23.0 software (SPSS, Chicago, IL).

Results

Concurrent validity

Pearson product-moment correlation coefficient showed a significant, very high relationship between the values obtained for MV (r = 0.97; SEE: 0.08 m/s; 95% CI: 0.95-0.98; p < 0.001) and PV (r = 0.97; SEE: 0.13 m/s; 95% CI: 0.96-0.98; p < 0.001) measured with the IMU and the LT (Figure 1).

Figure 1. Concurrent validity between both instruments for a) mean velocity and b) peak velocity.



LT: linear transducer; MV: mean velocity; PV: peak velocity.

Reliability of the measurements with the IS compared to the LT

There was a very high agreement between the values of MV and PV measured with the IMU and those measured with the LT as revealed by the ICC, Cronbach's alpha and Bland–Altman plots (MV: ICC = 0.945, CI = 0.834–0.974, α = 0.981; PV: ICC = 0.926, CI = 0.708–0.969, α = 0.977).

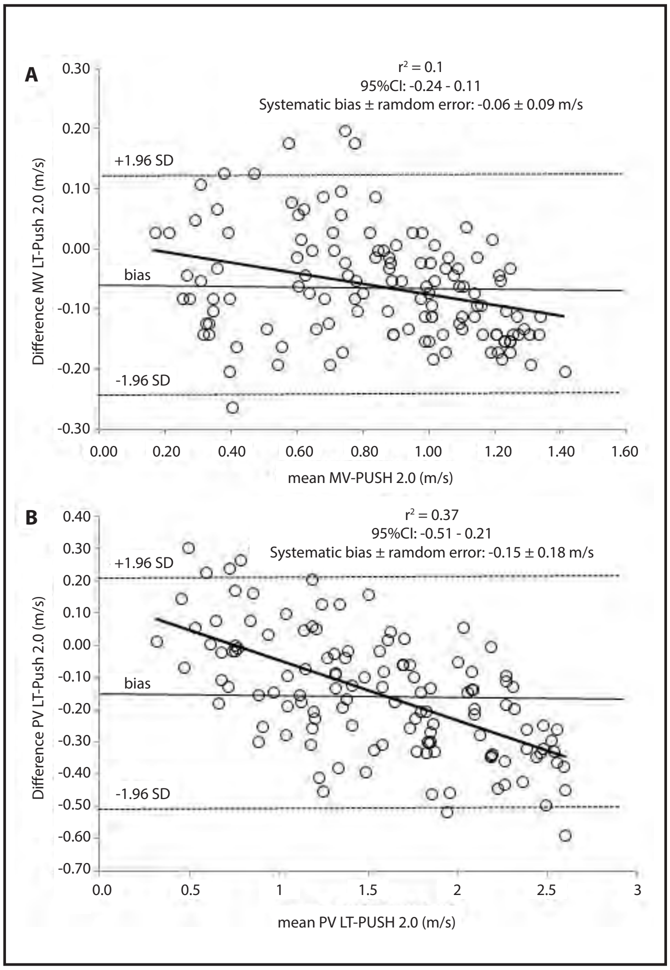
Paired sample t-test revealed systematic bias for MV (p <0.001; mean difference between instruments = 0.06 ± 0.09 m/s) and PV (p <0.001; mean difference between instruments = 0.15 ± 0.18 m/s). When analyzing the Bland-Altman plots a small, almost trivial relationship was observed for MV (r^2 = 0.1), while PV has shown a moderate relationship (r^2 = 0.37) (Figure 2).

Discussion

The PUSH™ Band 2.0 IMU was found to be reliable and valid for measuring MV and PV in comparison with a LT. Pearson product-moment correlation coefficient showed a very high relationship between values obtained with both instrument for MV (r = 0.97) and PV (r = 0.97) with very narrow CI via bootstrapping analysis (MV: 0.95-0.98; PV: 0.96-0.98). These results highlight the good association between the instrument for the measurement of MV and PV. In addition, slopes of the regression lines (Figure 1) for MV (s = 0.89) and PV(s = 0.81) were very close to identity line (y = x) indicating that values obtained with both devices were very similar. However, paired sample t-test revealed systematic bias between the two instruments by which values of the IMU tended to be higher than those of the LT for the MV and PV (see results for more detail). Finally, the ICC analysis and the Bland-Altman plots revealed a very high level of agreement between the IMU and the LT for MV and a very acceptable to high level of agreement for PV (see results for more detail).

Our results indicate that the PUSH™ Band 2.0 is a valid option to measure barbell velocity and are in line with previous studies which have shown that different inertial sensors can be used as cheaper and more practical alternatives to LT[15,16]. Its worth to note that the PUSH™ Band 2.0 tend to present slightly higher values for MV and PV compared to the LT in accordance with results obtained in the validation of the

Figure 2. Bland-Altman plots for the measurements of a) mean velocity and b) peak velocity. Horizontal thin lines represent the observed bias (95% CI), while the thick line is the regression line of the data points.



MV: mean velocity; PV: peak velocity.

Beast sensor IMU[15]. Interestingly, the previous version of the PUSH™ Band display values slightly lower compared with a LT for PV and slightly higher for MV[16]. These differences between studies could be in part due to the fact that different LT were used, the different sample frequency of both versions of the PUSH™ Band (version 1 use a 200 Hz sample frequency and version 2.0 a 1000 Hz sample frequency), the different place of attachment of the devices (version 1 has to be attached bellow the elbow of the subject and not directly to the barbell like version 2.0), or all the above. Another important point is that the back squat exercise was used for the validation of the first PUSH™ Band version while for the present study the bench press exercise was performed.

Despite the methodological differences between studies, it seems clear that PUSH™ Band 2.0 supposes and improvement in the accuracy of wearable devices for measuring barbell velocity compared to its previous version. In the study of Balsalobre-Fernández *et al.*[16] the level of association between PUSH™ Band and LT was lower than in the present validation of PUSH™ Band 2.0 for MV(r = 0.86, SEE: 0.08 m/s *vs* r = 0.97, SEE: 0.08 m/s) and PV (r = 0.91 , SEE: 0.1 m/s *vs* r = 0.97, SEE: 0.13 m/s), our results also show better agreement between PUSH™ Band 2.0 and LT (MV ICC: 0.945; PV ICC: 0.926) than the values presented in the study of Balsalobre-Fernández *et al.*[2] (MV ICC: 0.907; PV ICC: 0.944). Relative to the validation of the Beast sensor[15], both devices have showed a similar degree of validity for the bench press exercise when placed directly to the barbell (r ≈ 0.97) for MV, however Beast sensor showed lower SEE compared to PUSH™ Band 2.0 (0.05 m/s *vs* 0.08 m/s) and better ICC (0.981 *vs* 0.945) which could be explained by: 1) differences in the experience and training background of the subjects tested (competitive powerlifters vs healthy active males); and 2) the fact that Balsalobre-Fernández *et al.*[15] tested the IMU in a free weight movement while in our study we used a smith machine and this may have affect the values obtained with the LT which is designed to measure only in the vertical axis.

It´s worth to note that recently two studies[22,23] have examined the accuracy and validity of the first PUSH™ Band version and the Beast sensor. One study showed high concurrent validity for first PUSH™ Band but not for the Beast sensor[23], and the other found substantial errors for the validity of the first PUSH™ Band to measure barbell velocity[22].

One recent study[24] has analyzed the validity of PUSH™ Band 2.0 for MV and PV in the free weight bench press exercise. Contrary to our results, Lake *et al.*[24] show a better prediction precision of PV than MV, and found proportional bias for the latter. Consistent with our results, this study also found that PUSH™ Band 2.0 tends to overestimate the bar velocity values highlighting the need to be cautious when comparing data obtained with this device against pre-established load-velocity profiles measured with different instruments. The differences may be due to the fact that Lake *et al.*[24] used an optoelectronic 3D motion analysis system as a criterion method, while in our work a LT has been used, and the fact of implementing different statistical methods for data analysis. Furthermore, Lake *et al.*[24] analyzed the free weight bench press while in our study it was analyzed on a Smith machine. Finally, Lake *et al.*[24] analyze the standard bench press while in our study the subjects were instructed to pause between the eccentric and concentric phases to minimize the effect of SSC, which has been shown to increase the reliability of measurements for MV[20]. The contradictions exposed indicate the need for further research regarding the validity of this device.

Conclusions

In conclusion, the PUSH™ Band 2.0 was proven to be valid and accurate for measuring barbell velocity, especially for MV. However, systematic bias was observed so values obtained with the IMU should not be used as interchangeable with those of a LT. The PUSH™ Band 2.0 is an affordable and practical system that has been demonstrated to be reliable and valid in comparison with a LT for tracking movement velocity in the bench press exercise. Thus, the PUSH™ Band 2.0 can be used to monitor and control movement velocity accurately. These results have great practical application for practitioners or strength and conditioning coaches who want to implement velocity-based resistance training and are seeking for accurate alternatives to LT with lower cost.

Study limitations

The major drawbacks of the present study are, in first place, the use of mean velocity for the whole range of velocities ranging from loads <40% RM to >90% RM, since previous studies has shown that mean propulsive velocity (MPV) is more accurate and sensitive for light loads[25]. For that reason it could be recommended to use the PUSH™ Band 2.0 for measuring loads above 70% RM as has been recommended for the use of other instruments that only provide values of MV[17]. Secondly, another drawback is that only the bench press exercise was tested and the results obtained should be interpreted with caution for monitoring other exercises.

Future lines of research

Due to the limitation that only bench press exercise has been analyzed in the present study, and that there are some controversies between the three studies (including the present one) that have investigated the validity of the PUSH™ Band 2.0; our analyses should be replicated using different exercises performed with and without pause between eccentric and concentric phases, and performed using different materials like smith machines or free weights.

Conflict of interest

The authors do not declare a conflict of interest.

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Athletic, muscular and hormonal evaluation in CrossFit® athletes using the "Elevation Training Mask"

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Summary

Introduction: The possibility of performing intense workouts without falling into states of chronic fatigue stimulates the use of devices that improve muscular and hormonal functionality in athletes. The Elevation Training Mask (Training Mask LLC) (ETM) allows the application of hypoxia during exercise. The ETM is integrated into training routines increasing the physical stimulus to improve performance.
Objective: We evaluated the impact of ETM on Workouts of the Day (WODs), muscular and hormonal behavior in Crossfit® athletes.
Material and method: Prospective cohort study. During 12 weeks 20 Crossfit® athletes trained 60 minutes 3 days a week were randomly divided into 2 groups, control group (CG) (n=10) and ETM group (EG) (n=10) applying an additional progressive simulated altitude between 914 and 2743 meters. WODs (press, squat, deadlift, total CF and grace), macular markers: lactate dehydrogenase (LDH); creatine kinase (CK); myoglobin (Mb) and hormones: testosterone (T); cortisol (C), were evaluated at 2 time points of the study: day 1 (T1) and day 84 (T2).
Results: All WODs and parameters LDH, CK, Mb, T and C showed no significant difference (p>0.05) in the time group interaction. In EG, a substantially lower percentage change (Δ) between T1 and T2 was observed in Mb (-16.01±25.82%), CK (6.16±26.05%) and C (-0.18±4.01%) than in CG (Mb: -094±4.39%; CK: 17.98±27.19%; C: 4.56±3.44%). The Δ T1-T2 in the WODs were similar.
Conclusion: After 12 weeks of training under simulated hypoxia conditions with ETM there are no improvements in athletic performance assessed by WODs. However, the greater tendency to decrease Mb, CK and C, after using ETM, could stimulate recovery and indicate a lower muscle catabolism of the Crossfit® athlete in the long term.

Key words:
Elevation Training Mask. Hypoxia. Sport Performance. Muscle. Hormones. Crossfit®.

Evaluación deportiva, muscular y hormonal en deportistas de CrossFit® que emplean la "Elevation Training Mask"

Resumen

Introducción: La posibilidad de realizar entrenamientos intensos sin caer en estados de fatiga crónica, estimula el uso de dispositivos que mejoren la funcionalidad muscular y hormonal en deportistas. La *Elevation Training Mask* (Training Mask LLC) (ETM) permite la aplicación de hipoxia durante el ejercicio. La ETM se integra en las rutinas de entrenamiento incrementando el estímulo físico para mejorar el rendimiento.
Objetivo: Evaluamos el impacto de la ETM sobre los entrenamientos del día o Workouts of the Day (WODs), el comportamiento muscular y hormonal en deportistas de Crossfit®.
Material y método: Estudio de cohorte prospectivo. Durante 12 semanas 20 practicantes de Crossfit® entrenaban 60 minutos 3 días a la semana fueron divididos aleatoriamente en 2 grupos, grupo control (GC) (n=10) y grupo ETM (GE) (n=10) aplicando una altitud simulada adicional progresiva entre 914 y 2743 metros. Los WODs (press, squat, deadlift, CF total y grace), marcadores maculares: lactato deshidrogenasa (LDH); creatina quinasa (CK); mioglobina (Mb) y hormonas: testosterona (T); cortisol (C), se evaluaron en 2 momentos del estudio: día 1 (T1) y día 84 (T2).
Resultados: Todos los WODs y los parámetros LDH, CK, Mb, TT y C no mostraron ninguna diferencia significativa (p>0,05) en la interacción grupo tiempo. En el GE se observó un porcentaje de cambio (Δ) entre T1 y T2 sustancialmente menor en Mb (-16,01±25,82%), CK (6,16±26,05%) y C (-0,18±4,01%) que en GC (Mb:-0,94±4,395; CK: 17,98±27,19%; C: 4,56±3,44%). Los Δ T1-T2 en los WODs fueron similares.
Conclusión: Tras 12 semanas de entrenamiento en condiciones simuladas de hipoxia con ETM no existen mejoras del rendimiento deportivo evaluadas mediante los WODs. Sin embargo, la mayor tendencia a disminuir de Mb, CK y C, tras usar la ETM, podrían estimular la recuperación e indicar un menor catabolismo muscular del atleta de Crossfit® a largo plazo.

Palabras clave:
Elevation Training Mask. Hipoxia. Rendimiento deportivo. Músculo. Hormonas. Crossfit®.

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Introduction

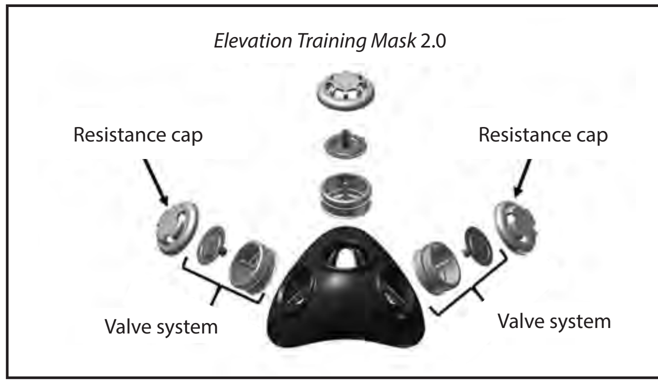
The demands of competition-level sport push us to seek out systems which improve results. Hypoxic stimulation in athletes has been used as a method to improve athletic performance since the 1960s[1]. Hypoxic training (HT) induces modifications in several body systems, including the central nervous, cardiorespiratory, hormonal and muscular systems, which do not occur in normoxic conditions or, if they do, do so to a lesser degree[2].

In recent years, the simulation of altitude training in sports medicine has worked to generate beneficial adaptations for both the health and the athletic performance of individuals[3]. These methods remove the drawbacks of travelling and the cost involved, and do not reduce the intensity of training as a result of staying at altitude for prolonged periods[1]. Consequently, the use of various altitude simulation methods to induce a normobaric hypoxic stimulus or minimise the amount of air that a subject is allowed to consume has become popular[4,5]. These methods are presented as ergogenic strategies for athletes to increase training-induced adaptations[6]. Devices have recently arrived on the market for professional and recreational athletes, and the general public to induce/simulate hypoxic conditions which are easy to acquire and economical[7] compared to the hypobaric chambers or portable devices for exposure to hypoxia available, such as the Altitrainer® or GO_2 Altitude® hypoxicator.

One of these is the *"Elevation Training Mask"* (ETM), a new instrument for use during workouts which the manufacturer describes as an exercise device with breathing resistance and adjustable capacity. The ETM aims to simulate training at altitude (914 to 5486 metres) by restricting the oxygen (O_2) supply, creating this condition when breathing through a system of flow valves designed to limit the amount of air that enters the mask[8]. The altitude simulation of the ETM does not generate a hypobaric situation (reduced partial pressure of O_2) but leads to mild arterial hypoxemia as a consequence of the reduced respiratory rate caused by the respiratory restriction produced by the resistance caps and the flow-valve system (Figure 1). Hypoxemia could also be intensified by inhaling carbon dioxide (CO_2) and the subsequent shift of the O_2 dissociation curve[9].

HT is known to produce pronounced changes in lactate concentrations in athletes when compared with normoxic training[10]. However, no significant differences were observed in lactate concentration between the control groups and the group that used the ETM during continuous exercise[11]. Fernandez-Lázaro *et al.*[1] described that a hypoxia stimulation programme in combination with training was able to stimulate improvements in the haematological profile which were related to better results in athletic performance assessment tests. During training with ETM, the haematological profile of the athletes does not change[12,13]. This would justify and corroborate that the ETM does not imitate or simulate altitude situations. Additionally, the restriction of the airflow caused by the valves on the ETM increases the work of the respiratory muscles, which could stimulate improvements in endurance performance through respiratory muscle training (RMT)[14] although the use of the ETM during a high-intensity training programme lasting several weeks has been shown not to increase lung function[7,12,13]. Therefore, although the physiological changes associated with the ETM are not induced[7,11-13], improvements have been reported on specific performance markers when compared with identical training without the EMT[7,12,13].

Figure 1. *Elevation Training Mask* 2.0 resistance caps and valve system



CrossFit® (CF) is a popular new exercise method involving functional movements performed at high intensity. Training consists of functional movements which make up *Workouts of the day* (WODs). In these sessions, all the WODs are performed quickly and repetitively at maximum intensity with little or no recovery time in between[15,16].

We do not know at present if the ETM could compromise the ability to train at the high intensities that CF demands. The lack of evidence regarding the mechanisms of the ETM on athletic performance calls for considerable research to develop protocols which optimise the balance between efficacy and safety concerning the biological effects of using the mask, fundamentally hormonal safety and muscle response, which have not yet been studied. For these reasons, we set out to evaluate the influence of using the ETM in combination with high-intensity training regimes in subjects who did CF in terms of WOD performance, hormonal response, testosterone (T) and cortisol (C), and the enzymes of muscle activity (damage and inflammation) produced by a training programme under these conditions.

Materials and method

A prospective cohort study was conducted. Twenty male volunteer CF practitioners took part in a non-placebo controlled, randomised study which evaluated the effect of the ETM 2.0 (Training Mask LLC, Cadillac, Michigan) on athletic performance, muscle response and hormonal behaviour during a 12-week training period. The protocol followed the recommendations of the Declaration of Helsinki, and the study was reviewed and approved by the Ethics Committee for research involving medicinal products in the East Valladolid area (PI 19-1361).

Physical examination

All the subjects signed informed consent forms. The participants were studied by means of a cardiopulmonary and electrocardiographic examination, and completed a medical questionnaire before joining the study. None of the CF athletes smoked, drank alcohol or took drugs or illegal substances capable of altering their muscular or hormonal response, or their sports performance. No injuries were suffered before or during the test, as these were ruled out by medical records and the clinical examination. All the subjects followed the same diet during the study, supervised by a nutritionist.

Subjects

The participants were allocated to two groups using a random sampling method. The study group (SG), which used the ETM, included a total of 10 male CF athletes (n=10) (38.4±3.8 years old; body mass index 24.6±2.7 kg/m^2; 51.5±6.5 mL-kg^{-1} -min^{-1}) and the control group (CG), which did not use the ETM, consisted of 10 male CF athletes (n=10) (36.7±5.3 years old; body mass index 22.9±3.1 kg/m^2; 53.1±7.3 mL-kg^{-1} -min^{-1}). All the study subjects (n=20) had at least one year's experience doing CF. No participant had been recently exposed to altitude, hypoxia or acclimatisation, bar the fact that they lived in Salamanca (802 metres) and Soria (1063 metres) in Spain.

Training

The workouts during the 12 weeks of the study consisted of 3 weekly sessions on alternate days. Each session lasted one hour and was divided into a specific warm-up, a strength and/or skill component, programmed strength or metabolic conditioning training lasting from 10 to 30 minutes, and a cooldown and/or mobility work. Each workout was supervised by a certified Level 1 CF Trainer. All the subjects performed the same physical activity routines to ensure that they did the same training during the study.

Dietary assessment

To calculate and record the nutrient composition and energy intake of the food and drink that the athletes consumed, the methodology used in some of our previous studies was followed[17,18].

Uso de la *Elevation Training Mask*

The ETM was employed in the 36 training sessions over the 12-week study period. The additional altitude simulation was 914 metres in the first week and 1829 metres in the second in order to accustom the participants to the airflow restriction and acclimatise them to altitude simulation. In the remaining weeks of the study, the simulated altitude was 2743 metres above the altitude at which training was taking place

Blood collection and testing

Antecubital venous blood samples were taken from the CF athletes on the first day of study (T1) without prior use of the ETM and after 12 weeks of training with the ETM (T2). For the collection, extraction and transport of the blood samples of the athletes, the methodology of the studies conducted by Fernández-Lázaro *et al.*[1,17] was used.

The athletes' lactate dehydrogenase (LDH), creatine kinase (CK) and myoglobin (Mb) blood serum concentrations were measured by enzymatic chemiluminescence[17]. Total T and C were determined by enzyme-linked immunosorbent assays[19].

Percentage changes in plasma volume (% ΔPV) were calculated using the Van Beaumont formula. The values of the analytical markers were adjusted for the changes in plasma volume, using the following formula: Corrected value = Uncorrected value x ((100 + % ΔPV) / 100)[17].

Athletic performance assessment

The performance of the subjects was evaluated in different WODs which respected CF methods considered internationally standard[15]. The exercises performed were: back squat, shoulder press and deadlift, CF Total and Grace.

Determination of perceived exertion

Before their blood was drawn, the participants were asked to score their perceived muscle discomfort at each point in time (T1 and T2), using the Borg CR-10 scale validated for rating perceived exertion (RPE)[20,21].

Statistical analysis

Processing was randomly assigned using the Random Sequence Generator. Statistical analysis was performed using the IBM Statistical Package (SPSS Version 22) and Graphpad Prism (Graphpad Software Version 6.01, San Diego, CA). The data are expressed as the mean ± standard deviation (SD). The differences in the parameters were evaluated using Scheffé's method to identify significant differences between T1 and T2 independently. Differences were considered significant when $p<0.05$. A repeated measures ANOVA was used to examine the existence of an interaction effect of training with the ETM (time by group) on all the parameters assessed. The percentage changes of the variables studied in each group between the baseline tests (T1) and post-ETM tests (T2) were calculated as Δ (%): [(T2 – T1) / T1] × 100). The differences between groups in terms of the changes Δ (%) were evaluated by means of a parametric or non-parametric test for independent samples after the normality of the data had been confirmed with the Shapiro-Wilk test.

Results

Dietary intake

There were no significant differences (p> 0.05) between the study groups (CG and SG) for total caloric, vitamin and mineral intake (Table 1).

Muscle markers

Table 2 shows the muscle behaviour markers (LDH, CK and Mb) at two points in the study, T1 and T2. No statistically significant differences (p>0.05%) existed in the two groups (CG and SG) for the muscle parameters analysed, except LDH in SG, in which an increase with a statistically significant difference (p<0.05) between the two points in the study was observed (T1: 167.55±21.30 U/L *vs* T2: 189.80±27.69 U/L) (Figure 2). None of the muscle markers analysed showed a significant difference in values (p>0.05) in the group by time interaction.

Table 3 shows the percentage changes of the muscle parameters at the end of the study. There were no significant differences (p>0.05) between LDH, CK and Mb. However, in the SG a greater increase in LDH (12.75±15.01%) and a significant downward trend in Mb (-16.01±25.82%) were both observed, as was a smaller increase in CK (6.16±26.05%) in the SG compared with the CG (CK: 17.98±27.19%).

Hormonal behaviour

No significant differences (p>0.05) were found in T and C hormones between the two groups (CG and SG) over the 12 weeks of the study.

Table 1. Energy and micronutrient intake. Daily mean in the study group (SG) and control group (CG) of CrossFit® athletes during the 12 weeks of study.

Group	Group Study (SG)	Group Control (CG)	*P*	Recommended daily*
Energy (kcal/kg)	38.3±5.8	39.7±5.2	0.273	
Ca (mg)	1036±214	1082±193	0.345	1000
Mg (mg)	542±99	551±95	0.863	320
P (mg)	2123±66	2076±84	0.583	700
Fe (mg)	21.1±4.6	23.5±5.7	0.801	10
Zn (mg)	13.7±0.8	14.7±0.8	0.699	8
Vitamin A (µg)	1859±1180	2002±775	0.659	689
Vitamin E (mg)	17.0±2.5	17.3±1.6	0.466	15
Thiamine (mg)	2.62±0.20	2.80±0.62	0.526	1.1
Riboflavin (mg)	2.76±0.23	2.75±0.28	0.693	1.1
Niacin (mg)	40.0±7.1	38.2±3.9	0.815	14
Vitamin B6 (mg)	4.11±0.73	4.36±0.94	0.831	1.3
Folic acid (mg)	634±171	636±169	0.885	400
Vitamin B12 (µg)	9.12±3.91	9.35±3.11	0.877	2.4
Vitamin C (µg)	347±138	356±119	0.733	700

Table 2. Biochemical markers of muscle behaviour and hormonal response in the CrossFit® athletes in the control group (CG) and the study group (SG) with the *Elevation Training Mask* at two points in the study: T1, at the beginning of the study, and T2, after 12 weeks.

	T1	T2	*P* (T x G)
LDH (U/L) [135 – 250 U/L]			
CG	200.00±46.49	195.71±33.70	NS
SG	167.55±21.30	189.80±27.69*	
Creatine kinase (U/L) [38 – 190 U/L]			
CG	437.56±467.80	500.22±510.25	NS
SG	301.20±237.51	315.70±232.48	
Myoglobin (ng/ml) [28 – 72 ng/ml]			
CG	32.67±17.38	33.33±21.17	NS
SG	38.00±26.25	26.11±5.55	
Total testosterone (ng/ml) [2.49 – 8.36 ng/ml]			
CG	6.19±0.87	6.52±0.91	NS
SG	6.19±1.03	6.39±1.06	
Cortisol (ug/dl) [6.0 – 18.4 ug/dl]			
CG	17.79±3.69	18.32±3.88	NS
SG	17.80±2.55	17.53±3.70	

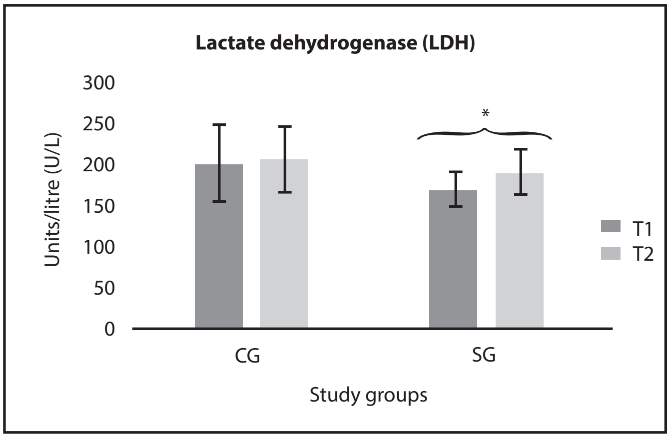
Data expressed as mean ± standard deviation.
Significant differences during the study period, calculated using Scheffé's method.
P (T x G): 2-factor ANOVA (time by group).
*: Significant difference between T1 and T2 (p<0.05).
NS: Not significant.
Reference values in square brackets.

Table 3. Percentage change in the biochemical markers of muscle behaviour and hormonal response in the control group (CG) and the study group (SG) with the *Elevation Training Mask* during the 12 weeks of training.

	Δ (T1-T2)	*P*
LDH (%)		
CG	-0.18±28.19	0.620
SG	12.75±15.01	
Creatine kinase (%)		
CG	17.98±81.59	0.296
SG	6.16±26.05	
Myoglobin (%)		
CG	-0.94±4.39	0.289
SG	-16.01±25.82	
Total testosterone (%)		
CG	5.79±0.57	0.762
SG	3.60±0.52	
Cortisol (%)		
CG	4.56±3.44	0.649
SG	-0.18±4.01	

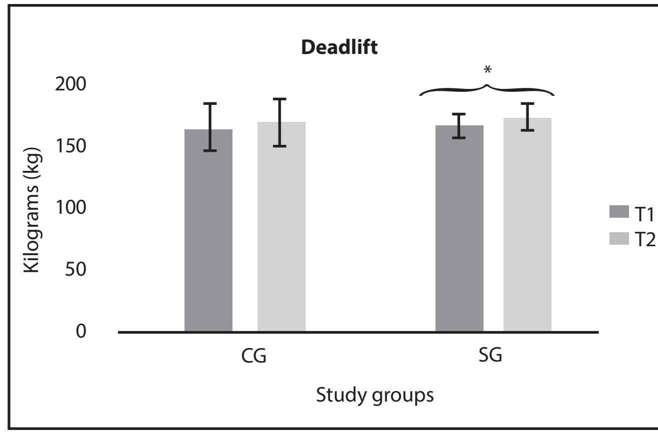
Data expressed as mean ± standard deviation.
Δ (T1-T2) = ((T2-T1) /T1) *100.
P: Statistical differences between groups

Figure 2. Lactate dehydrogenase (LDH) in the CrossFit® athletes in the control group (CG) and the study group (SG) with the *Elevation Training Mask* at two points in the study: T1, at the beginning of the study, and T2, after 12 weeks.



*: Significant difference between T1 and T2 (p<0.05)
Control group (CG); Study group (SG)

Figure 3. Deadlift in the CrossFit® athletes in the control group (CG) and the study group (SG) with the *Elevation Training Mask* at two points in the study: T1, at the beginning of the study, and T2, after 12 weeks.



*: Significant difference between T1 and T2 (p<0.05)
Control group (CG); Study group (SG)

Table 4. Performance tests, "Workouts of the day" (WODs), completed by the CrossFit® athletes in the control group (CG) and the study group (SG) with the *Elevation Training Mask* at two points in the study: T1, at the beginning of the study, and T2, after 12 weeks.

	T1	T2	*P* (T x G)
Press (kg)			
CG	70.83±10.69	76.67±10.80 *	NS
SG	69.17±11.58	80.00±11.40 *	
Squat (kg)			
CG	142.50±28.94	149.17±23.11	NS
SG	128.33±15.71	131.67±11.25	
Deadlift (kg)			
CG	160.83±19.34	165.83±18.28	NS
SG	162.50±9.87	170.00±10.49 *	
CF total (kg)			
CG	374.17±47.48	391.67±37.24 *	NS
SG	360.00±35.36	381.67±30.93 *	
Grace (segundos)			
CG	30.17±5.08	24.33±4.46*	NS
SG	28.00±6.23	22.67±5.92 *	

Data expressed as mean ± standard deviation.
Significant differences during the study period, calculated using Scheffé's method
P (T x G): 2-factor ANOVA (time by group)
*: Significant difference between T1 and T2 (p<0.05).
NS: Not significant

Table 5. Percentage change in the performance tests, "Workouts of the day" (WODs), in the control group (CG) and the study group (SG) with the *Elevation Training Mask* during the 12 weeks of training.

	Δ (T1-T2)	*P*
Press (%)		
CG	8.52±3.76	0.614
SG	10.70±3.76	
Squat (%)		
CG	5.70±9.83	0.126
SG	4.89±6.06	
Deadlift (%)		
CG	3.32±6.33	0.639
SG	3.78±4.18	
CF total (%)		
CG	5.07±16.05	0.624
SG	5.43±9.83	
Grace (%)		
CG	-24.73±2.48	0.524
SG	-23.46±1.63	

Data expressed as mean ± standard deviation.
Δ (T1-T2) = ((T2-T1) /T1) *100
P: Differences between groups

Neither were there any significant differences (p>0.05) in the group by time interaction (Table 2). The CG had a higher percentage of change for T (5.79±0.57%) and the SG showed a negative percentage change (-0.18±4.01%) for C (Table 3).

Sports performance

Table 4 shows the results of the performance tests at T1 and T2. A statistically significant increase in total kilograms was observed both in the CG (T1: 374.17±47.48 kg *vs* T2: 391.67±37.24 kg) and the SG (T1:

Table 6. Determination of exertion perceived, BORG CR-10, by the CrossFit® athletes in the control group (CG) and the study group (SG) with the *Elevation Training Mask* at two points in the study: T1, at the beginning of the study, and T2, after 12 weeks.

Test	Group	Time T1	T2	P (T x G)
BORG CR-10	CG	5.23±3.13	5.32±3.24	NS
	SG	5.70±1.29	5.86±1.1	

Data expressed as mean ± standard deviation. Significant differences during the study period, calculated using Scheffé's method.
P (T x G): 2-factor ANOVA (time by group)
*: Significant difference between T1 and T2 (p<0.05)
NS: Not significant; Control Group: SG; Study Group: SG

360.00±35.36 kg *vs* T2: 381.67±30.93 kg) in CF total. A statistically significant reduction (p<0.05) was also measured in the seconds needed to complete Grace in both the CG (T1: 30.17±5.08 s *vs* T2: 24.33±4.46 s) and the SG (T1: 28.00±6.23 s *vs* T2: 22.67±5.92 s). A significant improvement (p<0.05) in the deadlift was only observed in the SG (T1: 162.50±9.87 *vs* T2: 170.00±10.49) (Figure 3). None of the WODs analysed showed a significant difference (p>0.05) in the group by time interaction.

The percentage changes (Table 5) were similar for the CG and SG in CF Total (CG: 5.07±16.05% *vs* SG: 5.43±9.83%) and Grace (CG: -24.73±2.48% *vs* SG: -23.46±1.63%). .

Determination of perceived exertion

Table 6 shows the RPE in the CG. The Borg CR10 scale shows that there were no significant differences (p>0.05) between T1 and T2 in either group (CG or SG). Neither were there any significant differences (p>0.05) in the group by time interaction.

Discussion

The purpose of this study was to investigate the effect (36 training sessions) of the ETM on CF performance using WODs, examining muscle behaviour and hormonal variation in recreational CF athletes. To our knowledge, this is the first study of its kind. The study used a training methodology designed to cause a high degree of fatigue to permit biochemical and hormonal assessment, and to be employed as a programme focused on improving WOD performance. According to the results of our study, use of the ETM did not affect the participants' overall training programme. Nor were any side effects from the use of the ETM which led participants to abandon the study reported. Therefore, the use of the ETM during CF training was well tolerated, as confirmed by the absence of significant differences in RPE between the CG and SG, in agreement with the study conducted by Granados *et al.* [9] and contrary to Jagim *et al.*[6] in weightlifters. Our results may be the consequence of acclimatising to the ETM in the first two weeks of the study.

As for athletic performance, evaluated through WODs, the main finding after 12 weeks of training with the ETM was that there were no differences in sports performance between the two situations (CG and SG), although we did observe that the use of the ETM led to a significant increase in deadlift performance and a greater percentage of improvement in CF Total, which is the sum of the three WODs. These results are consistent with those reported by other authors[7,12,13]. Although the results between groups (CG and SG) were not significant, there was a greater increase in VO_{2max} [7,12,13] and anaerobic power output in a standardised cycle ergometer test[12] in the SG wearing the ETM compared with the control group, which did not wear the mask. One hypothesis as to why the use of the ETM may improve performance is that HT optimises muscle response through an increase in certain hormones, such as T[22], and the accumulation of metabolites which serve as components in the signalling of the key anabolic pathways that stimulate the recruitment of muscle fibres, thereby contributing to hypertrophy and increased muscle strength[2,23,24]. This hypoxic environment, which would permit HT, could be achieved by performing high-intensity exercise with the ETM and would potentially provide benefits similar to altitude training[25], such as increases in performance variables[26-28]. Furthermore, the restriction of respiratory flow caused by the ETM permits RMT, which would enhance performance in CF WODs due to a possible delay in the triggering of the respiratory muscle metaboreflex and increased respiratory performance[3].

Jagim *et al.*[6] reported that maximum speed in the execution of standardised movements such as back squat and bench press in weightlifters was lower with the ETM, although there were no significant differences between groups. Likewise, we observed in the Grace WOD (30 movements/time) a lower speed and intensity of execution in the SG, without significant differences between the two conditions of the study. Although we did not analyse blood lactate concentration values, one study[6] found that less lactate was collected at the end of weightlifting exercises with ETM compared with exercises without ETM. This could be explained by differences in fast muscle fibre recruitment patterns during exercise in the CG and SG[6]. Reduced recruitment of fast muscle fibres suggests an earlier onset of muscle fatigue[29], affecting the potential to reach maximum execution speed during the Grace WOD with the ETM. The ETM devices also induced respiratory acidosis by increasing CO_2 respiration, as occurs with RMT instruments[30]. This restriction of O_2 may lead to adaptations related to greater buffering capacity, which would lower blood lactate[11]. Therefore, the potential to reach maximum intensity during the Grace WOD could also be compromised with the ETM by the decrease in blood lactate as a consequence of the buffering effect[6].

The intense isometric and eccentric weight exercises used in CF workouts have a positive influence on body composition and physical fitness but also entail a high risk of skeletal muscle damage[16]. This situation triggers early fatigue, additional oxidative stress, a reduced capacity to carry out exercise, a greater perception of exertion and uncertain movements[31]. Individual monitoring by determining muscle biomarkers could define the training load and minimise these risks[32]. High circulating levels of enzymes such as LDH, CK, and Mb are indicative of increased exercise-induced muscle damage (EIMD), which negatively affects athletes because it reduces exercise performance and can also put their health at risk[32].

The findings of our study show that CK increased 10 percentage points less in the SG (6.16±26.05%) than the CG (17.98±81.59%), and the concentration of Mb decreased after 12 weeks of ETM (-16.01±25.82%) while remaining practically constant without the mask (-0.94±4.39%). These results seem to indicate that ETM training could modulate and prevent the muscle damage produced by CF training associated with reductions in CK and Mb compared with the CG. The hypoxic environment generated by CF exercise in combination with the ETM[25] could be responsible for the decrease in Mb, in the way that Villa *et al.*[33] and Fernández-Lázaro *et al*.[2] described in situations of hypoxia and physical activity. Since exercise and hypoxia are known to control the mitochondrial function and act positively on EIMD through the hypoxia-inducible factor (HIF), which plays an essential role in activating a molecular signalling cascade after exposure to hypoxia[34,35], the ETM could modulate the expression of HIF and thus attenuate the histopathological muscle damage caused by CF.

C is released from the adrenal cortex in response to psychophysical stress, and significant increases in C have been reported after endurance exercise which alters training adaptations through the direct catabolic effect[32]. Hypoxia has been reported to affect function in the hypothalamic-pituitary-adrenal axis and increase plasma adrenocorticotropic hormone (ACTH) levels. Hypoxia also stimulates the expression of the steroidogenic acute regulatory protein, increases the secretion of glucocorticoids, such as C[22], and decreases T[36]. Throughout our study, C levels in the SG remained constant (-0.18±4.01%) but increased in the CG (4.56±3.44%), which could suggest that it is adequate in CF training with ETM. That is, the stabilisation of C levels, in addition to the slight increase in T (3.60±0.52%), would permit the activation of protein synthesis, the antiglucocorticoid effect and the secretion of insulin-like growth factor 1 (IGF -1) and growth hormone (GH). This physiological situation would have an influence on muscle satellite cells which could contribute in part to generating greater muscle strength, less muscle damage and better recovery from training[2,23,37]. Therefore, the enhanced catabolic/anabolic ratio created in ETM conditions would contribute to significant improvements in WODs in the long term.

Certain limitations in this study need to be taken into account. One important limitation was that no dummy mask or placebo was used in the CG. Second, this study was only conducted at a resistance altitude of 2743 metres (after the first two weeks of acclimatisation to 914 and 1890 metres, respectively) even though the manufacturer makes several altitude resistances available (914 m to 5486 m). Applying different altitudes, or resistances, during exercise could lead to different results. Another limitation in our study was the small sample size. Including a larger number of subjects would provide a greater basis for eliminating error due to individual differences.

In conclusion, after 12 weeks of training with the ETM device, no improvements were observed in athletic performance, evaluated using WODs, compared to the control group. However, there were significant improvements in CF Total and Grace between T1 and T2 in the SG. Furthermore, the greater percentage trend in the decrease of Mb and C, together with the smaller increase in CK after ETM use could stimulate recovery and point towards a lower muscle catabolism in CrossFit® athletes in the long term. It is important to note that the results of this study suggest that the use of the ETM during training does not hinder CF practitioners from achieving the desired workloads or training volume. The ETM does not seem to negatively affect subjective perceptions, such as RPE, nor does it pose a risk of adverse events, as none were reported after the 12 weeks of the study. Such events should be considered before using the ETM device in training programmes in the future studies needed to determine whether this modest hypoxic condition or the increased work that the respiratory muscles are required to do is responsible for potential improvements in athletic performance.

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Conflict of interest

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

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Review

Effects of strength training on health determinants in men over 65 years: a systematic review

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Summary

Introduction: Aging is associated with a reduction in physical activity levels, leading to a decrease in strength and muscle mass, and affecting the minimum functional capacity to maintain an independent life. The literature agrees that strength training is one of the most important strategies to curb the effects of age, since it has been shown to be effective in increasing muscle mass and strength, promoting improvements in the functional capacity of the elderly. Therefore, the aim of this study was to analyze the effects of strength training on the conditioning factors of health and quality of life (e.g., body composition, muscle strength and functional capacity) in male adults over 65 years of age.
Material and method: A data search were conducted in PubMed, SPORTdiscus and Web Of Science (WOS) databases according to the recommendations and criteria established in the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) statement guidelines. For this, the search terms related to the target population (male older adults) and the type of training applied (strength training) were used.
Results: After applying the search strategies, a total of 2196 articles were obtained. After reading the title and abstract, 1687 articles were eliminated. After reading the full text, 151 articles were eliminated and 9 were selected, which met the inclusion criteria and were therefore included in this review.
Conclusions: The results suggest the importance of focus the strength training programs to the individual demands of each older adult man, in order to optimize its effects, and ultimately, improve their quality of life.

Key words:
Adult. Physical activity. Health. Resistance training.

Efectos del entrenamiento de fuerza sobre las capacidades determinantes de la salud en hombres mayores de 65 años: una revisión sistemática

Resumen

Introducción: El envejecimiento lleva asociado una reducción de los niveles de actividad física, propiciando la disminución de la fuerza y masa muscular, y afectando a la capacidad funcional mínima para mantener una vida independiente. La literatura coincide en que el entrenamiento de fuerza es una de las estrategias más importante para frenar los efectos de la edad, dado que se ha demostrado que es efectiva para incrementar la masa muscular y la fuerza, propiciando mejoras en la capacidad funcional del adulto mayor. Por ello, el objetivo del presente estudio fue analizar los efectos del entrenamiento de fuerza sobre los factores condicionantes de la salud y calidad de vida (p.e., composición corporal, fuerza muscular y capacidad funcional) en adultos masculinos mayores de 65 años.
Material y método: Se realizó una búsqueda bibliográfica en las bases de datos PubMed SPORTdiscus, y Web Of Science (WOS) de acuerdo con las líneas de recomendación para revisiones sistemáticas y meta-análisis PRISMA. Para ello, se utilizaron los términos de búsqueda relacionados con la población objetivo (adultos mayores masculinos) y el tipo de entrenamiento aplicado (entrenamiento de fuerza).
Resultados: Tras aplicar las estrategias de búsqueda, se obtuvieron un total de 2196 artículos. Tras la lectura de título y resumen se eliminaron 1687 artículos. Tras la revisión de los textos completos, se eliminaron 151 artículos y se seleccionaron 9, los cuales cumplieron los criterios de inclusión, por lo que fueron incluidos en esta revisión sistemática.
Conclusiones: Los resultados sugieren la importancia de orientar el entrenamiento de fuerza seleccionando el tipo de carga (moderada, alta o combinada) más adecuada para conseguir los objetivos individuales de cada hombre adulto mayor con la intención de optimizar sus niveles de composición corporal, capacidad funcional, masa muscular y fuerza máxima, para consecuentemente, mejorar su calidad de vida.

Palabras clave:
Adulto. Actividad física. Salud. Entrenamiento con cargas.

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Introduction

The demographic evolution in developed countries reflects an ageing population, due to rising life expectancy and the fall in birth rates[1,2]. According to the National Statistics Institute (INE), life expectancy was 80.43 years for men and 85.80 for women in 2018, with a rising trend in subsequent years. This leads to an ageing population, to the point that currently 19.2% of the Spanish population is aged over 65 years old and in 2033, this will reach 25.2% (INE, 2018). In this respect, ageing is a major problem, not only because of its socio-economic repercussions, but also due to the changes that occur in the subjects, usually associated with a drop in their quality of life[1].

In this respect, it has been demonstrated that ageing brings a physiological decline mainly seen in impairment of neuromuscular, cardiovascular and pulmonary systems[3-5]. However, it is the degeneration of the muscular system caused by the progressive loss of strength and muscle mass which limits the functional capacity and independence of older adults[6,7], increasing the risk of suffering disease and even death[8]. This loss of muscle mass, strength and functioning of muscles in older adults is commonly known as sarcopenia[9].

Given that a certain level of strength is required to carry out any daily activity, as they lose functionality, older adults must increase their physical effort for the same activity, which implies working at a relatively higher intensity in terms of their maximum capacity[10], thereby making the same task more tiring[11]. This physiological challenge means that older adults reduce their physical activity[12] and, like a self-perpetuating cycle, as physical activity is reduced, they lose strength and muscle mass[13]. On the other hand, with the increase in inactivity as a consequence of muscular weakness, there is a loss of mobility and functional capacity[14], which will negatively affect the risk of falls, generating greater deterioration among older adults[15].

There is robust scientific evidence to uphold the theory that physical exercise could reverse this situation[12,16–19]. Specifically, in the last few decades, strength training has been consolidated as the main strategy to reduce strength and muscle mass deficits in older adults[20]. In this respect, a large number of prior studies have applied different strength training programmes to older adult males, basically differentiated by the load used, although with similar results regarding the gain in muscular strength. For example, Radaelli *et al.*[21] applied a strength programme based on moderate loads [(50-65% of a maximum repetition (1MR)] and they observed significant strength gains in the 1MR test in the knee extension exercise ($P < 0.05$) and increases in the thickness and muscular quality of quadriceps ($P < 0.05$). On the other hand, Mitchel *et al.*[22] used high loads (85% 1MR) and obtained significant increases ($P < 0.05$) in the 1MR test for the leg press, knee extension and bench press after the intervention period. Other authors applied strength protocols based on combining moderate and high loads (from 65% to 95% of 1MR), demonstrating significant results ($p < 0.05$) in the increase of lean mass, in the reduction of fat mass and improvements in lower and upper body strength[23].

However, although strength training was demonstrated to have a positive effect on improving muscular function in older adults, there is no current evidence of consensus on what type of training and strength is the most appropriate and which generates the most beneficial effects as different results can be obtained depending on the loads used. Therefore, the main aim of this review was to analyse the effects of strength training on health determinants in older adult males, focusing on the loads used [i.e., moderate (50-80% 1MR), high (> 80% 1MR) or combined].

Material and method

To carry out this systematic review, the recommendations from the PRISMA[24] declaration were followed. The scientific literature was reviewed to analyse the effects of strength training on health determinants in older people (>65 years old). To do this, original experimental scientific articles were consulted, in English and Spanish, with a time filter from 1 January 2014 to 15 February 2019. The databases consulted were Pubmed, SPORTdiscus, and Web of Science (WOS).

The search strategy resulted from combining the following descriptors: "elderly" and "older adult" (target population); "strength training", "resistance training", "power training", "heavy resistance training", "moderate resistance training", "low resistance training", "maximal strength training", "velocity-based training", "circuit-based training", "high speed resistance training", "resistance exercise", "velocity-based resistance training", "circuit training", "high-velocity resistance training", "concurrent training", "multicomponent training".

The final search was carried out using the following combination of terms: (elderly OR "older adult") AND ("strength training" OR "resistance training" OR "power training" OR "heavy resistance training" OR "moderate resistance training" OR "low resistance training" OR "maximal strength training" OR "velocity-based training" OR "circuit-based training" OR "high speed resistance training" OR "resistance exercise" OR "velocity-based resistance training" OR "circuit training" OR "High-velocity resistance training" OR "concurrent training" OR "multicomponent training")

The inclusion criteria were: (a) use healthy men over 65 years old as a study sample, (b) apply a strength training programme evaluated by a pre-post test, (c) present the intensity of the programme indicated as a percentage of 1MR and (d) articles published in well-respected international journals, indexed in the Web of Science, while the exclusion criteria were: (a) studies that were not experimental, (b) application of the training programmes was not directly supervised, (c) intervention programmes where strength training was combined with training on other aspects, (d) strength training programmes combined with nutritional intervention and (e) interventions that lasted under 6 weeks. The search process was carried out independently by 2 authors (J.V.-P. and J.R.-G.) and in cases of discrepancies, a third author (D.C.) was consulted.

Results

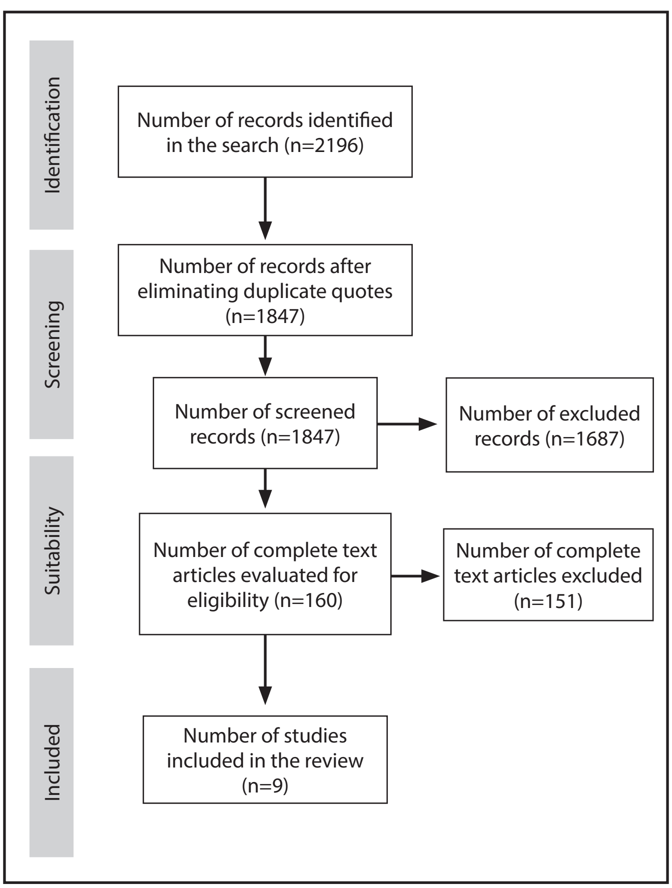
The preliminary search found 2196 articles. The articles were filtered by firstly eliminating the duplicate references extracted from the various databases, giving a total of 1847 articles. Subsequently, these articles were filtered by reading the title and abstract, leaving a total of 160 references. Finally, the selected articles were read in their entirety, applying the inclusion and exclusion criteria to obtain a total of 9 articles for the systematic review (Figure 1).

The sample size of the 9 selected studies was 128 participants, only including experimental subjects. The age range for the participants was between 50 and 80 years old. Analysis of the training protocols identified that the most frequently-used duration was 12 weeks (55%). Regarding the weekly training frequency, it was seen that 3 days a week was the most popular frequency (77%), followed by 2 days a week (44%). Regarding the load used, 2 studies used moderate loads, 3 used high loads and 5 combined loads. The studies included in the review, and their main characteristics, are presented in Table 1.

Discussion

The aim of this review was to analyse the effects of strength training on health determinants in older adult males, examining the loads used (i.e., moderate, high or combined).

Figure 1. Flow diagram to describe the systematic review procedure.



Focusing on the effects caused by strength training with moderate loads, Sundstrup *et al.*[25] applied a training programme over 12 weeks that consisted of a circuit of strength exercises involving the main muscles in the upper and lower body. The intensity ranged between 70 and 80% 1MR, performing 3-4 sets of each exercise, with repetitions ranging between 8 and 12. After the intervention period, the older adults obtained significant improvements in concentric strength (14%; $p < 0.01$) and isometric strength in quadriceps (23%; $p < 0.001$), and in isometric strength of hamstring musculature (44%, $p < 0.0001$), measured using an isokinetic dynamometer. Furthermore, 18% improvements were seen in the stair-climbing test ($p < 0.05$) and 21% in the sit-to-stand test ($p < 0.05$). Continuing with the moderate loads, Zdzieblik *et al.*[26] carried out a strength training programme with an intensity of 65-80% 1MR for 12 weeks. The older adults carried out this programme with a frequency of 3 days a week, composed of 4 exercises, 2 for the lower body (leg press and squats) and 2 for the upper body (bench press and lat pulldowns). Regarding the training volume, 3 sets of 15 repetitions were done in weeks 1-4, 10 repetitions in weeks 5-9 and 8 repetitions in weeks 10-12. The results showed an increase in lean mass and bone mass, and a reduction in fat mass. Furthermore, this strength programme with moderate loads allowed older adults to increase their muscular strength and improve their neuromuscular control.

Regarding the use of high loads with older adults, Baptista *et al.*[27] analysed the effect of a strength programme with 80% 5MR loads on the neuromuscular and structural properties of the muscle-tendon complex of quadriceps in 23 older adults. This programme lasted 12 weeks, it was performed with a frequency of 2 days per week and was based on a single exercise, concentric or eccentric knee extension. After the intervention period, it was observed that both protocols increased the maximum force of the knee extensor musculature and reduced the length of the vastus lateralis fascicle and increased its pennation angle. In the same way, significant increases were found in the length of the patellar tendon in both groups, while an increase in the anatomical cross section of the tendon only increased significantly in eccentric training. These anatomical variations after inclusion of the aforementioned strength training programme seem to affect the dynamic balance of older adults. Finally, after the intervention period, both groups increased the isometric and dynamic torque of the eccentric and concentric strength of the knee. Along this line, Beurskens *et al.*[28] studied the effects of a training programme with loads of 80% 1MR over the maximum production of unilateral and bilateral isometric strength (IMS) and over the bilateral limb deficit. The intervention took place with 58 men over 13 weeks and with a frequency of 3 days a week and they carried out 3 sets of 10 repetitions of the leg press, knee extension, ankle extension and foot dorsiflexion exercises. After applying this training programme, an increase was observed in maximum isometric strength, both bilateral and unilateral, and a reduction in the participants' bilateral limb deficit. Finally, Mitchell *et al.*[22] analysed the effects of the strength training with high loads over the strength and hypertrophy level in 16 older

Table 1. Strength training programmes applied using older adult males.

Study	Sample	Loads used	Training protocol	Results
Zdzieblik *et al*. (2015)	27 men (72.2 ± 4.68 years old)	Moderate	12 weeks 3d/week 65-80% 1MR. Lat pulldown, leg press; bench press; reverse squat.	↑LM, ↑BM,↑FM and ↓FM (p<0.001) and ↑IQS and ↑SMC; (p<0.01).
Sundstrup *et al.* (2016)	9 men (68.2 ± 3.2 years old)	Moderate	Month 1: [16-20 rep. (50-60% MR)]. Months 2-12: [8-12 rep. (70-80% MR)]. 3-4 sets 3 days a week Recovery: 1 min 30 s Leg press, seated knee extension, lying hamstring curl; lat pulldown, lateral raises, lunges with hand weights, seated row.	↓18% time climbing stairs (p<0.05) ↑CQS (14%; p<0.01) ↑IQS (23%; p<0.001) ↑IHS (44%; p<0.0001)
Beurskens *et al.* (2015)	19 men (60-80 years old)	High	13 weeks 3d/week 3 sets x 10 rep. (80% 1MR). Recovery: 2´. Leg press; knee extension; ankle extension; foot dorsiflexion.	Left leg IMS: ↑10%, p<0.001, d=2.3. Right leg IMS: ↑8% p<0.05, d=1.8. Bilateral IMS: ↑26%, p<0.001, d=5.7. BLD: ↓78%, p<0.001, d=3.4.
Mitchell *et al.* (2015)	16 men (74 ± 5.4 years old)	High	12 weeks, 3days/week; 4 sets 85% 1MR. Leg press, leg extension; hamstring curl; 45º ankle extension; bench press; lat pulldown; shoulder press; seated row; biceps curl; elbow push downs.	↑1MR in leg press, knee extension, bench press (p<0.05) ↑Type I fibres (p<0.008)
Baptista *et al.* (2016)	23 men (62.74 ± 2.20 years old)	High	12 weeks 2d/week 80% 5MR (4 rep.). Concentric group and eccentric group	Both groups ↑ Knee extension strength Both groups ↑ patellar tendon length, but patellar tendon CSA only in ECC, (p<0.05). Both groups ↓VL fascicle length and ↑ pennation angle with no change in muscular thickness. Both groups ↑ isometric and dynamic torque of the knee extensor musculature.
Andersen *et al*. (2014)	9 men (68.2 ± 3.2 years old)	Combined	16 weeks 2d/week Weeks 1-4: 3 sets x 16-20 MR (50-60%) Weeks 5-8: 3 sets x 12 MR (70%). Weeks 9-12: 3 sets x 10 MR (75%). Weeks 12-16: 4 sets x 8 MR (80%). Leg press, seated knee extension, hamstring curl; lat pulldown, lateral raises with hand weights	↓Walking HR, (p<0.05) ↓10%; Running HR and [La]: 30% (p<0.001). ↑STS: ↑26%
Schmidt *et al.* (2014)	9 men (68.2 ± 3.2 years old)	Combined	12 months Month 1-4: 2d/week 3 sets. Recovery: 90” Month 5-12: 3d/week 4 sets. Recovery: 90” Month 1: 16-20 MR (50-60% 1MR) Month 2: 12 MR (67% 1MR) Month 3: 10 MR (75% 1MR) Month 4 to 12: 8 MR (80% 1MR). Leg press, seated knee extension, hamstring curl; lat pulldown, lateral raises with hand weights.	↑ 5% (p<0.05) LV ejection fraction, with no significant changes in the diastolic function of the LV.
Villanueva *et al.* (2014)	7 men (68.1 ± 6.1 years old)	Combined	12 weeks 3d/week 2-6 set Day 1: 12-8 MR. 67-80% Day 2: 6-3 MR. 85-93% Day 3: 6-4 MR. 70% power 45º leg press, bench press on a machine, lat pulldowns, seated row, stair climbing with hand weights, dead lift with hand weights and knee extension and flexing.	↑LM (week 6) (p<0.05). ↓FM (p=0.05) ↓%CO (week 12) (p=0.05). ↑VO_{2max} (week 6 and week 12) (p<0.01)

(continúa)

Study	Sample	Loads used	Training protocol	Results
Fernández-Lezaun *et al.* (2017)	29 men (69 ± 3 years old)	Combined	9 months 1, 2 or 3 d/ week, depending on the group. Month 1-3: 2-3 sets x 15-20 repetitions (40-60% 1MR) Month 4: 2-3 sets x 10-12 repetitions (60-75% 1MR) Month 5: 2-4 sets x 8-10 repetitions (75-80% 1MR) Month 6: 2-4 sets x 4-6 repetitions (85-90% 1MR) Month 7: 3-4 sets x 8-12 repetitions (60-85% 1MR) Month 8: 3-5 sets x 4-6 repetitions (85-90% 1MR)	Month 1-3: All groups ↑VO2 ($p<0.05$). Months 4-9: no significant improvements. ↑1MR months 1-3 all groups except M2 and months 4-9 only in M3.

Abbreviations: rep: repetitions, CQS- concentric quadriceps strength; IQS - isometric quadriceps strength; IHS: - isometric hamstring strength; BM - bone mass; LM - lean mass; FM - fat mass; CO - cardiac output; FM - muscular strength; SMC - sensory-motor control; CSA - cross section area; IMS - maximum isometric strength; BLD - bilateral deficit; STS: sit-to-stand test; LV: left ventricle;.

adults. To do this, they designed a strength training programme based on bench press, leg press, lat pulldown, knee extension, military press, hamstring curl and bicep curl exercises. This programme was performed for 12 weeks and 3 days a week, with a training load of 4 sets at 85% of 1MR. After application, improvements were seen in the 1MR for leg press, knee extension, and an increase in the percentage of type I fibres although not type II fibres.

Regarding studies that applied programmes based on combined loads, Andersen *et al.*[29] analysed the effect of a 16-week multi-exercise intervention with a frequency of 3 times a week. The functional capacity performance and the physiological response to the test to walk at 4.5 $km{\cdot}h^{-1}$, the submaximal running test and the maximum incremental on the stationary bike (maximum oxygen consumption, lactate, time to exhaustion). The load applied progressed from the 3 sets of 16-20 repetitions at 50-60% 1MR, in the first 4 weeks, to 4 sets at 80% in weeks 12-16. At the end of the intervention period, the older adults reduced their heart rate walking and running, as well as demonstrating a lower concentration in lactate peak in the running test. Furthermore, 26% improvements were seen in the sit-to-stand test. The second study that applied combined loads was run by Fernández-Lezaun *et al.*[30], who analysed the effects of the frequency of a strength programme on the cardio-respiratory capacity and strength values. The study took place over 9 months with a different weekly frequency depending on the group (1, 2 or 3 sessions). The training load ranged from 4-6 repetitions to 15-20, sets between 2-5 and intensity from 30 to 90% of 1MR. After the intervention, it was seen that during months 1-3, all the groups improved their maximum oxygen consumption, although during months 4-9, improvements were not seen in any of the tests performed. Finally, during months 1-3, all groups improved 1MR for the leg press except for the group that did 2 weekly sessions and during months 4-9, only the 3 weekly session group improved. Subsequently, Schmidt *et al.*[31] studied the effects of a strength programme with combined loads lasting 12 months on cardiovascular adaptations in older adult males. The intensity of the programme varied from 40% 1MR up to 90% of 1MR, applied in the leg press, knee extension, hamstring curl, lat pulldown and side raises with hand weight exercises. After the intervention, a 5% increase was seen in the left ventricular ejection fraction with no significant changes in the rest of the markers analysed. Finally, Villanueva *et al.*[23] analysed the effects of a combined load strength programme applied over 12 weeks with a frequency of 3 days a week, varying the training load on each of those days. In this respect, on day 1, they did 8-12 repetitions at 67-80% 1MR; on day 2, 3-6 repetitions at 85-93% and on day 3, they did 4 to 6 repetitions at 70% 1MR. The exercises used in this programme were 45º leg press, bench press on a machine, lat pulldowns, seated row, stair climbing with hand weights, dead lift with hand weights and knee extension and flexing. After applying the strength programme, an increase in the lean mass was seen and a reduction in the fat mass. Furthermore, cardiac output was reduced, and maximum oxygen consumption increased.

Conclusion

In general, during the first phases of the training, and mainly in out-of-practice adults, strength training seemed to be a safe and effective strategy to improve body composition, muscular strength and the functional capacity of older adult males. Specifically, moderate loads seem to be appropriate to improve the body composition, functional capacity and isometric strength, possibly because these loads were located in the zone of maximum power production on the strength-speed curve. On the other hand, high loads seem to have greater influence on strength and muscle mass, a fundamental aspect to prevent and treat sarcopenia. Finally, the strength training with combined loads seems to improve the functional and cardiovascular capacity of older adults, and their body composition. The results of this systematic review suggest the importance of guiding strength training towards individual goals for each older adult male, to optimise its effects and in short, improve their quality of life.

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Conflict of interests

The authors do not declare any conflict of interests.

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Medical protection guide against doping
Guía de protección del médico del deporte ante el dopaje

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Preventing doping is one of the most important and unwaiverable professional responsibilities taken on by any doctor working with athletes. To do this job properly, the doctor must have in-depth knowledge of doping, its rules, its medical and legal consequences, and how to stop it happening. This knowledge will help doctors avoid consequences that might be damaging for both athlete and doctor.

It is undeniable that, like other physicians, by working with athletes, they run the risk of intentionally or inadvertently being in contact with athletes or other individuals who are doping or that undertake actions defined as doping rule violations. In this respect, there is a chance that, due to diverse circumstances, a doctor can find him or herself included in a doping investigation.

This guide aims to inform doctors working with athletes on matters that can help them find out about the most important aspects of the fight against doping, whilst providing recommendations on how to not get involved in procedures or situations related to doping that occasionally bear criminal liability and how to act preventively if this does happen.

This document aims to set measures to avoid doping for physicians working with athletes, reminding them that they should always report doping practices, even involving doctors, in the terms set in the legislation in force.

This document demonstrates to everyone (society in general and the world of sport in particular) the active, decisive stance of the collective against this type of practices that are not only illegal but clash directly with the essential principles of the medical profession and, as has been unfortunately witnessed on more than one occasion, are manifestly damaging for the athlete's health. There are innumerable examples of devastating and persistent outcomes, not only organic damage but also psychological.

The sad images we have all seen of a person taking the stand to declare, as a doctor, on the use of procedures or substances (often illegal medicines in the broadest sense, unauthorised, in experimentation, veterinary, obtained via smuggling or theft, or occasionally, direct copies from a suspicious origin), with the simple aim of improving an athlete's competitive professional performance that could happen again given the current panorama, have to be unequivocally and specifically detached from the sports medicine collective with a specific, active and decisive commitment from doctors in the field. This personal commitment exponentially encourages working with other collectives or agencies (sports federations, technical staff, trainers, sports directors, organisers of professional sporting events, State Security Forces and Bodies).

This "inter-agency" collaboration is fundamental to fight doping because, on their own, doctors are not capable of fighting this issue definitively and securely given this activity involves professionals from other specialist fields, not just medicine, seen when breaking up some surprisingly widespread crime rings behind athlete doping.

Furthermore, the guide will provide tools that allow doctors that do not take part in doping practices to address the risks of some aspects of their professional practice.

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Doping. What it means from a medical perspective

The dictionary definition of doping indicates that it is the action to dope, namely to "administer stimulating pharmaceuticals or substances to artificially improve the body's performance, sometimes endangering health"[1]. This is the essential concept of doping: use of substances or methods that are on the prohibited list to improve performance. However, doping, which must be considered from a legal point of view due to its consequences, is defined by the World Anti-Doping Code as "committing one or several anti-doping rule violations according to sections 1 to 11 of article 2 and 10.14.1 that is described in Table 1[2].

In the context of their career, doctors could commit the following violations (in principle, article 25 of the new Bill that sets sanctions for support personnel does not exclude any of the violations mentioned in article 20, so it might be understood that the doctor can commit any of them and in such case, in addition to the sanctions envisaged for violators, they would also be given any envisaged in said article 25, even if the sporting result in competition were unfavourable):

- Tampering or attempted tampering.
- Possession.
- Trafficking or attempted trafficking.
- Administration or attempted administration.
- Complicity or attempted complicity.
- Prohibited association (Table 2).
- Retaliation, threats or intimidation.
- Violation.

Regarding the more specific aspect of practising their profession, which involves prescription, doctors can commit the following types of violations[3]:

Table 1. Violations of the doping rules. World Anti-Doping Code 2021[2].

1. Test result	Presence of a prohibited substance or its metabolites or markers in an athlete's sample.
2. Use or attempted use	Use or attempted use by an athlete of a prohibited substance or a prohibited method.
3. Control avoidance	Evading, refusing or failing to submit to sample collection.
4. Whereabouts failures	Any combination of three missed tests and/or filing failures within a 12-month period by an athlete.
5. Tampering or attempted tampering	Tampering or attempted tampering with any part of doping control.
6. Possession	Possession of a prohibited substance or prohibited method by the athlete or person supporting athletes.
7. Trafficking or attempted trafficking	Trafficking or attempted trafficking in any prohibited substance or prohibited method.
8. Administration or attempted administration	Administration or attempted administration of a prohibited substance or method.
9. Complicity or attempted complicity	Complicity or attempt to be complicit by an athlete or other person.
10. Prohibited association	Sporting or professional relationship with persons who are in the situation described in table 2.
11. Retaliation, threats or intimidation	Actions to dissuade someone from informing authorities about a possible case of doping or taking retaliation against a possible informant.
12. Breach	This is behaviour that, although the Code does not state it as such, falls into a similar category to the rest and can also be sanctioned. It implies noncompliance or violation of a sanction for doping.

Table 2. Situations considered in prohibited association.

- Person supporting the athlete subject to the authority of an anti-doping organisation who is currently suspended for a period.
- If they are not subject to the authority of an anti-doping organisation, and when suspension has not been addressed in a process considered in the World Anti-Doping Code, when they have been sentenced or found guilty in a legal court, disciplinary or professional case for behaviour that constitutes a violation of the anti-doping rules if the rules applied to this person had been adjusted to the World Anti-Doping Code. The disqualification of this person will be maintained for a period of six years from when the criminal, professional or disciplinary decision is taken or while the criminal, disciplinary or professional sanction is in force.
- When they are acting to cover or as an intermediary for a person subject to the authority of an anti-doping organisation, they are suspended for a period, or if they are not subject to the authority of an anti-doping organisation, and when suspension has not been addressed in a process considered in the World Anti-Doping Code, when they have been sentenced or found guilty in a legal court, disciplinary or professional case for having undertaken behaviour that constitutes a violation of the anti-doping rules if the rules applied to this person had been adjusted to the World Anti-Doping Code. The disqualification of this person will be maintained for a period of six years from when the criminal, professional or disciplinary decision is taken or while the criminal, disciplinary or professional sanction is in force.

- Prescription of medication or nutritional supplements included on the prohibited list, by a doctor who does not normally work with athletes.
- Prescription of medication or nutritional supplements included on the prohibited list, by a doctor who does usually work with athletes in the context of a lawful treatment not for the purposes of doping, without requesting the relevant therapeutic use exemption.
- Prescription of a doping procedure.
- Use of a prohibited method (such as intravenous therapies > 100 ml/12 hours).
- Noncompliance with the administrative rules against doping.

Sanctions for doping

Doping rule violations are paired with sanctions which can be applied when each violation is made.

According to the World Anti-Doping Code[2], violation of an anti-doping rule (Table 1) by an athlete or other person can lead to one or more consequences as mentioned in Table 3.

In addition to the specific sanctions from the anti-doping authorities, doctors in Spain can also be given the following sanctions:

Criminal Code. Although it is true that article 362 on minor crimes4 specifically refers to sports doping and envisages sentences of up to two years in prison and special disqualification from public employment or positions, profession or trade, from two to five years, this type of crime can be related to others regarding the supply of medicines regardless of the purpose, which envisages jail sentences of up to four years and disqualification for the profession for up to three years. Given that the articles envisaged in the Spanish Criminal Code clearly need to be updated, it seems that the legislator initially tried to "defend" himself by also giving importance to the origin of the medicines or medical devices used or administered for the purposes of doping. In our case, and precisely the technical characteristics and, for example, the origin or conservation of the medicines, might stretch out the sentences as mentioned above. The fact that these practices had been committed by a doctor would mean lead to imposing the maximum sentence. In this chapter of crimes against public health, the legislator also focuses on several individuals coming together to commit a crime, surprisingly considering the need for people from several worlds to come together for these criminal purposes, which might fit the figure of "belonging to a criminal group" depending on the circumstances, "union of more than two persons", as aggravating circumstances in these cases. Finally, the profit obtained from these practices against public health must also be followed up by the justice system, which might lead to other criminal liabilities due to money laundering, crimes against the Inland Revenue Office and forging public documents referring to the use of prescriptions.

It seems reasonable to think, and in fact many people follow this line of thought, that Spain does not crack down "hard" criminally on sport doping because our Criminal Code objectively only provides one specific mention of sport doping among its articles. However, in practice, these activities necessarily require other complementary actions that are also considered as criminally punishable, producing a list of crimes that worsen the sentence that was initially envisaged. It is debateable whether healthcare workers, in this case doctors, are more greatly punished as such, not so much in criminal laws but in administrative rules, given that this figure is completely trusted as an "ally" in the fight against these practices and this is exactly why it is so dangerous for this figure to take an active part in the fraudulent activity as it removes important control tools such as diagnosis, treatment, prescription or management of Therapeutic Use Exemptions.

- *Protection of Athlete's Health Law.* Disqualification from pursuing healthcare or professional roles involved with athletes, entities,

Table 3. Consequences of violations of the anti-doping rules. World Anti-Doping Code 2021[2].

- **Disqualification**. Invalidation of the athlete's results in a competition or event, with all the resulting consequences, such as losing any medal, point or prize. In Spain, disqualification or to be more precise, cancellation of the results is not actually a sanction, but it is known as a measure to re-establish the legality, it is not considered a sanction and it is not governed by the rules of the sanctioning administrative law.
- **Ban.** Exclusion of the athlete or other person for violating the anti-doping rules for a specific period of time due to participating in any composition or other activity or financing (article 10 of the 2021 Code). This leads to the loss of the sporting licence, and it will be impossible to obtain another licence for a determined time.
- **Provisional suspension.** Temporary prohibition for the athlete or other person in any competition or activity before the court's final decision.
- **Economic consequences.** Economic sanction imposed for a violation of the anti-doping rules or to recover the costs associated with a violation of the anti-doping rules. Unlike national legislation, the World Anti-Doping Code does not determine a catalogue of pecuniary sanctions associated with the violation. The World Anti-Doping Code considers paying the economic quantities more from a compensatory point of view rather than an actual sanction.
- **Public dissemination.** Broadcasting or distribution of information to the general public or persons beyond those who had the right to prior notification.

clubs, teams, federations or sporting institutions for a period of four years[5].

- *College of Physicians*. Committing a violation of the doping rules can lead to the anti-doping authorities contacting the College of Physicians about the acts performed by the personnel who carry out healthcare functions for the relevant disciplinary purposes.
- *Spanish Federation of Sports Medicine*. Violating the doping rules can leads to the sanction derived from applying the Code of Ethics in Sports Medicine of the Spanish Federation of Sports Medicine[6].

The prescription

The greatest risk for doctors regarding doping is prescribing medicines, nutritional supplements or other substances.

This section does not consider prescriptions made out for doping purposes and that implies that the prescriber is consciously aware of committing the violation.

Doctors who do not usually work with athletes should be aware of the prescription rules relating to doping, not only because this can lead to a sanction for them but also because it can affect the athlete who receives the prescription.

Basically, the following types of prescription exist:

- Drugs included in the Spanish Agency of Medicines and Medical Devices - AEMPS (https://www.aemps.gob.es/home.htm) compiled in its section on "Medicines for human use" (https://www.aemps.gob.es/medicamentosUsoHumano/portada/home.htm)
- Drugs and products for hospital use.
- Drugs from other sources.
  - Purchased on the Internet
  - Foreign drugs
- Nutritional supplements.

Physicians in Spain can prescribe medicines for human use that are listed by the Spanish Agency of Medicines and Medical Devices – AEMPS. They can also prescribe nutritional supplements of legal origin that have been listed and managed by the Spanish Agency for Food Safety and Nutrition (foods for specific groups, food complements and natural mineral waters communicated in Spain, https://rgsa-web-aesan.mscbs.es/rgsa/formulario_producto_js.jsp), they can purchase products on the Internet and abroad and they can use hospital drugs following the set rules.

The really important issue is that the prescribing doctor must make sure that the product to be prescribed is not included on the list of substances and methods that are prohibited due to doping[7].

Unintentional doping

The best-known form of doping takes place when the athlete makes the conscious and agreed decision to use a prohibited substance or a method for doping purposes.

On the contrary, there is a form of unconscious doping called unintentional doping. This doping has two methods: inadvertent doping and accidental doping.

Inadvertent doping is a form of unintentional doping where the athlete takes a medicine without being aware that its composition contains prohibited substances. Inadvertent doping also refers to when the necessary paperwork has not been completed to grant a *Therapeutic Use Exemption* (TUE).

Accidental doping is a form of unintentional doping where the athlete takes a prohibited substance or uses a prohibited method by chance. For example, there are the cases of doping by consuming adulterated or contaminated nutritional supplements that contain prohibited substances in sport without declaring this in its composition. In these cases, the athlete must demonstrate this contamination and also that there has not been gross negligence and even then, they might be sanctioned with a warning or even have their licence withdrawn for 2 years, depending on the severity of their guilt or negligence.

Police authorities from several countries, including Spain, have already carried out operations against adulteration of food supplements in the world of sport. Generally, this refers to imported products that sometimes arrive adulterated or are sometimes made in the destination country, not to mention cases of falsifications that, temporarily and occasionally, might become available on the market.

It is important to mention that the athlete's intention is not to commit a violation but simply to consume a substance or use a method. In other words, an intentionally consumed substance or method used: INTENTIONAL, even when the intention is not to dope. Consumed substance or method used unintentionally: UNINTENTIONAL. In other words, a consumed substance or method used consciously will be considered INTENTIONAL, even when doping was not the purpose. On the other hand, a consumed substance or method used unconsciously will be considered UNINTENTIONAL.

In the case of specific substances or methods, the sanctioning body must demonstrate the intention to use it. In the case of non-specific substances or methods, the athlete must demonstrate their lack of intention. In both cases, if this intention does not exist, the severity of the negligence will be assessed in taking it, using it and possessing it and the sanction will thereby be evaluated (ranging from a warning to 2 years for a specific substance or method and 1 or 2 years for non-specific).

When an adverse laboratory result comes back in a competition control and the substance is only prohibited in competition, the athlete can demonstrate that consumption took place outside competition (prior to 11.59 of the day before the competition) and can demonstrate that their intention was not to improve their sporting performance: lack of intention will be reported.

Therapeutic Use Exemption

Therapeutic Use Exemption (TUE) is the procedure determined by the World Anti-Doping Agency so that athletes who require it can use prohibited substances when necessary to treat diseases.

Granting a TUE is subject to the athlete being able to demonstrate that all the following conditions have been met:

- That the prohibited substance or method in question is necessary to treat an acute or chronic pathology to the extent that not administering this prohibited substance or method to the athlete would seriously affect their health.
- That it is highly improbable that therapeutic use of the prohibited substance or method would improve performance, beyond what can be attributed to the athlete recovering their health after treatment for the acute or chronic pathology.
- That there is no authorised alternative therapy to replace the prohibited substance or method.
- That the need to use the prohibited substance or method is not the partial or total consequence of having used a substance or method before (without a TUE) that would have been prohibited at the time of use.

An athlete must have a TUE before using or possessing said prohibited substance or method unless one of the following exceptions exists, in which case the athlete must obtain a backdated authorisation:

- In the case of a medical emergency and treatment of an acute pathology.
- When, due to other exceptional circumstances, there has not been enough time or the chance to present the application.

The athlete must present the TUE application to the corresponding anti-doping organisation using the ADAMS system or as specified by the anti-doping organisation. This form should be accompanied by these two pieces of information:

- A certificate from a qualified doctor confirming the need for the athlete to use the prohibited substance or method in question for therapeutic reasons.
- A complete clinical history that will include the documentation issued by the doctor who made the initial diagnosis (if possible) and the results from all tests, laboratory analysis and imagery studies inherent to the application.
- When a TUE is granted, these two points are stated:
- The approved substance or method, and its permitted dosage, frequency and means of administration, duration of the TUE and any other conditions imposed regarding the TUE.
- TUE application form, and the relevant clinical information.

The physician must be aware of the rules for granting a TUE to be able to prescribe prohibited medication safely[8].

Checking prohibited substances or methods

Before writing a prescription, it is necessary to check that the substances in it are not on the list of prohibited substances and methods in force.

The list of prohibited substances and methods can be found on most sporting federation websites, but it is best to consult official sources:

- World Anti-Doping Agency website: https://www.wada-ama.org/en/what-we-do/the-prohibited-list.
- Spanish Agency of Health Protection in Sport website - AEPSAD: https://aepsad.culturaydeporte.gob.es/normativa/normativa-internacional.html
- Consult the WEBSITE or MOBILE apps. NØDoPApp or NØDopWeb https://aepsad.culturaydeporte.gob.es/inicio/nodopapp-nodopweb.html
- A similar app can be consulted in several countries (United States, United Kingdom, Canada, Switzerland, Japan, Australia, New Zealand): GLOBAL DRO. https://www.globaldro.com/Home
- GLOBAL DRO contains similar links for many other countries. https://www.globaldro.com/home/other-countries
- Boletín Oficial del Estado (Official State Gazette), which is where it is officially published each year: boe.es

Medicines for human in use in Spain can be consulted on the Spanish Agency of Medicines and Medical Devices - AEMPS (CIMA: AEMPS Medicines Online Information Centre): https://cima.aemps.es/cima/publico/home.html

Nutritional supplements in Spain can be consulted on the Spanish Agency for Food Safety and Nutrition (foods for specific groups, food complements and natural mineral waters reported in Spain, https://rgsa-web-aesan.mscbs.es/rgsa/formulario_producto_js.jsp)

Prescription algorithm

The following algorithm (Figure 1) simply indicates the prescription procedure for a substance or method to treat an athlete who is likely to have to pass a doping control at any time[3].

Before using the substance or method, the first thing to do is check whether it is included on the prohibited list.

If it is not on the prohibited list, the prescription can be written.

If it is on the prohibited list, a therapeutic alternative must be found. If there is an acceptable alternative for the treatment, then the alternative is prescribed.

If the need for treatment is a medical emergency or treatment of an acute pathology, it can be prescribed, and a backdated TUE is requested.

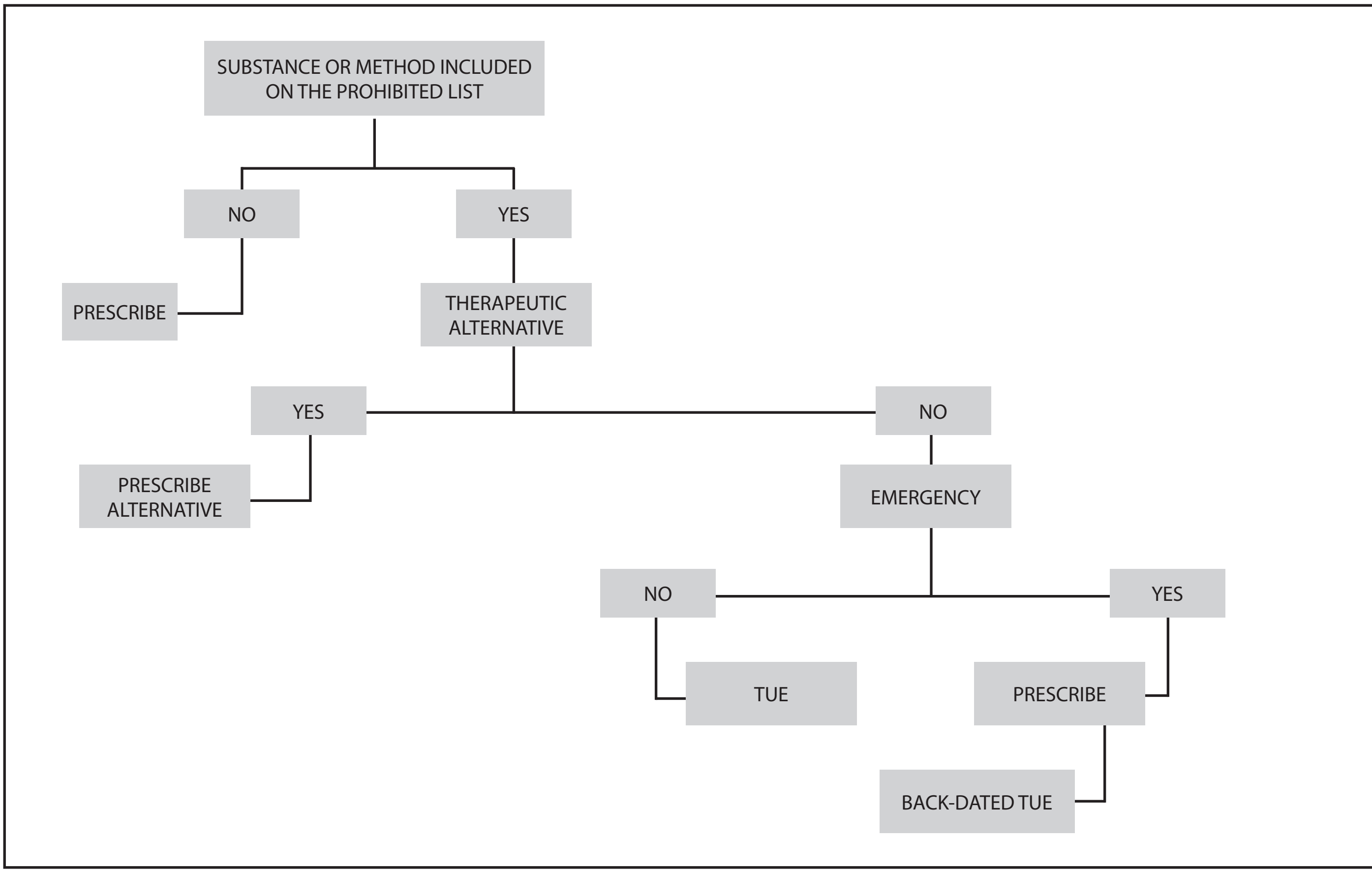
If the need to prescribe does not involve a medical emergency or treatment of an acute pathology, a Therapeutic Use Exemption (TUE) must be requested.

First-aid kit

The doctor can keep substances and methods in their workplace first-aid kit that are included on the prohibited list when they are necessary to be used in legitimate clinical situations, such as treating urgent cases, but in appropriate quantities for this purpose and, in any case, substances and methods that are for a known clinical use.

The doctor's travelling first-aid kit should be governed by the same principle, although the quantities it contains are in proportion to the

Figure 1. Prescription algorithm.



number of people that it might be necessary to help, including technical personnel in the team and other types of companions.

In some competitions, such as the Olympic Games and the Paralympics, there is a specific set of rules to prepare the contents of the first aid kit and how to transport it.

Behaviour in the consulting room. Doctor-athlete/patient relationship

A doctor who works with athletes must scrupulously follow the principles of the doctor-patient relationship, in this case the athlete.

In normal situations, the doctor, whose relationship with the patient involves providing help, expects the patient to be honest and honourable, although circumstances might arise that the athlete, in this case, wishes to obtain information on doping or, much more dangerously, aims to involve the physician consciously or unconsciously, so the doctor must consider that their relationship with athletes, particularly in competition and high performance, is high-risk.

Please refer to article 27 of the Code of Medical Ethics, to which doctors must comply[9]:

- Medical secrecy is one of the pillars founding the doctor-patient relationship, based on mutual trust, regardless of how the profession is practised.
- For the doctor, secrecy comprises the obligation to remain discrete and respect the confidentiality of anything that the patient has revealed and entrusted to them, what they have seen and deduced as a consequence of their work and that is related to the patient's health and intimacy, including the content of their clinical records.

To reduce the risk of implicating the physician in a doping case, the following recommendations are made:

- Be aware of the doping prevention rules.
- Check the list of prohibited substances and methods for doping in force.
- Be aware that relationships with athletes likely to be involved in doping cases must be considered as high-risk, particularly referring to prescription of medicines or nutritional supplements, treatments and consultations on improving performance.

– Note down in detail everything discussed with the athlete in their clinical records, particularly any prescriptions for medicines and food supplements and recommendations on improving performance. The prescriptions must be made with a copy and a receipt signed by the athlete, and the doctor keeps this signed copy, in case there is any falsification.
– If the athlete raises topics related to doping, note this in their clinical record:
  - Demonstrate that the doctor is opposed to any procedure or action related to doping.
  - Ask the athlete to give up any plans for doping, explaining the risks to their health and the legal consequences.
  - Do not give information on doping substances, such as:
  - Effects that improve performance.
  - Average life of the product.
  - Advice on hiding, masking or "cleaning" the substance.
  - How to purchase doping products.
– If you suspect that the athlete is considering doping, record the conversation, inform the athlete of this and get their consent.
– If you are going to administer any medication, particularly intravenously, show the athlete the packaging or the blisters, check that they have read the name and create a section in the records with the prescription and the athlete's signature accepting that they have been shown the product identification. When it is administered by IV and more than 100 ml / 12 hours, a TUE must be requested.
– Phone calls can be taken out of context. It is recommended to use means of communication that leave a record of what was said. They can be recorded by mutual agreement in the event of covering topics related to any aspect of doping.
– Be very careful with what you say in relation to doping or substances and avoid any type of collusion or agreement, total or partial, with topics related to doping.
– It is possible to have substances in the consulting room that are included on the doping list, but only substances that are really useful in usual clinical practice and in the quantities required for clinical practice.
– Be aware that internet searches on doping can be considered proof of various doping offences. Consequently, the reason for the consultation must be made very clear.
– In the case of carrying out clinical studies or research with individuals likely to carry out doping practices or on the use of substances or methods related to doping, it is recommended to contact the Spanish Agency of Health Protection in Sport and/or the Civil Guard and National Police anti-doping units.

Some circumstances indicate a higher probability that there is doping in reference to sport and athletes. The doctor must recognise the characteristics that might suppose a greater risk of doping and that are described below.

Risk of doping depending on the sport. The following sports have a greater risk of doping, in accordance with the data provided by the *Anti-Doping Rule Violations* (ADRVs) *Reports*[10] and the *Anti-Doping Testing Figures Reports*[11]:

– Sports/specialisations involving strength, power and speed: weightlifting and other similar disciplines (including body-building), athletics (throwing, jumping and speed), American football.
– Fighting and combat sports: wrestling, boxing, taekwondo.
– Sports/specialisations involving stamina: cycling.
– Other sports: motor racing, snooker, motorcycling.

Risk of doping depending on the athlete[12]. The characteristics of the athlete, given below, must be seriously considered by any doctor caring for athletes, because there is a clear risk that the subject in question might be implicated in a doping procedure:

– *Athlete's level of competition*. The higher the level and dedication, the greater the doping risk. Although there is still truth in this statement, it has wavered in the light of some doping systems and substances that, in principle might not require a doctor to take part but on many occasions end up requiring medical care, to counter possible side effects from self-medication for doping purposes at any level. As the system is quick to respond, an early warning could be raised on the presence of "medicines" (always bought on the black market) that might be contaminated and/or cause a public health issue.
– *Athlete's results*. It is logical to consider that athletes with the best sporting results might be doping, but it is particularly high risk when these results are achieved at a later age, unexpectedly compared to previous results, if the athlete has never achieved such results before, or if they are achieved after a period of inactivity or nonappearance at competition.
– *Age*. Older athletes should be considered a doping risk although this should not be taken as a general rule because young people who enter professional or semi-professional sport are also a risk collective. Not so much the age but the circumstances that surround the sporting practice in each specific case, along with what they ask from the doctor, are going to give a generally reliable indication of the real purpose of the consultation.
– *Economic support*. If the athlete receives public economic support, grants, aid from the State, region or town.
– *Negative information*. If the doctor has information on the risk of doping from the sports technicians or professionals from reliable environments. Much more if it is known that the athlete is the subject of any type of investigation by the anti-doping or judicial authorities or the State Security Bodies and Forces.
– *Whereabouts compliance*. If it is known that the athlete has previous history of failing to provide their whereabouts for anti-doping tests outside of competition.
– *Intelligence data*. If there is data from different sources, such as from the State Security Bodies and Forces, that suggests doping procedures.
– *Support staff*. That the athlete is trained, treated, collaborates with or is close to support staff (trainers, technicians, nurses, physiotherapists, masseuses, representatives, managers, teammates or other doctors) who are suspected of encouraging doping.

Never forget that there is a risk of doping *dependent on the doctor,* already sadly demonstrated in several police operations against doping rings. We should not reject news of participation or even induction into doping from a doctor, particularly if it is persistent. This news can be checked by means of the tools legally provided for this (medical and pharmaceutical inspections, criminal investigation if necessary). These legal tools are designed to cause as little damage as possible, and their use reflects directly on the good health of the collective.

Finally, article 38 of the Code of Medical Ethics says that "it is not lack of fellowship for a doctor to notify their College of Physicians discretely of their colleagues' violations of the rules of medical ethics or professional practice[9]." Not reporting them to the Anti-Doping Organisation with powers in this matter could be considered a Complicity violation, mentioned in Table 1.

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7. **Tables and figures.** Tables and figures will be sent on separate files in JPEG format. Tables must be sent in word format.

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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.

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