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Volumen 34(2) - Núm 178. March - April 2017 / *Marzo -Abril 2017*

Summary / Sumario

Clinical Exercise Physiology: The role of exercise physiology in chronic diseases

Fisiología clínica del Ejercicio: la fisiología del ejercicio aplicada a las patologías crónicas

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Doctor en Medicina. Especialista en Medicina del Deporte. Responsable de la Unidad de Medicina del Deporte (Fisiología del Ejercicio y el Deporte, Traumatología del Deporte, Fisiología Clínica y Prescripción de Ejercicio). Hospital Universitario Sant Joan de Reus. Profesor Asociado. Facultad de Medicina. Universidad Rovira i Virgili.

General physiology deals with the functioning of the organism and its parts, whilst the physiology of exercise is the branch of physiology that studies the functioning of the body during physical exercise and the adaptations that it provokes when it is performed regularly.

The clinical physiology of exercise, which I will refer to as clinical physiology, studies the response to physical exercise of patients with chronic illnesses (psychiatric, neurological, metabolic, cardiovascular, pulmonary), the limitations they display to it, and uses knowledge acquired by the physiology of exercise to cause adaptations induced by physical work as another therapeutic resource (prescription of therapeutic exercise).

Over the last 60 years, scientific evidence relating to physical exercise-health has increased, but since the last decade of the 20th century not only has it become clear and resounding, but also unarguable and accepted by the vast majority of scientific societies and organisms, such as the World Health Organisation.

Scientific evidence acknowledges that physical condition is an excellent predictor of life expectancy and quality of life. Over recent years, numerous studies have revealed an inverse association between physical condition and morbi-mortality in the population, very marked in patients with cardiovascular risk factors. Improvements in both physical and mental health are observed.

Physiological values such as maximum consumption of oxygen (VO2 max.) constitute an excellent marker of the maximum cardiovascular capacity, observing an almost linear relationship between the reduction of mortality and the increase of physical condition (METs). Therefore for each MET of improvement, there is a 12 % increase in life expectancy in men and 17% in women. These figures indicate that poor physical condition is an added risk factor, as well as a morbi-mortality predictor.

Along with this evidence, it is observed how the physical inactivity of a large part of the population is responsible for the reduction in functional capacity: cardiovascular, metabolic, as well as in muscle strength, which increases the incidence-prevalence of chronic illnesses when it does not make them worse.

It has been highlighted that the most important health benefits gained from physical exercise focus on cardiovascular or metabolic illnesses, those affecting the locomotive apparatus, certain types of cancer and psychiatric illnesses.

The latest studies place physical inactivity among the 5 top causes of the overall risk of mortality on a world scale, and as the cause of a major economic cost for health systems.

Thus, either physical inactivity is the direct responsible element behind the appearance of these pathologies, or, as observed in clinical practice, the appearance of a primary illness (excess weight-obesity, cardiovascular, diabetes, etc.) results in a deficit that provokes the physical inactivity of the patient, a progressive loss of functional capacity, closing a perpetuating cycle of the progressive reduction and worsening of the state of health.

Performing regulated physical exercise on a regular basis (correctly prescribed depending on medical and physiological criteria: clinical physiology) can reverse this process.

The good praxis of clinical physiology requires: a thorough knowledge of the medical pathology, of the physio-pathology of the exercise and of the use of the most appropriate functional assessment tests.

These tests for the functional assessment of the physical condition can be sophisticated and complex: ergometric, ergo-spirometric, isokinetic or simple, such as the 6-minute walking test, or the hand dynamometer.

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Therapeutic physical exercise should have some specific characteristics and be orientated towards the improvement of some of the qualities of the physical condition that are related to health, giving way to beneficial effects for it, such as: the reduction of blood pressure, the improvement of tolerance to glucose, the positive modification of the lipid profile, the increase of muscle and bone mass, among others.

Prescribing exercise should be based on its customisation, i.e. adapting the prescription as far as possible to the characteristics of each patient. The frequency and duration are still generally accepted standards, but there should be a more in-depth analysis of physiological customisation in the re-training programme (intensity). There are different approaches to this physiological customisation, among which are: ventilatory, lactate and dyspnoea thresholds, the visual analogue scale, as the most used.

In addition to the physiological perspective, the prescription should also be customised, taking into account the associated pathologies present in the patient, the medical treatment being followed, and the socio-cultural and economic level.

To prescribe physical exercise safely, recommendations, warnings, and the reduction of risk should be taken into account as another of the priority objectives.

The experience acquired over these years and the bibliography consulted confirm the need to routinely include the evaluation of the physical condition in the control and clinical follow-up, as a base for the prescription of physical exercise and its evolutionary control. Specifically, and in the majority of patients: the 6-minute test to assess aerobic resistance (distance covered) and to calculate the VO_2max. indirectly and the strength test as the hand dynamometer. If necessary, more specific tests will be carried out, such as: ergometries, ergo-spirometries, isokinetics of the lower extremities.

The physical exercise programme proposed is intended to be easy to prescribe, without the need for complicated or complex complementary tests, easy for the targeted patients to follow, both in terms of the type of exercise to perform as well as their intensity (note that the majority are sedentary patients).

The main aim is to improve the physical condition qualities that are linked to the reduction of cardiovascular risk and that of morbi-mortality: VO_2max, tolerance to aerobic exertion-resistance, muscle strength.

Finally, negative effects should be avoided: dropping out, locomotive system injuries, increased cardiovascular and metabolic risk, for which the periodical supervision of these patients by medical specialists in clinical physiology is required.

In short, therapeutic physical exercise designed from clinical physiology becomes a *"polypill"*, as described by some authors, and is an essential part of medicine, as highlighted equally in the United States by American College of Sports Medicine: "Exercise is Medicine", as well as in Europe by Pedersen and Satin: "Exercise is Medicine".

Since the second half of the 20th century, the physiology of exercise applied to sporting performance has undergone extraordinary development, both on a world scale as well as in Spain, positioning us as a benchmark country in this sphere. However, in the area of clinical physiology, development in Spain has not been aligned with that occurring internationally.

There are medical groups of the clinical physiology of exercise in our country, researchers and some highly interesting public and private initiatives that are undertaking this task, but in an isolated and uncoordinated way, and the very few that are stable and official form part of the public and private range of medical services.

It can also be observed that there is a profound lack of knowledge of this branch of exercise medicine on an institutional level by the majority of private health insurances, and even by our medical colleagues.

I believe that it is time to revalue and vindicate this area of our speciality. I would like to put forward some proposals from the recognition of the difficulty of this task in the socio-economic and health situation we are currently experiencing:

– As doctors, specialists in Sporting Medicine, we should aim to give our very best by deepening our training and keeping up to date with the clinical physiology/prescription of exercise.
– Gather the support of scientific societies and medical groups. In this respect, the Spanish Society of Sporting Medicine is taking the (already advanced) steps of providing training and updating courses in physiology and the prescription of physical exercise.
– Manage to enable the general public to get to know clinical physiology and its necessary presence in the health care offer to citizens.
– Raise the awareness of those responsible for healthcare so that they invest in a medical area that in the mid and long term improves the health of individuals and populations and represents a saving for public healthcare services.

The task is far from simple, but health and the quality of life of our fellow citizens deserve it, and scientific evidence and current economies require it.

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Campaña de aptitud física, deporte y salud

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

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

Closed kinetic chain isokinetic values in football players: Pilot test

Pavel Loeza Magaña[1,2], Wolfgang Fritzler-Happach[1], Joaquin Barrios-González[1]

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Summary

Objectives: To determine the feasibility of an isokinetic test for lower limbs in kinetic closed-chain in football players in two moment of the season, in addition to obtaining their reference values of peak force and power output.
Design: This is a longitudinal, prospective, observational study with a descriptive phase and comparative phase and open.
Methods: 16 professional football players from second division of Mexican League between 17 and 21 years were evaluated, making a isokinetic testing for lower limbs in kinetic closed chain at 60 °/s, 10 repetitions, at the beginning and end of the season.
Results: The analysis was realized by laterality. Isokinetic reference values were obtained in this group of players for force (Nm) and power (W); the difference of peak force between both sides of the extensors chain was 5.45% initially and 9.52% at the end; for flexors was 14.30% and 9.19% at the end; for the flexor/extensor relationship was 23% initially an 24% in the final test. The progression between the beginning and the end of the season showed increased isokinetics values between measurements of non-dominant mainly muscle groups.
Conclusion: The test meets the characteristics required to perform a new test, is applicable and useful for evaluating individual performance in the biomechanics of muscle strength and power at low speed in a functional muscle chain, multiaxial and will identify imbalances, prevent injuries and even make assessments after recovery in the event of an injury.

Key words:
Dynamometry. Anaerobic power. Agility. Closed kinetic chain.

Valoración isocinética en cadena cinética cerrada en futbolistas: Prueba piloto

Resumen

Objetivo: Determinar la viabilidad de realización de una prueba isocinética en cadena cinética cerrada de miembros pélvicos en futbolistas en dos momentos de la temporada, además de obtener sus valores de referencia de fuerza pico y potencia.
Diseño: Se trata de un estudio prospectivo longitudinal observacional con una fase descriptiva y una comparativa y abierto.
Métodos: 16 jugadores profesionales de segunda división de la Liga Mexicana de fútbol de entre 17 y 21 años de edad fueron evaluados, realizando una prueba isocinética de miembros pélvicos en cadena cinética cerrada a 60°/s, 10 repeticiones, al inicio y final de la temporada.
Resultados: El análisis de hizo por dominancia. Se obtuvieron valores isocinéticos en este grupo de jugadores para fuerza (Nm) y potencia (W); la diferencia de fuerza pico entre ambos lados de la cadena extensora fue de 5,45% inicialmente y final de 9,52%; para flexores fue de 14,30% y final de 9,19%; en cuanto a la relación flexores/extensores fue de 23% inicial y 24% al final. Además, la comparación entre el inicio y final de temporada mostró incremento de los valores isocinéticos entre las mediciones de los grupos musculares no dominantes principalmente.
Conclusión: La prueba cumple con las características requeridas para la realización de un nuevo test, es aplicable y es útil para evaluar el rendimiento individual desde la biomecánica de la fuerza y potencia a baja velocidad en una cadena muscular funcional, multiaxial y que permitirá detectar desequilibrios, prevenir lesiones e incluso realizar valoraciones después de la recuperación en el caso de una lesión.

Palabras clave:
Dinamometría. Potencia anaeróbica. Agilidad. Cadena cinética cerrada.

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Introduction

Strength and power are among the capacities needed to play football[1-3]. Isokinetics is an assessment system that uses IT and robotics to obtain and process muscle capacity in quantitative data[4]; the parameters can be measured with an analytic movement in one or multiple axes[5]; and within them agonist and antagonist muscles can be assessed alternately, in concentric and eccentric direction[6]. The results are obtained in physical magnitudes, mainly in terms of strength, power and work[6]. The closed kinetic chain (CKC) is a movement that requires multi-joint efforts[6], which has been described as "functional", proprioceptive, and that requires less anterior tibia movement over the femur, reducing the demand on the anterior cruciate ligament[7]. Via isokinetic dynamometry, muscle performance can be assessed in search of bio-mechanical balance between the same muscles on both sides (what we will call "inter-side balance") and between agonists and antagonists; this balance is associated with greater sporting performance and the prevention of injuries among athletes[8,9]. Regression forms have been obtained for theoretical isokinetic strength values, but these are only for the Open Kinetic Chain (OKC)[6,10]. During dynamic movements in football, the balance between strength and elasticity between the dominant and non-dominant sides increases joint stability; the asymmetry between strength and elasticity, as well as the reciprocal balance between agonists and antagonists (especially in the lower half of the body), play an important role in sports with asymmetrical movement patterns. This is due to the fact that the dominant side is used for play whilst the non-dominant side is used as a support[11]. To get the best performance, there should be a suitable assessment for working on improving strength and muscle power, and with it the prevention of injuries through bio-mechanical alterations in the active or passive stabilisers[6].

Anaerobic power is the capacity to produce strength and speed from energy systems that are not dependent upon oxygen[12]. The result will be a reflection of the capacity to produce energy via systems such as phosphocreatine and lactic glycolysis. Although diverse measurement methods have been created, no correlation between them have been found, perhaps due to the energy production method[13].

To have an assessment of the complete capacities, there must be reference values in both the preparation and the competition period, so as to help regulate the external and internal loads for specific players, to improve their performance and to report data that suggests over-training or fatigue[14], or to have a reference point for recovery following an injury.

In this study, the aim was to establish a pilot test of functional characteristics and to obtain their peak strength and power values in order to assess the lower body and to compare modifications that may arise over time. Until now, the isokinetic regulation values have been performed on single axis movements, which is why there are no reference values for football players in a closed chain dynamometry; for this reason it is important to have new assessments that have an impact on the performance of movements similar to the motor gesture and that provide objective results in terms of physical magnitudes.

Material and method

It is a prospective, longitudinal, observational and open study, with descriptive and comparative phases, and which aimed to establish the viability of performing an isokinetic test in a closed kinetic chain of pelvic limbs in footballers at two points of the season, as well as obtaining their reference values of peak strength and power.

The inclusion criteria were: healthy male football players, in periods of preparation and competition, that agree to participate in the study and that sign an informed consent form in accordance with the Helsinki declaration and current Mexican legislation; the exclusion criteria were: presence of joint, rheumatic or cardiovascular co-morbidities and a history of joint pathology of the pelvic limbs in the past year; whilst those eliminated were: footballers that presented skeletal-muscle injuries of the pelvic limbs during the performance of the study, those that presented complications for co-morbidities during the study, and those that dropped out of the study.

The work was carried out at the University of Football and Sports Sciences, Pachuca, Hidalgo, Mexico; between January and May 2013, with an initial sample of 18 footballers from the 2nd professional division of the Pachuca Club, during the preparatory phase and at the end of the competition period; 2 players were eliminated from the study for presenting injuries during the season. The average age of the players was 19-18 years (S ±1.51), weight 72.15 kg (S ±4.73), height 178 cm (S ±4.26), 9 right-footed and 7 left-footed, established according to their ball kicking profiles.

It started with a warm-up on a static exercise bike SciFit Iso 1000R, 5 min with no resistance at a rhythm of 70 revolutions per minute. Next, each player performed the isokinetic dynamometry on a CSMI Humac Norm equipment, which was adjusted in the following way:

The participant lay face up, with a starting position of a 90º hip flex, a 90º knee flex, -20º maximum knee extension, with the foot positioned in the arm rest of the dynamometer, with the foot and ankle held down with a Velcro band. Sitting: 40º rotation, 15º position forward/back, 0º horizontal backrest. Position of the dynamometer: 0º inclination, rotation 40º, height level 5. Movement of the Monorail in 28 (Figures 1 and 2).

10 repetitions were carried out at a speed of 60º/s, for both pelvic limbs starting with the right, with a continuous flexed movement - extension of the assessed limb, completing the range of movement in a concentric/concentric exercise mode. Upon completing the measurement, there had to be a co-efficient of variation in the repetitions below 10% to consider the test as valid, ensuring a minimum intraclass relationship of 0.906. Between each measurement there was a 1 minute rest. With this measurement, peak strength and isokinetic power values were obtained. At the end of the test, a cool-down was performed, just like the warm-up, and the participant also performed a series of static stretches of the quadriceps, hamstrings and triceps sural muscles for 5 minutes, with which the first assessment was considered completed.

Figure 1. Positioning for the isokinetic dynamometry.

Figure 2. Lateral view of the test.

Later, on 8th May 2013, during the end of competition (prior to the post-season), new assessments were carried out using the same procedure, thus concluding the clinical part of the study.

Results

The data analysis was carried out using the following statistical methods:

- Value average (µ).
- Standard deviation (S).
- Confidence interval at 95% (CI95%).
- Student t Test (t) for dependent samples, considering a value $p \leq 0.05$ to be statistically significant.
- The variables obtained were strength peak (Nm) and isokinetic power (W).
- The statistical analysis was carried out using the Microsoft Office Excel 2010® programme.

Values were obtained in the pre-season as well as prior to the post-season. In the parameters in which comparatively no seasonal differences were found, these values were added to establish the population to be averaged. These results are displayed in Table 1.

The ordering of the values and analyses was carried out by dominance (in the ball kick) due to the fact that there were 9 right-footed and 7 left-footed players, organising the data by "dominant" and "non-dominant". Dvir[6] reported a variation between both sides of up to 10% in strength due solely to laterality. Literature suggests that the discrepancy between both limbs should be less than 10% to be considered normal[4,6].

In this study, the difference of peak strength was discovered between both sides of the extensor hip of 5.45% (S±7.15, CI95% 3.50 $p = 0.01$), and a final value of 9.52% (S±6, 28, CI95% 3.07, $p = 0.03$) whilst for the group of flexors in the initial measurement, the percentage of difference between both sides was 14.30% (S±10.07, CI95% 4.93, $p = 0.0003$) and in the final measurement 9.19% (S±9.04, CI95% 4.43, $p = 0.02$). In terms of the existing relationship in the antagonist-agonist muscle groups (flexors/extensors), the relationship was on average 23% at the start and 24% at the end. With regards to isokinetic power, no notable difference was found in the numerical value between both sides.

Discussion

Demographic analysis

This study was carried out on young professional footballers, aged between 17 and 21 years, belonging to the same team during a tournament. Nikolaïdis[13] carried out the Wingate power test in his study, studying footballers aged between 12 and 20 years, with a very large age range considering that in this stage there are major physical changes secondary to the process of adolescence (his study objective), with some of this study group falling within the range assessed by us, however our standard deviation is not so wide (58 Nm in the dominant extensor group and 18 Nm in the non-dominant flexor group), which enables the observation that in this final stage of transition between adolescence and adulthood there is no longer a major modification. These changes were analysed by Degache *et al*[15] via the isokinetic dynamometer in OKC to 60 and 180°/s in footballers aged between 11 and 15 years, and being a smaller range, there was a major variation between those of 12 and 13 years; given this, we consider that the age range of our chosen demographic will not influence the variation of strength and power. Both authors mentioned had far greater samples than those assessed in this study.

Values obtained

The isokinetic measurements in CKC were not very widespread, despite the fact that within them no isolated muscle was found, rather

Table 1. Values obtained.

Variable	Initial values				End values			
	µ	S	CI95%	n	µ	S	CI95%	*p*
Nm ext Dom	428.56	58.14	20.14	32	***			0.09
Nm ext no Dom	389.81	67.01	32.83	16	463.75	49.40	24.20	0.0002**
Relationship between sides	5.45	7.15	3.50	16	9.52	6.28	3.07	0.01**
Nm flex dom	101	18.50	9.06	16	112.5	13.63	6.68	0.002**
Nm flex no dom	103.87	26.04	9.02	32	***			0.46
Relationship between sides	14.30	10.07	4.93	16	9.19	9.04	4.43	0.00001**
Rel ext/flex dom	24.03	4.51	1.56	32	***			0.13
Rel ext/flex no dom	23.18	3.74	1.83	16	25.87	3.30	1.61	0.02**
W ext dom	578.03	94.52	32.75	32	***			0.46
W ext no dom	586.15	102.86	35.63	32	***			0.09
W flex dom	127.81	20.76	10.17	16	153.43	30.63	15.01	0.009**
W flex no dom	131.88	26.61	13.04	16	162.06	33.49	16.41	0.003**

Nm: peak torque (strength); Rel: relation; ext: extensors; flex: flexors; dom: dominant side; no dom: non-dominant side; µ: arithmetic average; S: standard deviation; CI95%; confidence interval 95%; n: total sample; ***with no significant variation between the first and second measurements. for which the absolute value was taken as the total of measurements; **statistically significant.

the complete chain, in functional movements and with less anterior movement and patello-femoral compression. For the same reason, no bibliography can be found in different databases (Bidi - UNAM - EBSCO - MedLine, Cochrane Library) where regulatory values are established for these tests. In our literary search we found the Liebensteiner[16] reference, in which an assessment of linear CKC was carried out at a speed of 0.2 m/s, which differentiates from our measurement as its measurement units were absolute N and no Nm, our assessment was concentric and furthermore, no reference values were reported, rather simply a relationship was established in the strength between men and women.

On the other hand, it can be seen in strength that the inter-side differences between both sides coincides with the <10% described by other authors[6,17] for the extensor group (5.45±3.50%), but does not behave this way with the flexor muscles, where the discrepancy was 14.30+4.93% at the start ($p = 0.0006$), though at the end of the season the difference range diminished (9.19±4.43%, $p = 0.59$).

This coincides with the study by Rahnama *et al*[18] in which they observed a difference of >10% in the flexors between the dominant and non-dominant sides, though Lanshammar and Ribom[19] only found a difference of 8.3% for the flexors. Both authors studied groups of athletes, footballers and healthy people, but in OKC. In this latter study a difference of 5.3% was found for extensors, coinciding with our results. The study carried out by Schulz *et al.*[20] is worth a mention, as it entailed a study group of 18 footballers and a control group of 18 healthy people, aged between 16 and 36 years. Here a discrepancy of around 10% was found between both sides in the control group, a result similar to that obtained in this study, however in the group of footballers, the strength difference was of 25% in the hamstring muscles, a very large range not obtained in this or other studies analysed, which the authors put down to the effects of training, which does not coincide with that indicated by Dvir[6] or Huesa[4] as normal parameters, nor is it similar to our result (14% at the start and 9% at the end of the season, still undergoing training). Daneshjoo *et al*[11] hypothesised that the dominant side is more used for play, whilst the non-dominant side is used as support (use in CKC). In their work with 36 footballers, 97.2% had an imbalance between the dominant and non-dominant sides.

In terms of the relationship between the agonists and antagonists, our study revealed a proportion of 24±1.56% on the right side, whilst the initial left side was of 23.18±1.83 and final 25.87±1.61%. Here the peculiarity of a large difference is highlighted, when compared with the assessment in OKC, as in the reviewed studies the references already spoke of 60% of proportion[6,15] or a little less, as described by Lanshammar and Ribom[19] of 46% on the dominant side and 53% on the non-dominant. It is important to take this model into account, as it is not just a single axis movement, rather a complete muscle chain, where the strongest group of flexors is the hamstring, whilst the hip flexor and ankle extensors groups (dorsiflexors) produce less strength, whilst the extensor group, composed of extensors of the hip, the knee and ankle flexors (plantarflexors) are anti-gravity muscles, which is why the development of strength will be greater. However, it is very important to take into account that there should be a balance, both between the antagonistic muscles as well as in laterality, so as to help prevent injuries[6,11].

There are no studies in which a value of normality is determined for the flexor/extensor relationship in CKC with which to compare our result (23-25%), remaining for the time being a reference value for this age and training plan group, and as pending for comparison against another group of similar characteristics performing a different training plan, as well as considering the specific point in the season to be assessed by this parameter.

Seasonal comparison

Not all the values altered with the season. A parameter such as bilateral isokinetic power reflects that the work undertaken by the muscle fibres does not tend to change in the extensor groups. Considering that W = N x Speed, that maximum strength was used, that the speed was controlled and applying the Law of Henneman[21], it can be explained that as all the muscle fibres are used and the speed does not change, power is not notable in the change in this particular group (extensor). Anaerobic energy systems are also involved, as it is a maximum test in a short period, which determines that the co-efficient of variation of the repetitions in the test will be less than 10%: football is a low to moderate-intensity sport[2], and although anaerobic efforts are made such as repetitive sprints[1,3], they do not last long enough or intensely enough to change these variables. On the other hand, the strength of the dominant extensor and non-dominant flexor groups did not change, whilst there was a change in the dominant hip flexor. This could be explained from the bio-mechanics of the kick, which perhaps is modified during the season because of technique, not because of the strength of the ball kick. From this point of view, the dominant hip extensor will help the kick, whilst the non-dominant hip flexor will be the active stabiliser in the supporting leg; the dominant flexor group will have a quick adaptation (translated as a change of the values) as being required less, it will improve rapidly with training.

To assess the strength between both sides of the extensor muscles, a relationship was maintained below 10% as the literature mentions[4,6], however between the flexor group a difference greater than this 10% was obtained. In the strength of extensors the dominant side did not reveal statistically significant progress, whilst the non-dominant side did, perhaps therefore because the non-dominant side underwent this improvement with training due to greater adaptation, whilst that of the dominant side does not have such a rapid change as it is a side with more developed capacities. There was a seasonal variation in the relationship between both sides, though it remained below 10%. The dominant extensor-flexor relationship did not have as much statistical significance as the non-dominant extensors. The power of the extensors did not change significantly, whilst that of the flexors did, on both sides, similar to the phenomenon with the strength of the non-dominant flexor group.

This test was designed for this research, following the aspects proposed by Rodríguez[22] to assess strength:

– *Analyse the characteristics of the test in question,* as well as the strength requirements that are called upon in the search for efficiency and performance: we consider that the closed kinetic chain is functional, and that movements are required in football in which an activation of strength and power, with a point of support, are performed constantly during the changes of direction, turns, jumps, sprints, etc.
– *Select the type of main strength that has to be worked on and establish all the factors that result in the latter and that can be trainable:* likewise, with this test we will be obtaining maximum strength from the lower limbs when complete muscle chains are activated (flexion and extension) and not just isolated muscles, determining if there are deficiencies in the strength between both limbs, both hips, or muscle power, and, failing that, carry out training that aims to modify them.
– *At all times use the data provided by the corresponding assessment tests as a starting point for the design of the training programmes:* the data gathered from this research will contribute to the development of a functional technique to assess strength and power, and will therefore provide values that may be used as a reference for future assessments carried out under this procedure. In this way, we can target training towards the capacity of improving in accordance with the result and the time of the test.

  On the other hand, the key scientific criteria are also fulfilled to determine their use, proposed by the same author:
  - *Objectivity:* in this case, the examiner shall only position and guide the subject, but given that the results are obtained in physical magnitudes, they do not depend on the manipulation of the assessor.
  - *Reliability:* the results are measured with quantitative variables, approved physical units and with a high reproducibility rate[6].
  - *Validity:* with this test the strength and power were assessed reliably; and given that all the variables are controlled (lever arm, degree of movement, speed of the test, etc.) the results will always be valid as long as the procedure described is followed.

Once again, in accordance with Rodríguez[22], it should be considered which are the objectives for carrying out the test, completing the isokinetic dynamometry in closed kinetic chain with them:

– *The search for performance for a specific strength modality:* in this case the search for the production of maximum strength based on using low speed, in accordance with the Law of Hill[4,21], and counting on a complete muscle chain in agonist and antagonist direction.
– *Establish the possible tests in which the subject establishes improved performance rates and that could be the profile of sporting intervention:* with the seasonality established in the targets of this study, the test seeks to take reference from the pre-season and the end of the tournament, seeking to establish these performance rates and in the direction we wish to direct the performance.
– *Modulate the training process based on the results obtained:* given that referential parameters are established, training during the competition could be directed towards improving a capacity, which, being established by this test, is below that expected of it.

Conclusions

This work should be considered as a pilot study, however the trial proposed complies with the characteristics required to carry out a new test, with the demographic studied it is clear that it is applicable and that the assessment table presented here is useful in assessing individual performance. We consider it to be more appropriate to group the values for laterality to dominant and non-dominant, and not just right-left, due to the variation that there could be if they were organised with a total value without considering laterality, as seen in some studies that propose normative values. The values obtained in this study act as a reference parameter in this type of players according to the age group, level of competition and sport played, subject to studying an older population or other kinds of athletes. This suggested test is useful in the bio-mechanical assessment of maximum strength muscle performance and power at low speed in a functional muscle chain, that is multi-axial and that is hugely important for different sports, as it will enable the detection of muscle imbalances that carry risk (between both sides and between agonists and antagonists), for the prevention of injuries, as a global, functional movement is performed and in a movement that reduces that anterior movement of the tibia and the tension on the anterior cruciate ligament, and even for performing assessments after recovery in the case of injury.

Study limitations

The sample was small and not random, without being representative of all players in the professional second division for which the values apply to a pilot study. Likewise, the positions of play of the participants were not taken into account, which could lead to a difference in the values as each part of the team follows specific training.

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Peak oxygen uptake prediction in overweight and obese adults

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Summary

Peak oxygen uptake ($\dot{V}O_{2peak}$) is an important risk predictor for cardiovascular mortality and morbidity. The main aim of this study was to develop equations for estimating $\dot{V}O_{2peak}$ in sedentary and active overweight and obese subjects. The second objective was to compare the newly created equations with the standard equations that are widely used. One hundred and twenty-nine overweight and obese subjects (57 males), aged 18-50 years, were randomized into two groups: development group (n = 94) and validation group (n = 35). Individuals performed a modified Bruce protocol before (sedentary) and after (active) a 24-week weight loss program. Body composition was measured by bioelectrical impedance analysis. Stepwise multiple regression models were performed; the following factors: age, body weight (BW), lean body mass percentage (%LBM), and time of effort test (TIME) were included in the model. Four equations were developed: with and without effort test data for sedentary and active subjects. In the validation group, equations with and without TIME underestimated $\dot{V}O_{2peak}$ values in sedentary ($p = 0.002$ and $p = 0.008$, respectively), but not in active subjects. Furthermore, the equations derived from this study presented the greatest determination coefficients and the lowest values for the standard errors of estimate, for both development and validation groups. The following equation presented the highest determination coefficient, using effort test data for active subjects: $\dot{V}O_{2peak}$ (L/min) = -5.017 + (0.040×BW) + (0.127×TIME) + (0.046×%LBM) + (-0.010×AGE). The predicted $\dot{V}O_{2peak}$ values using the Bruce equation were significantly lower than the measured values in active participants ($p = 0.046$); whereas those predicted by ACSM's equation were significantly higher in comparison to the measured $\dot{V}O_{2peak}$ levels in sedentary and active subjects ($p < 0.001$), for both groups. In conclusion, equations developed in this study were adequate to predict $\dot{V}O_{2peak}$ in overweight and obese subjects, whilst the most commonly used equations in the literature, ACSM and Bruce, reported an inaccurate estimation of $\dot{V}O_{2peak}$.

Key words:
Oxygen consumption. Sedentary. Active. Prediction equations.

Predicción del consumo pico de oxígeno en adultos con sobrepeso y obesidad

Resumen

El consumo de oxígeno pico ($\dot{V}O_{2peak}$) es un predictor importante de riesgo cardiovascular. El principal objetivo de este estudio fue desarrollar ecuaciones para estimar el $\dot{V}O_{2peak}$ en sujetos con sobrepeso y obesidad, tanto sedentarios como activos. El objetivo secundario fue comparar las ecuaciones desarrolladas con ecuaciones ampliamente utilizadas. Ciento veintinueve sujetos con sobrepeso y obesidad (57 varones), de entre 18 y 50 años, fueron aleatoriamente divididos en dos grupos: de desarrollo (n=94) y de validación (n=35). Los sujetos realizaron un protocolo de Bruce modificado antes (sedentario) y tras un programa de pérdida de peso de 24 semanas (activo). La composición corporal se midió con impedancia bioeléctrica. Se realizaron modelos de regresión múltiple por pasos y los siguientes factores fueron incluidos en el modelo: edad, peso corporal (PC), porcentaje de masa magra (%MM) y tiempo máximo en la prueba de esfuerzo (TIEMPO). Fueron desarrolladas cuatro ecuaciones: con y sin dato de prueba de esfuerzo para sedentarios y activos. En el grupo de validación, las ecuaciones con y sin TIEMPO subestimaron los valores de $\dot{V}O_{2peak}$ en sedentarios (p = 0,002 y p = 0,008, respectivamente), pero no en sujetos activos. Por otra parte, nuestras ecuaciones presentaron los mayores coeficientes de determinación y los valores más bajos en errores estándar de estimación, tanto para el grupo de desarrollo como para el grupo de validación. La ecuación con el coeficiente de determinación más alto fue la desarrollada para los sujetos activos con datos de prueba de esfuerzo: $\dot{V}O_{2peak}$ (L/min) = -5,017 + (0,040×PC) + (0,127×TIEMPO) + (0,046×%MM) + (-0,010×EDAD). La ecuación de Bruce calculó valores de $\dot{V}O_{2peak}$ significativamente menores que los valores medidos en sujetos activos (p = 0,046); mientras que los valores predichos por la ecuación de ACSM fueron significativamente mayores en comparación con los valores de $\dot{V}O_{2peak}$ medidos, tanto en sedentarios como en activos (p <0,001), para ambos grupos. En conclusión, las ecuaciones desarrolladas en este estudio fueron adecuadas para predecir $\dot{V}O_{2peak}$ en sujetos con sobrepeso y obesidad, mostrando una mayor precisión que otras ecuaciones utilizadas en la literatura.

Palabras clave:
Consumo de oxígeno. Sedentario. Activo. Ecuaciones de predicción.

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Introduction

Peak or maximum oxygen consumption ($\dot{V}O_{2peak}$) represents cardiovascular fitness and is recognized as an important predictor for cardiovascular mortality and morbidity[1]. Moreover, $\dot{V}O_2$ is an important factor for exercise prescription and control[2]. $\dot{V}O_{2peak}$ measured by indirect calorimetry was used to assess cardiorespiratory fitness, using a variety of ergometers until the highest level of physiologic exertion is reached. Although $\dot{V}O_{2peak}$ testing is considered the "gold standard" for assessing aerobic capacity, it is often unfeasible and challenging to achieve a true value as its practice may be influenced by variables such as fatigue, motivation, injuries and physical limitations[3,4]. Therefore, a wide variety of equations to predict $\dot{V}O_{2peak}$ have been developed and published over the last 10 years[3]. Notwithstanding this, most of equations were developed for subjects within a normal weight range[5]. As a result, errors may occur when applying these equations to an overweight/obese population because obese individuals have lower cardiovascular fitness than lean subjects[6]. Therefore, specific equations for the overweight and obese population should be created. Cycle ergometer testing is a popular mode for assessing $\dot{V}O_{2peak}$ in overweight and obese individuals[7,8]. Cycle ergometer testing is influenced by peripheral fatigue and often do not reflect the actual consumption of oxygen[9-11]. Body composition, particularly lean body mass (LBM) may influence $\dot{V}O_{2peak}$. Since LBM is a reflection of metabolically active tissues, it should be considered when predicting $\dot{V}O_{2peak}$[12]. In addition, walking and running are more familiar and habitual modes of exercise for the average individual, thus it would be beneficial to develop equations for treadmill-specific tests[13]. Moreover, another factor that influences oxygen consumption is the level of physical activity; hence equations estimating $\dot{V}O_{2peak}$ should continue to include this variable[14,15]. Therefore, the aim of this study was two-fold. Firstly, to develop equations for estimating $\dot{V}O_{2peak}$ in sedentary and active overweight and obese subjects. Secondly, to compare the equations developed with other widely used equations. A cross-validation study with an independent sample was conducted to determine the accuracy of the new equations.

Material and method

Participants

The present study was part of a randomized clinical trial by *Nutrition and Physical Activity Programs for Obesity Treatments* (PRONAF according to its Spanish initials); the aim of which was to assess the usefulness of different types of physical activity and nutrition programs for the treatment of adult obesity. The inclusion criteria included subjects living in the region of Madrid, aged 18 to 50 years, overweight (Body Mass Index (BMI): ≥25 ≤29.9 kg/m^2) or obese (BMI: ≥30 ≤34.9 kg/m^2), sedentary (<30 min physical activity/day), normoglycaemic and non-smoker. In agreement with the guidelines of the Declaration of Helsinki[16], regarding research on human subjects, all participants were carefully informed about the possible risks and benefits of the present study and signed an institutionally approved document of informed consent. The PRONAF study was approved by the Human Research Review Committee of the University Hospital La Paz (HULP) (PI-643).

Study design

The intervention consisted of a 6-month diet and exercise-based program, with a particular focus on creating a behavior change. Participants entered the study in two sample waves (overweight and obese phase) they were then split into four randomly assigned groups, stratified by age and sex. The following groups were: strength, endurance, combined strength and endurance, and the control group, adhering to physical activity recommendations. All participants were measured pre- and post-intervention, in week 1 and week 24, respectively. Physical activity was assessed by a SenseWear Pro3 Armband™ accelerometer (Body Media, Pittsburgh, PA). Participants wore the monitor continuously for 5 days following general recommendations[17]. Daily energy expenditure was calculated using the Body Media propriety algorithm (Interview Research Software Version 6.0). Additionally, participants were asked to report physical activity habits and chronicle their food consumption during the intervention through a personal diary. From a total of 180 participants, who concluded the PRONAF study, 129 participants (57 males and 72 females) completed all the tests and were included in this study. Individuals of the control group were excluded from the analyzes because their physical activities were not supervised. Individuals were randomized into two groups: development group (*n*=94) and validation group (*n*=35), both groups included the same ratio of men to women and a proportional representation of training groups (strength, endurance and combined). With the development and validation groups representing 73% and 27% of the total sample, respectively. The data of development group were used to create the equations, while the data of validation group were used to validate these equations. According to classifications of physical activity level used elsewhere[13], individuals on baseline and post-intervention were considered sedentary and active, respectively. For both classifications, sedentary and active, two equations with the same variables were created; however, one considered the effort test, whilst the other did not. Moreover, measured $\dot{V}O_{2peak}$ was compared to predicted values by American College of Sport Medicine[18] and Bruce[19] equations (Table 1).

Diet intervention

Before initiating the intervention, negative energy balance was calculated for all participants; taking into account their own daily energy expenditure based on accelerometry data and the 3-day food log. As a result, they followed an individualized hypo-caloric diet with a 25-30% caloric restriction. Macronutrient distribution was set according to the Spanish Society of Community Nutrition recommendations[20].

Table 1. ACSM and Bruce equations utilized.

ACSM Equation
$\dot{V}O_{2peak}$ (L/min) = (((Speed×0.1)+(Speed×Grade×1.8)+3.5)/1000)×BW
Bruce Equation
$\dot{V}O_{2peak}$ (L/min) = ((85.42 - (13.73×Sex) - (0.409×Age) - (3.24×PAS) - (0.114×BW))/1000)×BW

$\dot{V}O_{2peak}$: peak oxygen uptake; speed in miles; grade in decimal percentage (10% = 0.1); BW: body weight (in kilograms); sex (1 = male, 2 = female); age in years; PAS: physical activity status (active = 1; sedentary = 2).

Exercise intervention

All exercise training groups followed an individualized training program; which consisted of three exercise sessions per week, for 22-weeks. All exercise sessions were carefully supervised by certified personal trainers. Details of the different protocols developed by the groups are described elsewhere[21].

Measurements

Cardiovascular fitness

Evaluation of cardiovascular fitness was conducted through a maximal effort test with the modified Bruce protocol, broadly used in overweight and obese populations[22,23], with a computerized treadmill (H/P/COSMOS 3PW 4.0, H/P/Cosmos Sports & Medical, Nussdorf-Traunstein, Germany). During testing, minute ventilation (VE), oxygen uptake ($\dot{V}O_2$), and carbon dioxide expiration ($\dot{V}CO_2$) were constantly measured through indirect calorimetry using the gas analyzer Jaeger Oxycon Pro (Erich Jaeger, Viasys Healthcare, Germany). $\dot{V}O_{2peak}$ was assessed using calculations that evaluated the volume and composition of expired gas using the Haldane transformation. All subjects were asked to refrain from intense exercise/physical activity 24 hours preceding the test. The measurements took place in similar environmental conditions. The analyzer was calibrated using certified gas mixtures before each run. Heart rate, in response to increasing exercise, was continuously monitored with a 12-lead electrocardiographic monitor. The following criteria were used to determine $\dot{V}O_{2peak}$: performance must attain ≥85% of the theoretical maximum heart rate, achieve a superior respiratory exchange ratio (RER) to 1.10 and perform until exhaustion[24]. The mean of the three highest measurements determined $\dot{V}O_{2peak}$[25]. All tests were evaluated by two researchers in a double blind process. The coefficient of variation between the assessments of these two studies and those of a highly-experienced expert was 1.3%. The time of effort test (TIME) was used as the independent variable in the equations, with regards to the effort test.

Body composition

A Tanita BC 418 body composition analyzer (Tanita Corp., Tokyo, Japan) was used for the bioelectrical impedance analysis (BIA). Subjects stood with the ball of their feet and heels in contact with the metallic electrodes. Once weight was recorded, subjects were instructed to grasp the hand grips and hold them down by their sides so that the metallic electrodes were in contact with the palm and thumb. The precision error for BIA measures in our laboratory was 0.52% of body fat percentage. All measurements were done in agreement with the normal protocol at least 3 hours after a meal (including drinks), and subjects were instructed to refrain from strenuous exercise 12 hours prior to the measurements. Subjects were asked to empty their bladder before the measurements. Females were not measured during their menstrual period[26]. Body weight (BW), fat mass percentage (%FM) and lean body mass percentage (% LBM) measures were obtained. Height was measured using a SECA stadiometer (range 80-200 cm, Valencia, Spain). BMI was calculated as: body mass (kg)/height (m)^2.

Statistical Analysis

The arithmetic mean and standard deviation were used as descriptive statistics. Stepwise multiple regression models were performed to verify the influence of certain variables in the $\dot{V}O_{2peak}$. In each case, the dependent variable was $\dot{V}O_{2peak}$ and the independent variables were age, gender, BW, BMI,%FM and %LBM, and TIME. If the slope for an independent variable was not found to be statistically significantly different than zero at $\alpha = 0.05$, that independent variable was excluded from the model. Independent variables selected for the final regressions were age, BW and %LBM and TIME. The validity of the model was assessed through the analysis of colinearity statistics and Q-Q plots of unstandardized residuals. Pearson correlation coefficients (*r*) and determination coefficients (R^2) were calculated. Differences between the coefficients of determination from the validation and elaboration groups would be within 0.075. Standard error of estimate (SEE) was calculated. Bland-Altman plots 95% limits of agreement analysis (LoA) were constructed to determine the level of agreement between the measured and predicted $\dot{V}O_{2peak}$ for each equation. In addition, Lin's concordance correlation coefficients were obtained and classified according McBride[27] where values >0.99 is considered almost perfect, >0.95-0.99 substantial, >0.90-0.95 moderate and ≤ 0.90 poor. Independent samples t test was used to compare characteristics at baseline between development and validation groups. Paired samples t tests were performed to compare measured and predicted $\dot{V}O_{2peak}$ values. The analyzes were conducted using SPSS statistical software (Version 17; SPSS, Inc, Chicago, IL) and MedCalc (Medical Calculator) software (version 12.1.4.0). The statistical significance level was set at 5% (p <0.05).

Results

The characteristics of participants at baseline were similar in the development and validation groups (Table 2). Percentages of men were 43.6 and 45.7 in the development and validation group, respectively. All tests were considered maximum, in accordance to the criteria described in methods. Multiple regression models with exercise included BW, TIME, %LBM and age. Models without exercise included the same variables, except TIME. Equations before (sedentary, 1a and 1b) and after (active, 2a and 2b) the intervention were developed (Table 3).

Table 2. Characteristics at baseline.

	Development Group (n=94)	Validation Group (n=35)
Age	37.3 ± 7.3	39.0 ± 8.9
Body weight (kg)	88.8 ± 13.8	88.0 ± 11.9
Height (cm)	169.1 ± 9.3	168.2 ± 9.5
Body mass index (kg/m^2)	30.9 ± 3.2	31.0 ± 2.6
Percentage fat (%)	35.6 ± 7.0	36.1 ± 7.5
Fat mass (kg)	31.7 ± 8.3	31.8 ± 8.0
Lean body mass (kg)	54.2 ± 10.0	53.4 ± 9.6

Data are presented as mean ± SD. No significant differences were found between development and validation groups for any of the variables.

Table 3. Equations obtained in this study.

Equation 1a (sedentary with effort test)

$$\dot{V}O_{2peak}\ (L/min) = -4.119 + (0.038\times BW) + (0.147\times Time) + (0.027\times \%LBM) + (-0.014\times Age)$$

Equation 1b (sedentary without effort test)

$$\dot{V}O_{2peak}\ (L/min) = -3.519 + (0.045\times BW) + (0.050\times \%LBM) + (-0.020\times Age)$$

Equation 2a (active with effot test)

$$\dot{V}O_{2peak}\ (L/min) = -5.017 + (0.040\times BW) + (0.127\times TIME) + (0.046\times \%LBM) + (-0.010\times Age)$$

Equation 2b (active without effort test)

$$\dot{V}O_{2peak}\ (L/min) = -4.849 + (0.046\times BW) + (0.069\times \%LBM) + (-0.010\times Age)$$

$\dot{V}O_{2peak}$: peak oxygen uptake; BW: body weight (in kilograms); TIME: time of effort test (in minutes); %LBM: lean body mass percentage.

Table 4. Measured and predicted peak oxygen uptake in development group (n=94).

Sedentary	**Measured $\dot{V}O_{2peak}$**	**Equation 1a**	**Equation 1b**	**ACSM (2006)**	**Bruce *et al.* (1973)**
Mean ± SD (L/min)	2.830 ± 0.805	2.729 ± 0.707	2.786 ± 0.691	3.630 ± 0.888#	2.876 ± 0.866
95% LoA (L/min)	---	-0.074 ± 0.374	-0.017 ± 0.411	0.826 ± 0.677	0.073 ± 0.483
r	---	0.885*	0.859*	0.684*	0.835*
R^2	---	0.757	0.738	0.468	0.697
SEE (L/min)	---	0.383	0.414	1.077	0.491
CCC	---	0.874	0.849	0.460	0.830
Active	**Measured $\dot{V}O_{2peak}$**	**Equation 2a**	**Equation 2b**	**ACSM (2006)**	**Bruce *et al.* (1973)**
Mean ± SD (L/min)	3.038 ± 0.852	3.065 ± 0.782	3.052 ± 0.755	3.625 ± 0.889#	2.941 ± 0.832#
95% LoA (L/min)	---	0.026 ± 0.339	0.013 ± 0.401	0.586 ± 0.520	-0.097 ± 0.464
r	---	0.917*	0.882*	0.825*	0.849*
R^2	---	0.841	0.778	0.681	0.721
SEE (L/min)	---	0.342	0.403	0.790	0.477
CCC	---	0.914	0.876	0.672	0.842

*$p<0.001$; #$p<0.05$ - mean differences between predicted and measured values; analysis of the 95% limits of agreement (LoA) expressed as bias (±1.96 SD diff); SEE: standard error of estimate; CCC: concordance correlation coefficient.

The equations derived from this study reported the greatest determination's coefficients and lowest values of SEE, for both development and validation groups. In the development group, $\dot{V}O_{2peak}$ predicted values, using the Bruce equation, were significantly lower than the measured values after the intervention ($p = 0.046$); whereas those predicted by ACSM's equation were significantly higher compared to the measured $\dot{V}O_{2peak}$ levels before and after the intervention ($p <0.001$) (Table 4). In the validation group, equations 1a and 1b underestimated $\dot{V}O_{2peak}$ values at baseline ($p = 0.002$ and $p = 0.008$, respectively); similarly, Bruce's equation also underestimated these values at post intervention ($p = 0.019$). Equally for the elaboration group, ACSM's equation overestimated $\dot{V}O_{2peak}$ measured values, before and after the intervention ($p <0.001$) (Table 5). Before the intervention, concordance correlation coefficients were considered "poor" for all the equations. However, the highest values were reported by the equations from the present study. After the intervention, concordance correlation coefficients were classified as "moderate" for the equations 2a and 2b in the validation group. ACSM's equation presented the lowest values of concordance correlation coefficients in all the cases.

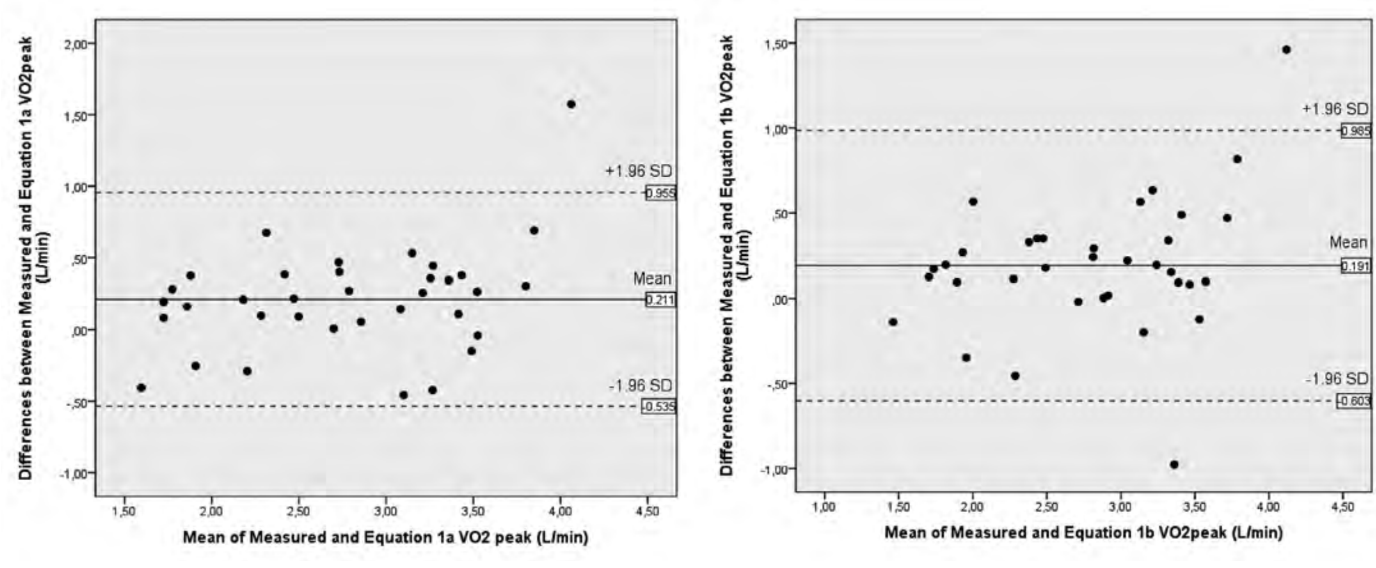
Bland and Altman plots indicated that, on average, the equations of this study in the validation group underestimated $\dot{V}O_{2peak}$ by 0.200L/min (standard errors of mean) in sedentary subjects ($p <0.05$) (Figure 1). However, the standard errors of mean for the same subjects for ACSM and Bruce equations were -0.707 L/min and 0.076 L/min, respectively.

Table 5. Measured and predicted peak oxygen uptake in validation group (n=35).

Sedentary	**Measured $\dot{V}O_{2peak}$**	**Equation 1a**	**Equation 1b**	**ACSM (2006)**	**Bruce *et al.* (1973)**
Mean ± SD (L/min)	2.888 ± 0.778	2.678 ± 0.653$^{\#}$	2.698 ± 0.665$^{\#}$	3.596 ± 0.740$^{\#}$	2.813 ± 0.776
95% LoA (L/min)	---	-0.211± 0.373	-0.191 ± 0.396	0.707 ± 0.475	-0.075 ± 0.469
r	---	0.879*	0.860*	0.805*	0.817*
R^2	---	0.772	0.740	0.648	0.667
SEE (L/min)	---	0.436	0.448	0.873	0.483
CCC -	--	0.828	0.821	0.556	0.814
Active	**Measured $\dot{V}O_{2peak}$**	**Equation 2a**	**Equation 2b**	**ACSM (2006)**	**Bruce *et al.* (1973)**
Mean ± SD (L/min)	3.019 ± 0.859	3.025 ± 0.759	2.991 ± 0.746	3.516 ± 0.756$^{\#}$	2.846 ± 0.753$^{\#}$
95% LoA (L/min)	---	0.004 ± 0.294	-0.030 ± 0.337	0.494 ± 0.397	-0.176 ± 0.417
r	---	0.941*	0.921*	0.886*	0.874*
R^2	---	0.885	0.848	0.785	0.764
SEE (L/min)	---	0.298	0.343	0.649	0.461
CCC	---	0.934	0.912	0.738	0.846

*$p<0.001$; $^{\#}p<0.05$ - mean differences between predicted and measured values; analysis of the 95% limits of agreement (LoA) expressed as bias (±1.96 SD diff); SEE: standard error of estimate; CCC: concordance correlation coefficient.

Figure 1. Bland and Altman's limits-of-agreement plot between measured and estimated $\dot{V}O_{2peak}$; calculated through equations 1a (sedentary with effort test) (left) and (sedentary without effort test) (right) in subjects of the validation group.



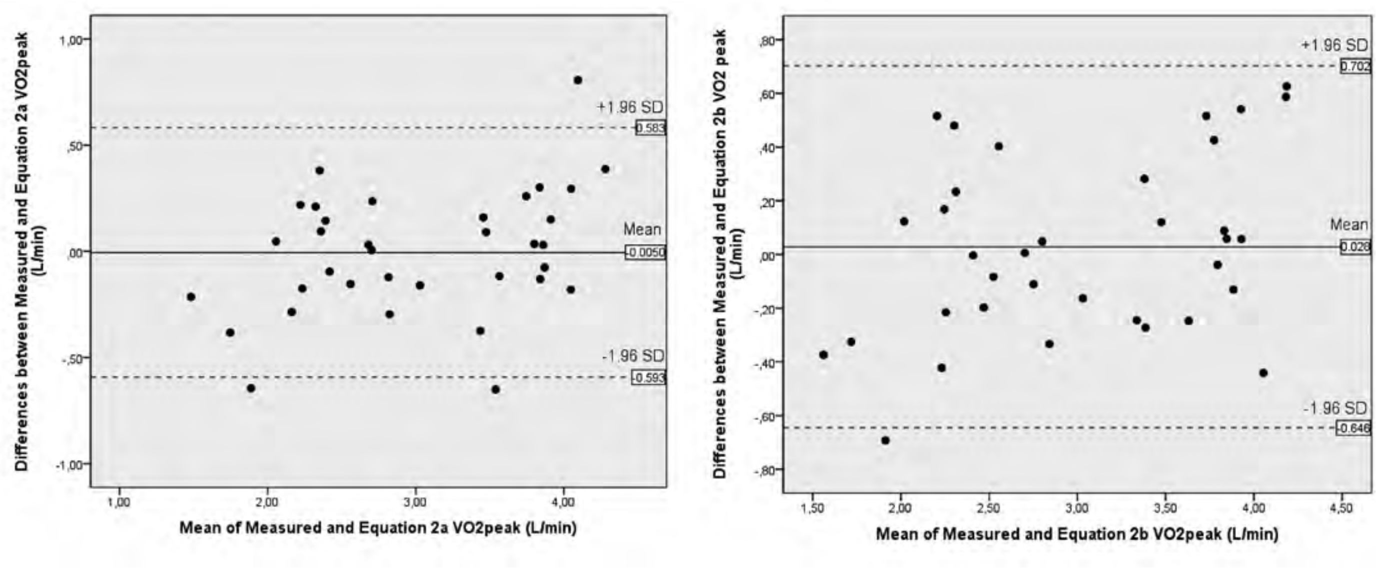
——— Observed average agreement; - - - - - - 95% Limits of agreement: $y = 0$ signifies the line of perfect agreement.

On the other hand, when the subjects were active, the equations predicted $\dot{V}O_{2peak}$ well, with the mean differences close to zero (Figure 2). ACSM and Bruce equations presented standard errors of mean of -0.496 and 0.174, respectively.

Discussion

The purpose of the present study was to develop equations for predicting $\dot{V}O_{2peak}$, with and without effort test data in overweight

Figure 2. Bland and Altman's limits-of-agreement plot between measured and estimated $\dot{V}O_{2peak}$; calculated through equations 2a (active with effort test) (left) and 2b (active without effort test) (right) in subjects of the validation group.



Observed average agreement; 95% Limits of agreement: *y* = 0 signifies the line of perfect agreement.

and obese subjects, before and after a weight loss intervention. Our results revealed that BW, %LBM, age and TIME, used in combination, is an adequate method to predict $\dot{V}O_{2peak}$ in this population, explaining almost 80% of the variation in $\dot{V}O_{2peak}$. Moreover, our data showed that equations commonly used in the literature inaccurately estimate $\dot{V}O_{2peak}$.

Several studies found differences between men and women in the oxygen consumption[28,29]. In our data, other variables, such as BW and %LBM, were better predictors than gender. Body composition, particularly muscle mass, seems to have a stronger correlation with the development of some physical capacities than genetic sexual characteristics[30,31]. Furthermore, hormone responses also seem to relate to body size, and greater values of BMI could blunt a sexual dimorphism[32]. It is important to note that many variables influence the muscle mass percentage values obtained by bioimpedance. For this reason, it is recommended that the conditions should be the same, as previously indicated in this study's methodology, to ensure better precision in the equations.

Besides BW and %LBM, age was also included as a predictor of $\dot{V}O_{2peak}$ in the equations of this study. This is in agreement with the results of Loe *et al*[29], which indicated that the oxygen consumption decreases approximately 6% every decade between the second and fifth decade of life in both genders.

Furthermore, TIME was included in the equations instead of velocity, since the Bruce protocol is not graded and time is a simple and easy variable to measure[33].

Although our equations at baseline in the validation group presented significantly different values compared to measured values, equations developed in the present study obtained the best concordance correlation coefficients and greatest determination coefficients compared to ACSM and Bruce equations. Moreover, these equations reported lower values than measured ones. Nonetheless, when working with obese individuals, who commonly have some pathology associated with excess weight, it is better to underestimate than overestimate $\dot{V}O_{2peak}$ predictions. A greater health risk could be incurred if $\dot{V}O_{2peak}$ values were overestimated, and subsequently utilized for the purpose of an intervention program[34]. ACSM's equation overestimated all $\dot{V}O_{2peak}$ values in this study as well as in other studies[35-37]. Also, determination coefficients of this study were higher than coefficients showed in other studies in different populations[8,14,28,38,39]. It is important in the selection of an equation to consider certain factors, such as population, medical conditions or medication, the mode of ergometer in terms of safety, familiarity and availability[4]. Therefore, our equations could be used in other populations with similar characteristics to our sample.

The prediction of $\dot{V}O_{2peak}$ through models without exercise can be a viable alternative for the evaluation of cardiorespiratory fitness in epidemiological studies. It is beneficial for prescribing exercise programs when is not possible to perform an effort test and to estimate $\dot{V}O_2$, and relate it to life expectancy[40]. Bruce and colleagues[19] established prediction equations without exercise, demonstrating that oxygen consumption could be predicted by variables such as gender, age, weight and physical activity habits. These authors were the first to use adults and to consider lifestyle factors such as daily physical activity, in addition to anthropometric characteristics. However, in our study Bruce equation showed significant differences in the estimated oxygen consumption after the intervention. This fact may be due to the sample used by the authors that included elderly individuals which probably altered the regression results, particularly with improving $\dot{V}O_{2peak}$ levels after a training period[19]. Furthermore, Bruce equation did not use the effort test; similar to our equations, specifically those without effort test data presented a satisfactory estimation of $\dot{V}O_{2peak}$.

According to Eston *et al.*[14] sedentary individuals are understandably unfamiliar to the associated signals of exertion emanating from acute cardiorespiratory, thermal, and metabolic changes associated with an increase in exercise intensity. Our results reported improvement in the accuracy of $\dot{V}O_{2peak}$ prediction after the intervention, as suggested by others[15,41].

Duration of the intervention allowed verifying changes in predictive variables due to training, detected by models with and without exercise. Our data contributed to the rectification of the lack of studies in clinical populations, since there are few studies specifically focused on the development of models applied to special groups. And when they are presented, they have a low potential for widespread use due to reduced samples used in their development. In addition, BIA, an easy and low cost instrument, prevents measurement errors of the evaluators and expands its use to different populations. Skinfolds, for example, require well-trained operators to adequately collect data and often use other equations to predict the percentage of fat, which increase errors[42]. In this line, dual X-ray absorptiometry is still an expensive and impractical procedure for general population.

Limitations of this study include the relatively small sample size and joint treatment for females and males. However, the difference between genders for oxygen consumption was reflected in the equations when considering the lean body mass. Additionally, we have to take into account that the predicted $\dot{V}O_{2peak}$ values would be the theoretical value obtained by the subject in a Bruce protocol test on the treadmill with indirect calorimetry.

In conclusion, equations developed in this study including the variables age, BW, %LBM and TIME, were adequate to predict $\dot{V}O_{2peak}$ in overweight and obese subjects. ACSM and Bruce equations, commonly used in the literature, showed inaccurately estimation of $\dot{V}O_{2peak}$.

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Do the changes in acid-base status and respiratory gas exchange explain the voluntary termination of a test performed above the maximum lactate steady state?

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Summary

Stress tests at a constant load have been a great subject of interest for physiologists to analyze the factors which lead to voluntary termination. Several factors are responsible for voluntary termination in such efforts. The objective of this work was to study if any of the respiratory gas exchange and acid-base status variables could justify fatigue during a constant load test performed above maximum lactate steady state. Twelve amateur road cyclists performed a 30 min test on a road bicycle at an intensity of 5% above maximal lactate steady state ($MLSS_{5\%}$). Gas exchange and acid-base data were analyzed at rest and at 5, 10 and 15 min during the test. A two-way analysis of variance for repeated measures was conducted to test the effect of time and group (An alpha of 0.05 was used as the level of statistical significance for all analyses). The group that did not finished the $MLSS_{5\%}$ (N-$MLSS_{5\%}$) started from a more pronounced state of metabolic acidosis than the group that ended the test (Y-$MLSS_{5\%}$) (44,6 versus 41,7 nm/l H^+) ($F_{1,9}$ = 9.43, P = .013; η^2 = 0.51). During the test, the acid-base status was greater in the N-MLSS group than the Y-MLSS group (at 15 min, 44,3 for the Y-MLSS group and 49,2 for the N-MLSS group). Neither of the two groups showed an altered ventilation perfusion ratio, estimated by the V_D/V_T relationship, although the behaviour of PET CO_2 could suggest this outcome. A change in the breathing pattern (V_T/T_I) does not explain the termination of steady exercise in the N-MLSS group. In conclusion the results of this study do not explain the voluntary termination of exercise in a group of cyclists (N-MLSS) that made a steady effort over the maximal lactate steady state. This finding reinforces the hypothesis that fatigue occurs due to an integration of the afferent feedback of various physiological systems.

Key words:
Maximum lactate steady state. Fatigue. Acid-base status. Respiratory gas exchange.

¿Pueden los cambios del estado ácido-base e intercambio de gases respiratorios explicar el abandono de una prueba realizada por encima del máximo estado estable de lactato?

Resumen

Las pruebas de esfuerzo realizadas a intensidad constante han sido objeto de interés de los fisiólogos, analizando los factores responsables del abandono. El objetivo ha sido estudiar si variables de intercambio respiratorio y del estado ácido-base podrían justificar la fatiga durante un esfuerzo constante realizado a una intensidad superior al máximo estado estable de lactato. Doce ciclistas realizaron una prueba en su bicicleta durante 30 min a una intensidad del 5% por encima del máximo estado estable de lactato ($MLSS_{5\%}$). Se analizaron determinados parámetros de intercambio de gases respiratorios y del estado ácido-base en reposo, a los 5, 10 y 15 min de la prueba. Para determinar el efecto del tiempo y del grupo se realizó un análisis de varianza repetido de dos factores. Para valorar las posibles diferencias estadísticas se consideró un valor de alfa de 0,05. El grupo que no finalizó la prueba $MLSS_{5\%}$ (N-$MLSS_{5\%}$) comenzó con un estado de acidosis metabólica mayor que el grupo que si completó la prueba (Y-$MLSS_{5\%}$) (44,6 *versus* 41,7 nm/l H^+) ($F_{1,9}$ = 9,43, p = 0,013; η^2 = 0,51). Durante la prueba, el estado ácido-base fue mayor en el grupo N-MLSS que en el Y-MLSS (a los 15 min, 44,3 para el grupo Y-MLSS y 49,2 para el grupo N-MLSS). Ninguno de los dos grupos mostró una alteración de la relación ventilación/perfusión (relación V_D/V_T), aunque el comportamiento de la PET CO_2 podría sugerirlo. El cambio en el modelo respiratorio (V_T/T_I) tampoco explica el abandono del ejercicio estable en el grupo N-MLSS. En conclusión, los resultados de este estudio no explican el abandono del ejercicio en un grupo de ciclistas (N-MLSS) durante el esfuerzo realizado. Este hallazgo refuerza la hipótesis relativa a que la fatiga sucede debido a la integración de la retroalimentación aferente de diversos sistemas fisiológicos.

Palabras clave:
Estado de máximo estado estable de lactato. Fatiga. Estado ácido-base. Intercambio de gases respiratorios.

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Introduction

Stress tests at a constant load have been developed from two points of view: theoretical and practical. On the one hand, the interest of physiologists was focused on the physiological mechanisms that may explain fatigue as many endurance sports present a relatively constant intensity. For example, in track athletics and the triathlon, the fastest pace an athlete can sustain during an endurance event is strongly related to the rate of aerobic energy production approximating the threshold of blood lactate accumulation (LT), or the onset of hyperventilation (ventilatory threshold, VT)[1,2]. This has motivated many researchers to identify a variety of different physiological variables (*i.e.* maximum oxygen uptake, anaerobic threshold, lactate threshold, ventilatory threshold) as key predictor variables. Thus, the reasons for researchers to study steady state exercises can be summarized in two major goals: 1) to discover the physiological mechanisms that lead to fatigue when performing tests at a constant load at different intensities[3-6]; and 2) to identify the physiological factors that may predict better performances.

There are a several factors responsible for inducing local muscle fatigue, including the failure of sarcoplasmic reticulum calcium release[7], impaired sodium/potassium pump activity[3,8,9], and the slowed cross-bridge cycling[10] due to a variety of metabolic mediators including reactive oxygen species[11]. It is also clear that these muscle factors stimulate a number of neural pathways[12] that ultimately lead to reduced central motor drive and neural activation[13]. It is highly likely that many of these factors are redundant, and may be more or less prominent in leading to termination of effort under different circumstances. The link among metabolic demand, cardiovascular control (regulation of cardiac output and local muscle blood flow), neural pathways and nervous central integration (The Central Governor Model) will explain fatigue in all of its dimensions[14-17]. All efferent signals would be processed by the central command that would send a signal to all physiological systems involved or not during the exercise performance in order to protect the individual from a catastrophic failure that would force them to stop the exercise.

Based on everything noted above, the objective of this work was to study if any of the respiratory gas exchange variables and the concentration of lactate and protons could justify the fatigue that can be experienced during an exercise test at a constant load above maximum lactate steady state (MLSS). Some parameters of respiratory gas exchange, such as the ratio of the volumes of physiological dead space and tidal volume (V_D/V_T), could be modified during an exercise at a constant load. Likewise, a disturbance of acid-base status could determine a state of metabolic acidosis causing the termination of exercise. Therefore, it was hypothesized that the gas exchange and acid-base variables in MLSS+5% would explain the fatigue observed at intensities above MLSS.

Material and method

Subjects

Twelve amateur road cyclists (elite-sub23 category) were selected for this investigation (21.0 years (2.6), 179.8 cm (7.5), 72.2 kg (9.0)). The athletes had an amateur competition experience of 2.8 (1.0) years, and in particular, some of these athletes ranked among the best cyclists in Spain (i. e., top 20 in the 2008 ranking of the *"Real Federación Española de Ciclismo"* [Royal Spanish Cycling Federation] (RFEC)). A physical examination before the start of the study was used to ensure that each participant possessed a good health status. The benefits and risks of the protocol were explained and the subjects signed an informed consent form. The study obtained the approval of the ethical committee of the Technical University of Madrid.

Experimental design

Each subject carried out two constant load tests of 30 minutes corresponding to MLSS and 5% above (MLSS $_{+5\%}$). These steady state tests were carried out with a 48 h interval between tests. Each cyclist performed all tests at the same time and under similar environmental conditions (22.8 ºC (0.6) and 62.4% (4.4) relative humidity). Subjects were asked to refrain from hard physical work and consumption of any medication or stimulants for at least 24 before each experimental session.

During the tests, subjects adopted the conventional upright cycling posture. This posture is characterized by a trunk inclination of ~75º and by the subject placing their hands on the handlebars with elbows slightly bent (~10º). Before the tests, each cyclist adjusted the corresponding ergometer and used their own clip-on pedals.

Gas exchange data were collected continuously during two steady state tests using an automated breath-by-breath system (Jaeger Oxycon Pro gas analyzer, Erich Jaeger, Viasys Healthcare, Germany). The following variables were recorded during the tests: oxygen uptake (VO_2), carbon dioxide output (VCO_2), respiratory exchange ratio (RER), ventilation (VE), respiratory rate (RR), tidal volume (V_T), inspiratory time (T_I), expiratory time (T_E) and the relationships between T_I and total time (T_{TOT}) (duty cycle; T_I/T_{TOT}), V_T and T_I (V_T/T_I), V_T and T_E (V_T/T_E) and V_D and V_T (V_D/V_T). The values were averaged for a 15 s period. A 12-lead electrocardiogram (ECG; Viasys Healthcare, Germany) was continuously recorded during the tests to determine heart rate (HR).

The two steady state tests were performed on a road bicycle fitted with a SRM powermeter (Schoberer Rad Messtechnik SRM, Jülich, Germany). The bicycle was then mounted on a Tacx CycleForce Grand Excel ergometer (Technische Industrie Tacx BV, Netherlands). The Tacx CycleForce Grand Excel was not used for analysis purposes and was only used as a platform to mount the test rig on. Participants were allowed to use their own pedals and saddle. Height and reach were adjusted to match the participant's own bicycle as closely as possible.

The first constant workload trial was performed at an intensity corresponding to the mean point of VT, previously calculated by a maximal incremental test. Another 30 min test with a maximal workload (W_{max}) of 5% higher intensity was performed 48 h later if, during the first test, a steady state or a decrease of [La$^-$] was observed (MLSS+5% intensity). Inversely, if the [La$^-$] increased continuously or the exercise was interrupted due to the subject's fatigue during the first 30 min test, the workload was decreased by 5% W_{max}. Only two steady state tests were necessary to determine MLSS: MLSS and MLSS$_{+5\%}$ intensities. MLSS was defined as the highest workload that can be maintained with an increase in [La$^-$] lower than 1.0 mmol/l during the final 20 min of the constant load tests[18-22]. The Borg's Scale 6-20 was used to evaluate RPE at the end of the constant workload trials[23].

Blood processing and data analysis

Before each test, an 18G catheter was inserted into a forearm vein for arterialized venous blood sampling. Arterialization was ensured by warming the forearm with an electric heating pad[24,25]. Arterialized venous blood samples were drawn prior to and during exercise at different times in order to determine the concentration of different metabolites: at the moment when maximal effort was deemed to have been reached in the incremental test and every 5 min throughout the steady state tests (0, 5, 10, 15, 20, 25 and 30 min) and at exercise termination if the test could not be maintained.

Blood samples were collected (1 ml) into pre-heparinized syringes (PICO 50, Radiometer, Copenhagen, Denmark) and analyzed immediately using a blood gas analyzer (ABL 77, Radiometer, Copenhagen, Denmark). Hydrogen ion concentration ([H^+]), partial pressure of carbon dioxide (PCO_2), sodium concentration ([Na^+]), potassium concentration ([K^+]), chlorine concentration ([Cl^-]), bicarbonate concentration ([HCO_3^-]), base excess (EB) and anion gap (AG) were measured. Blood lactate concentration ([La^-]) was analyzed by the enzymatic method (YSI 1500, Yellow Springs Instruments Co., Ohio, USA). The strong ion difference (SID) was calculated as the difference between strong cations ([Na^+] + [K^+] + [Ca^{+2}]) and strong anions ([Cl^-] + ([La^-]).

Two blood samples were drawn in rapid succession at determined sample points during the constant workload trials (0, 10, 20 and 30 min). The first 1 ml sample was taken for the measurements explained above. A second 3 ml sample was collected in EDTA tubes and used for the measurement of catecholamine (epinephrine, norepinephrine and dopamine) concentrations by high-performance liquid chromatography.

Of the 12 subjects, 4 subjects completed the constant trial at $MLSS_{+5\%}$ (group Y-$MLSS_{5\%}$) and 8 did not (group N-$MLSS_{5\%}$). The gas exchange variables were averaged every 5 minutes (0, 5, 10, 15, 20, 25 and 30 min), corresponding to the determinations of the variables of acid-base status ([La^-], [H^+], PCO_2, [Na^+], [K^+], [Cl^-], SID, [HCO_3^-], EB and AG).

Statistical analysis

All data was reported as mean (±SD). The Shapiro-Wilk test was used to assess the normality of the data. A two-way analysis of variance for repeated measures (ANOVA) was conducted to test the effect of time (within-subject independent variable with 5 levels for acid-base variables and 4 levels for gas exchange variables) and group (between-subject independent variable: Y-$MLSS_{5\%}$ and N-$MLSS_{5\%}$ groups) on the gas exchange and acid-base dependent variables. The Bonferroni test was applied post hoc and partial η^2 was used as the effect size index. For data that violated the assumption of normality the Mann-Whitney test was applied. The effect size $\eta^2=Z^2/(N-1)$ for Mann-Whitney test was calculated[26]. Thresholds of .01, .06, and .14 for small, medium, and large effect size, respectively, were used[27]. All analyses were carried out with SPSS version 19 (Chicago, Illinois, USA). An alpha of 0.05 was used as the level of statistical significance for all analyses.

Results

Acid-base balance

The differences between the two groups in averaged acid-base parameters are presented in Table 1. At rest, the [H^+] levels for the Y-$MLSS_{5\%}$ group were significantly lower than those obtained by the N-MLSS group ($F_{1,9}$ = 9.43, P = .013; η^2 = 0.51) and these differences were maintained at the different times evaluated ($F_{4,36}$ = 0,74; P = 0,572). The [SID] of the two groups were not significantly different: ($F_{1,9}$ = 0.42, P = .532).

Measured ions that determine the SID were significantly lower at rest, at the beginning and at 15 min for Na^+ in the Y-$MLSS_{5\%}$ group (Z = 2.01; P =0.024; η^2 = 0.37 at rest, Z = 2.40; P =0.008; η^2 = 0.52 at the beginning; Z = 2.18; P = 0.012; η^2 = 0.37 at 15 min), for K+ significantly higher at the beginning and 15 min for the group N-$MLSS_{5\%}$ (Z = 2.64; P = 0.002; η^2 = 0.63 at the beginning; Z = 2.08: P =0.021; η^2 = 0.39 at 15 min), significantly lower at the beginning for the Ca^{2+} (Z = 2.72; P = 0.003; η^2 = 0.67) for the N-$MLSS_{5\%}$ group and showed no differences for the Cl^- ($F_{1,9}$ = 0.27, P = .616) and for the HCO_3^- ($F_{1,9}$ = 0.27, P = .616) between the two groups studied. Finally, the plasma L- showed no significant difference ($F_{1,9}$ = 0.27, P = .617) between the two groups studied. AG levels in the group that completed the test were not significantly different to those obtained by the group that did not complete it ($F_{1,9}$ = 2.64, P = .139).

For both groups, the test carried out did not correspond to a maximum steady state test[10] because lactate concentration exceeded 1 mmol /L at 20 min during the constant load tests: Y-MLSS 2.8 (0.5) and 4.8 (1.3) and N-MLSS 3.3 (1.1) and 5.2 (2.3), for 5 to 15 minutes. The $PpCO_2$ did not show significant differences ($F_{1,9}$ = 1.49; P = .253) between the two

Table 1. Differences between two groups in averaged acid-base parameters during a test 5% above maximal lactate steady state.

	Y $MLSS_{5\%}$ (N = 4)				N $MLSS_{5\%}$ (N = 11)			
Time	[H^+] (nmol/l)	[SID] (mmol/l)	AG (mmol/l)	[HCO_3^-]	[H^+] (nmol/l)	[SID] (mmol/l)	AG (mmol/l)	[HCO_3^-]
rest	41,7 (±2,4)	34,4 (±2,1)	8,0 (±1,2)	26,5 (±1,7)	44,6 (±2,1)	33,6 (±2)	7,8 (±1,2)	25,9 (±3)
0	39,4 (±1,6)	32,3 (±1,5)	8,4 (±1,6)	23,7± (3,2)	43,5 (±2)	33,2 (±1,6)	9 (±1,9)	24,2 (±2,2)
5	43,5 (±2,8)	31,7 (±2,7)	13 (±1,5)	20,6 (±3,1)	45,7 (±2,2)	32,6 (±0,9)	13,7143 (±1,6)	21 (±0,8)
10	43,8 (±4,1)	31 (±1,3)	14,3 (±2)	19,7 (±2,4)	47,7 (±2,1)	30,9 (±2)	16,6 (±1,7)	17,6 (±2)
15	44,3 (±4)	28,6 (±2,4)	15,1 (±2,1)	17,4 (±2,8)	49,2 (±2,8)	30,3 (±2,9)	17,7 (±2,4)	16,7 (±2,9)

groups studied. Although, the lactate concentration of the Y-MLSS$_{5\%}$ group was not significantly different from the N-MLSS$_{5\%}$ group ($F_{2,36}$ = 0.12; P = .771), they were higher.

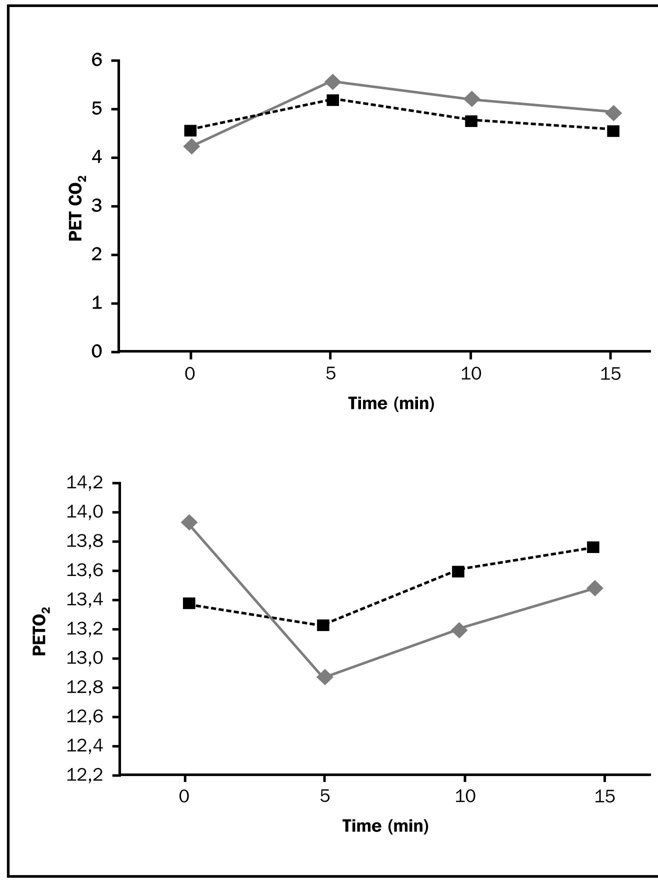
Gas Exchange variables

The change in the breathing pattern (V_T/T_i and V_T/T_e) could be due to central and peripheral factors (Clark and von Euler, 1972, Dempsey *et al*., 1986) that may be responsible for the termination of the test by the N-MLSS cyclists group. However, in the present study, V_T/T_i values, a representative central generator respiratory parameter, showed no significant differences between the two groups, rejecting the hypothesis of a change in the breathing pattern to explain the termination of steady state exercise, although ventilation at 5, 10 and 15 min was not significantly higher in the N-MLSS group.

Table 2 shows the results obtained in gas exchange data averaged variables. The averaged VO_2, VCO_2, HR and VE, showed no significant differences between the two groups: VO_2 (in L/min $F_{1,9}$ = .33; P = .580; in ml/min/Kg $F_{1,9}$ = .01; P = .933); VCO_2 ($F_{1,9}$ = 0.45; P = .522); HR ($F_{1,9}$ = .21; P = .655); V_E ($F_{1,9}$ = 0.24; P = .638). At 5, 10 and 15 minutes the PET CO_2 of the Y-MLSS$_{5\%}$ group showed higher values that of the N-MLSS$_{5\%}$ group (Figure 1a; $F_{1,12}$ = 3.53; P = .034; η^2 = 0.27;). PET O_2 resting values of the Y-MLSS$_{5\%}$ group were higher than those of the N-MLSS$_{5\%}$ group, but no significant differences between groups were observed at 5, 10 and 15 min ($F_{2,13}$ = 6.74; P = .002; η^2 = 0.43; Figure 1b).

Indirect parameters of ventilation/perfusion ratio (V_D/V_T) and respiratory pattern (V_T/T_i, V_T/T_e) response during the constant workload trials are represented in Figure 2. No differences were demonstrated between the two groups for V_D/V_T ($F_{1,9}$ = 0.02; P = .906) and V_T/T_i ($F_{1,8}$ = 0.01; P = .960).

Figure 1. PET CO_2 (side a) and PO_2 (side b) data for two groups at rest and during a test 5% above maximal lactate steady state. In solid line the Y-MLSS group and broken line the N-MLSS group.



Discussion

The main finding of this study demonstrated the physiological reasons that explain exercise termination or fatigue at 5% intensity above maximal steady state lactate (>5% MLSS).

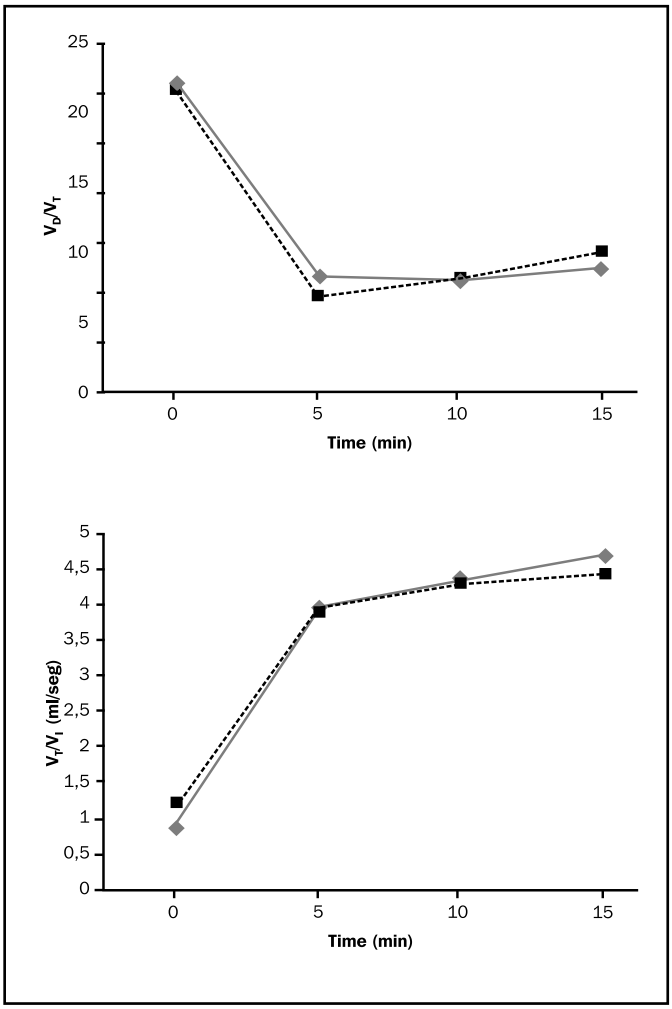
Firstly, it is noteworthy that the N-MLSS group started from a more pronounced state of metabolic acidosis. This might indicate that the rest time between the two stable tests (48 hours) was insufficient for cyclists from the N-MLSS group. It is possible that the recovery time after intense exercise could affect the muscular acid status, conditioning the next steady state test[28]. As noted by McKelvie *et al*[29], it is possible that the recovery time for the N-MLSS group was not enough for renal function to compensate for the acid load during the test made 48 hours before.

Secondly, the acid-base status was greater in the N-MLSS group than in the Y-MLSS group. For example, at 15 minutes, the [H^+] was 44.3 nmol/l and 49.2 nmol/l for the Y-MLSS and the N-MLSS groups respectively. That is, both groups had an acute metabolic acidosis, but it was significantly higher for the N-MLSS group. However, the [SID] in the 15th minute was lower for the Y-MLSS group. While we have mea-

Table 2. Gas exchange data averaged variables during a test 5% above maximal lactate steady state.

Time	Y MLSS$_{5\%}$ (N = 4)				N MLSS$_{5\%}$ (N = 11)			
	VO_2 (ml/min)	VCO_2 (ml/min)	HR (beats/min)	V_E (L/min)	VO_2 (ml/min)	VCO_2 (ml/min)	HR (beats/min)	V_E (L/min)
rest	517,7 (±71,2)	470,7 (±94,9)	55 (±11)	16 (±3)	443,7 (±146,7)	378,6 (±132,7)	60 (±14)	14 (±4)
5	4267,8 (±410,1)	4134,6 (±310,4)	165 (±16)	106 (±7)	4147,9 (±511,3)	4029,1 (±576,8)	164 (±7)	111 (±17)
10	4474,7 (±436,8)	4257 (±210)	171 (±9)	118 (±6)	4401,9 (±468,8)	4143,4 (±460,5)	174 (±7)	126 (±16,96479)
15	4568,1 (±446,2)	4279,7 (±181,7)	175 (± 9)	127 (±8)	4316,2 (±520,2)	4013,4 (±534,5)	179(±7)	130 (±17)

Figure 2. V_D/V_T (side a) and V_T/T_i (side b) ratios for two groups at rest and during a test 5% above maximal lactate steady state. For V_D/V_T ratio, in solid line the N-MLSS and broken line the Y-MLSS group. For V_T/T_i, solid line the Y-MLSS group and broken line the N-MLSS group.



sured the actual SID[1], not considering plasma ions that can affect this measure[7,30]. The greatest value of the SID in the N-MLSS group confirms the heightened state of acidosis at the end, since it is considered that effective SID is lower by about 2 mEq/l than apparent SID[2].

The highest value of the SID in the N-MLSS group may have several explanations. More [K+] and lower [Na+] in extracellular fluid in the Y-MLSS group at 5, 10 and 15 min could explain the mechanism of fatigue, as was suggested by Lidinger[8,9]. These variations of ionic plasma concentration could be the result of a "burnout" of the sodium / potassium pump in muscle cells which would determine an increase in intracellular sodium and a decrease in the intracellular fluid. Moreover, the displacement of water occurs from the interstitial fluid into the cell during exercise[31] which could cause a variation of the concentration of total anions and then the SID[11] .

The change in the breathing pattern (V_T/T_i and V_T/T_e) could be due to central and peripheral factors that may be responsible for the abandonment of the N-MLSS cyclists group. However, in the present study, V_T/T_i values, representative of the respiratory central generator parameter[28], showed no significant differences between the two groups, rejecting the hypothesis of a change in the breathing pattern to explain the termination of steady exercise, although ventilation at 5, 10 and 15 min was not significantly higher in the N-MLSS group. The VE increase in the N-MLSS group probably reflects a decreasing contractile capacity of the inspiratory muscles when experiencing a continuous stable load[32].

The V_D/V_T ratio is a parameter that can indicate indirectly changes in the ventilation/perfusion relationship[33]. Neither of the two groups (Y-MLSS and N-MLSS) shows an altered ventilation perfusion ratio (from the point of view of gas exchange) (Figure 1). By contrast, the tendency of the V_D/V_T ratio is an adaptation to the increased demand produced during the stable test, with no significant differences between the two groups. A limitation of this study was to not evaluate the changes in PaO_2, P_AO_2, and $P(A–a)O_2$ that could prove hypothetical arterial hypoxemia. Despite following the Foster methodology[34] the results of the arterialized venous blood were not acceptable for analysis. Therefore, the result allows us to reject the hypothesis that a possible modification of the ventilation perfusion ratio caused the N-MLSS group to terminate the test.

However, although no differences were observed in the V_D/V_T relationship, the interaction effect between time and group of cyclists ($F_{1,12}$ = 3,53; P = 0,034; η^2 = 0,27) for PET CO_2 is noteworthy. While PET CO_2 resting values of the Y-MLSS group were lower than the N-MLSS group, at 5, 10 and 15 minutes, the Y-MLSS group showed higher values (Figure 2a). By contrast, for PET O_2 (interaction effect $F_{2,13}$ = 6.74; P = .002; η^2 = 0.43) no significant differences were found between groups at 5, 10 and 15 minutes during the $MLSS_{5\%}$ (Figure 2b). Due to the behaviour of PET CO_2 it is interesting to point out that the N-MLSS group tended towards an alteration of the ventilation/perfusion relationship, reflecting insufficient removal of carbon dioxide (lower values of PET CO_2). However, because the results of the arterialized venous blood were inadequate it cannot be thought that a change in ventilation perfusion ratio for PET CO_2 values could justify the termination of the test by the N-MLSS group.

In summary, the results of this study do not explain the voluntary termination of exercise in a group of cyclists (N-MLSS) that made a steady effort over the maximal lactate steady state and are not in agreement with our initial hypothesis, because breathing pattern and acid-base variables did not show a different response compared with the Y-MLSS group. The differences found in the acid-base status between the two groups are not sufficient to explain the termination of the exercise. In addition, the results of the trends in the respiratory exchange variables studied do not suggest a modification of the ventilation/perfusion ratio in the N-MLSS group. Our results are in accordance with previous studies and reinforce the hypothesis that fatigue occurs due to an integration of the afferent feedback of various physiological systems[35].

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Validity of blood lactate measurements between the two LactatePro versions

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Summary

Introduction: The blood lactate concentration to measure the exercise intensity in the lab or in the field is very usual in the exercise physiology and training control. The main aim was to measure the validity and the concordance in the measurement between two lactate-pro models in the market.
Methods: 34 voluntary sportmen (3 cyclist, 17 rowers, 10 long distance runners and 4 mountains runners) performed a staggered, progressive, intervallic, maximal test of effort. Constant increases of intensity (every 3 min) were done. The peripheral blood lactate was measured at the same time in both models by a heparinized capilar during the 10 next second after the step.
Results and Conclusion: A high correlation between devices was presented (r = 0,991 and r^2 = 0,983; p <0.001), with a high concordance for the medium results (0,31 mmol/l), being a little beat higher in the model LactatePro LT-1710. The stretch of values (0 – 5,0 mmol/l) presented a high correlation between devices (r = 0,965 and r^2 = 0,931; p <0.001). The stretch of medium values (5,1 – 10,0 mmol/l) determined a high correlation between them (r = 0,921 and r^2 = 0,848; p <0.001) and high concordance (0,54 mmol/l). In the stretch (10,1 – 20,0 mmol/l) the correlation is high, similar than the medium group (r = 0,926 and r^2 = 0,858). The concordance in this group is for the mean results (0,40 mmol/l). For high [La^-] (>10 mmol/l), the correlations and the concordance are high. The measurements of the [La^-] values by the old model LactatePro LT-1710 versus the new one LT 1730 (Akray Factory Inc. KDK Corporation, Siga, Japan) is possible, given that the correlation and the concordance for the total data as well as groups are high.

Key words:
Lactate analyzer.
Validity. Measurement.

Estudio de la validez en la medición de los valores de lactato sanguíneo entre los dos modelos existentes de LactatePro

Resumen

Introducción: La medición de la concentración de lactato sanguíneo ([La-]) para el control de la intensidad del esfuerzo, tanto en laboratorio como sobre el terreno, es muy habitual en la fisiología del ejercicio y en el control del entrenamiento. El objeto de este estudio es analizar la validez y concordancia en la medición de [La-] entre los dos modelos existentes de LactatePro en el mercado.
Métodos: Han participado 34 deportistas voluntarios (3 ciclistas, 17 remeros, 10 corredores de larga distancia y 4 de montaña), los cuales llevaron a cabo un test Escalonado Progresivo Incremental Máximo (EPIM) con escalones de 3 minutos hasta el agotamiento subjetivo, con toma de una muestra sanguínea con un capilar heparinizado, la cual se analizó simultáneamente ambos modelos.
Resultados y conclusión: El análisis mostró una alta correlación entre aparatos (r = 0,991 y r^2 = 0,983; p <0.001), con concordancia alta para la media de resultados (0,31 mmol/l), siendo ligeramente más alta en el modelo LactatePro LT-1710. El tramo (0 – 5,0 mmol/l) muestra una alta correlación entre aparatos (r = 0,965 y r^2 = 0,931; p <0,001). El tramo de lactato medios (5,1 – 10,0 mmol/l) determina una alta correlación entre ambos (r = 0,921 y r^2 = 0,848; p <0,001) y concordancia alta (0,54 mmol/l). En el tramo de valores de lactato (10,1 – 20,0 mmol/l) la correlación es alta, similar a la del tramo medio (r = 0,926 y r^2 = 0,858). La concordancia en este grupo es alta para la media de los resultados (0,40 mmol/l). Para los de [La^-] mayor (>10 mmol/l) la correlación y la concordancia son altas. El cambio en la medición de los valores de [La^-], sustituyendo el modelo antiguo de LactatePro LT-1710 por el nuevo LT 1730 del mismo fabricante (Akray Factory Inc. KDK Corporation, Siga, Japan), es posible dada la alta correlación y concordancia tanto para todo el conjunto como para los grupos.

Palabras clave:
Analizador de lactato.
Validez. Medida.

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Introduction

The use of measuring blood lactate concentration values ([La-]) to control the intensity of exercise, both in the laboratory and in the field, is a very habitual practice of the physiology of exercise[1-6]. These measurements of the [La-] are necessary in both phased and constant efforts. Their validity, reliability and precision are a fundamental part of the control of training[7,8]. For this reason, any appearance in the market of a more modern version of measuring apparatus for the same biological variable as a preceding one requires an assessment study of the results, so that the change in its use does not entail a significant alteration in the controls performed[9].

Diverse studies have analysed the possible difference that may exist in the [La-] values analysed using the different portable measuring devices available on the market: Lactate Pro, Accusport, Analox GM7, Kodak Ektachem lactate, Lactate Scout, Lactate Plus, Lactate Pro2, Lactate Scout+, Xpress™, Edge[9-13]. As such, the substitution of the lactate analyser from the manufacturer Akray Factory Inc. (KDK Corporation, Siga, Japan) Lactate Pro LT-1710 for the new version called Lactate Pro2 LT-1730 requires an assessment of the concordance of the lactate values measures with both apparatus, given that until now and to our knowledge, no studies have been published that analyse the validity of this instrument. Therefore, the aim of this study is to analyse the validity and concordance in the measurement of blood lactate values between the two existing LactatePro models on the market.

Material and method

Participants

34 voluntary athletes participated in the study (3 cyclists, 17 rowers, 10 distance runners and 4 distance fell runners). The characteristics of the subjects can be seen in Table 1. During the study, all the subjects carried out the complete training programme. The athletes were informed about the experimental protocols and the possible risks and benefits of the project, which was approved by the local ethics committee, which granted its written consent in accordance with the Helsinki Declaration and the Organic Act 15/1999, 13th December, governing personal data protection, as well as after having explained to them the details of the study and after having received their written consent.

Method

The blood test samples were performed in the ergometric tests carried out by athletes of different levels, taken in the Sports Medicine Centre Tolosa Kirol Medikuntza. The tests were performed in different ergometers: 17 on rowing ergometers, 3 on cycle-ergometers, 10 on treadmills with speed protocol, and 4 on treadmills with gradient protocol (Table 1). In all the cases, the athletes carried out a Maximum Incremental Progressive Phasing test (MIPT), with phases of 3 minutes, until subjective exhaustion was reached.

Table 1. Anthropometric data of the athletes.

	Height	Weight	BMI	% Fat	Age
Average	176.4	74.3	23.8	11.6	32.7
SD	8.6	12.0	3.3	4.1	10.1
Max.	191.5	114.1	38.1	26.4	54.0
Min.	151.0	46.5	18.6	7.1	19.0

During the performance of the habitual ergometric tests, the same blood samples were analysed simultaneously with the two models of LactatePro, Lactate Pro LT-1710 and Lactate Pro2 LT-1730. For this, in each of the effort test phases, performed by 40 athletes that attended their habitual controls, the blood tests were taken with a heparin-containing capillary, so that the time of the blood test was the same.

There were 269 blood samples, which were measured a maximum of 10 seconds after taking them, with the two lactate analysers of the study used simultaneously.

The blood extractions were taken from the earlobe and the collection did not take more than 10 seconds, with the aim of discovering the precise [LA] level.

Lactate analysers

Both analysers (Lactate Pro LT-1710 (LP1) and Lactate Pro2 LT-1730 (LP2)) used the oxidase lactate enzyme electrode method. The LT-1710 model requires 5 µl of blood, whilst the LT-1730 model only requires 0.3 µl. An important difference, though it does not influence the results obtained, is that the first model requires 60 seconds to obtain the results, whilst the second gives the results in 15 seconds. The measurement range is of 0.8-23.3 mmol/l for the LactatePro LT-1710 model, and 0.5-25.0 for the LactatePro LT-1730[7] model.

Statistical analysis

A descriptive analysis was carried out of the data, describing average ± standard deviation (SD), including range, typical error of the average and minimum and maximum values. The Normality test was analysed using the Kolmogorov-Smirnov test. All the variables revealed a standard distribution. Therefore, we used parametric tests. Likewise, an analysis of the homogeneity was also carried out with the ANOVA analysis of Levene, with a signification of $p = 0.000$. The null hypothesis was rejected, as the p value associated with the result observed is the same or less than the level of established signification ($p < 0.05$). The result of the size of the effect analysis produced an $r = 0.44$, therefore the size of effect is medium. Considering that the sample measures were obtained in progressive ergometric tests, the [LA-] values obtained can be classified as low, medium and high, following the approach of the study performed by Bonaventura *et al.* (2014)[9]. In this study a global analysis was performed of all the data collectively. In a second phase, the same studies were carried out in each group of values, which have been divided into low 0-5.0 mmol/l; medium 5.1-10.0 mmol/l; high > 10.0 mmol/l, which according to the measurements is between 10 and 20 mmol/l.

To get information about the agreement observed and regarding the presence of systematic differences between the measurements, the Concordance Correlation Coefficient (CCC) by Lin[14] was applied, following the method developed by Bland and Altman, which is based on the analysis of the differences between the individual measurements[15], studying the trend as well as the concordance limitations for 95%. For the statistical analysis, the computing package IBM SPSS Statistics21.0 (Chicago IL, USA) was used. The signification was calculated using an analysis of variance and was established for p <0.05.

Results

The application of the Pearson Correlation Coefficient displays high correlation between both apparatus (r = 0.991 and r^2 = 0.983) with a probability of p <0.001. The regression equation between both methods in this range was LP2 = 0.936 LP1 + 0.080 (Figure 1).

The analysis of the concordance between the results obtained with the two methods studied reveals that this concordance is high for the average results (0.31 mmol/l), being slightly higher in the measurements with the previous model (LactatePro LT-1710). The margin for the values to 95%, limited by the double Standard Deviation (±2SD), is positioned between +1.65 and -1.03 mmol/l which entails a difference of 2.68 mmol/l (Figure 2a). If the margin for the values to 95% is calculated with direct Standard Deviation (±SD), the same way it appears in the study by Bonaventura and collaborators[9], it is positioned between +0.98 and -0.31 mmol/l, which entails a difference of 1.34 mmol/l (Figure 2b).

Values between 0 and 5 mmol/l

In the section of low lactate values (0 – 5.0 mmol/l) the application of Pearson's Correlation Coefficient reveals a high correlation between both apparatus (r = 0.965 and r^2 = 0.931; p <0.001), but less than in the case of the values as a whole. The regression equation between both methods in this range was LP2 = 1.093LP1 + 0.023 (Figure 3).

In this section of values the concordance analysis is high for the average of the results (0.39 mmol/l), similar to that obtained in the collection of data as a whole, and slightly higher in the measurements with the previous model (LactatePro LT-1710). The margin for the values to 95%, limited by the double Standard Deviation (±2SD), is positioned between +0.95 and -0.17 mmol/l, which entails a difference of 1.12 mmol/l, slightly lower than when compared to the collection of data as a whole (Figure 4a). Upon establishing the reliability margins with ±SD, they are positioned between +0.67 and +0.11 mmol/l, which is a difference of 0.56 mmol/l (Figure 4b).

Figure 1. Correlation between LactatePro LT-1710 and LactatePro LT-1730.

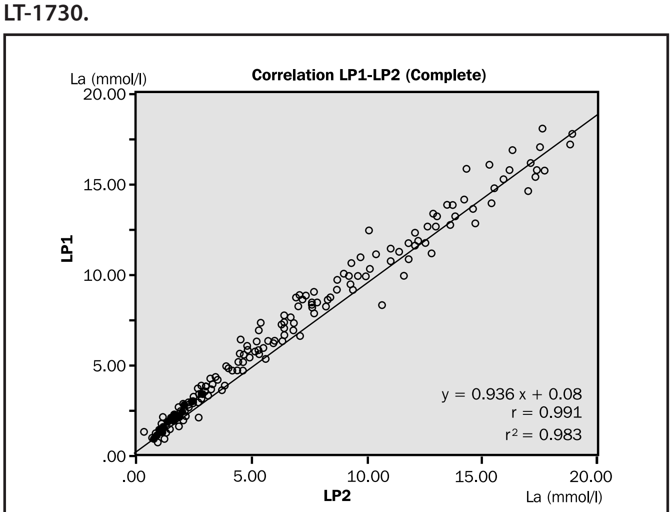


Figure 2. Concordance between LactatePro Lt-1710 and LactatePro Lt-1730.

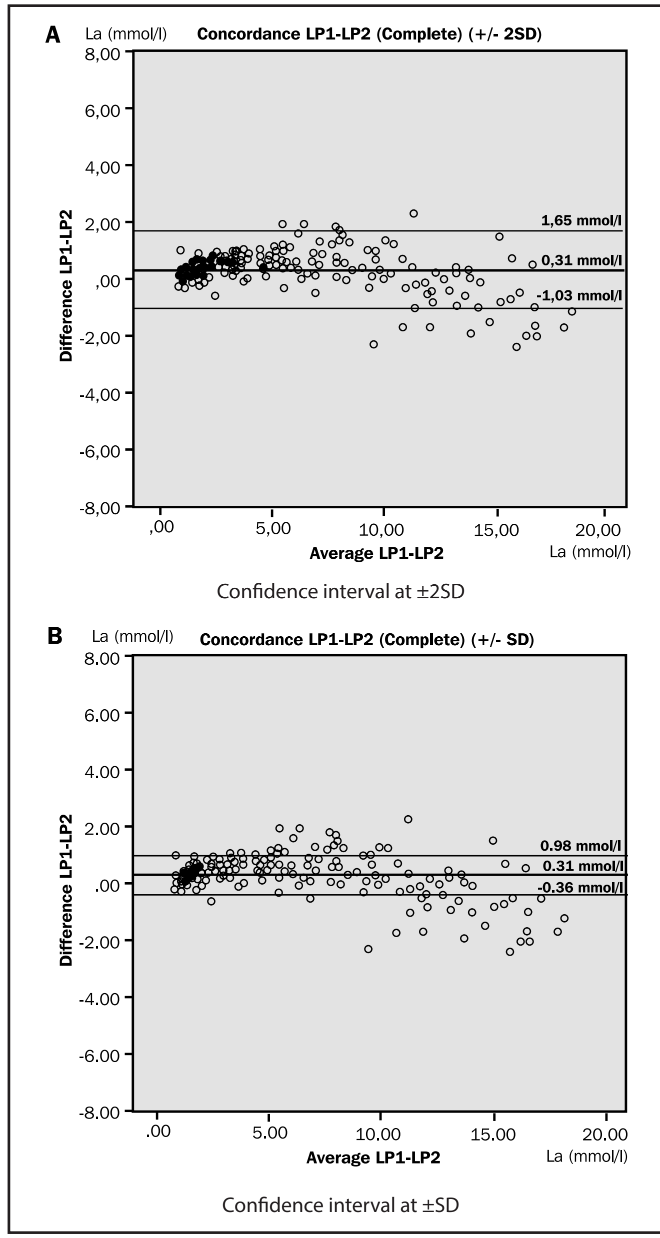


Figure 3. Correlation between LactatePro LT-1710 and LactatePro LT-1730 for the values between 0 and 5.0 mmol/l.

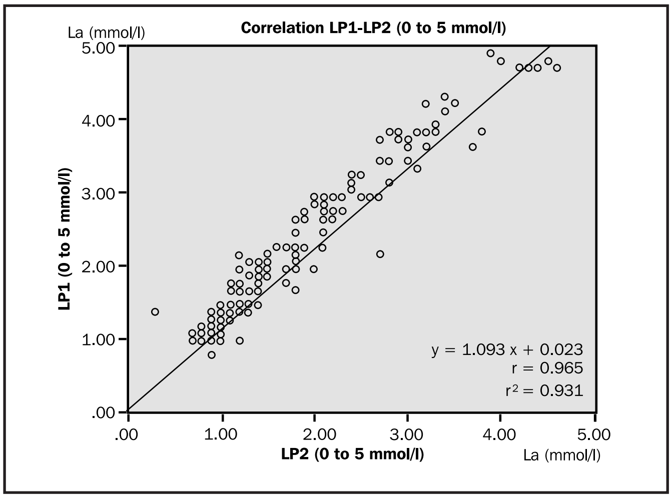


Figure 4. Concordance between LactatePro LT-1710 and LactatePro LT-1730 for the values between 0 and 5 mmol/l.

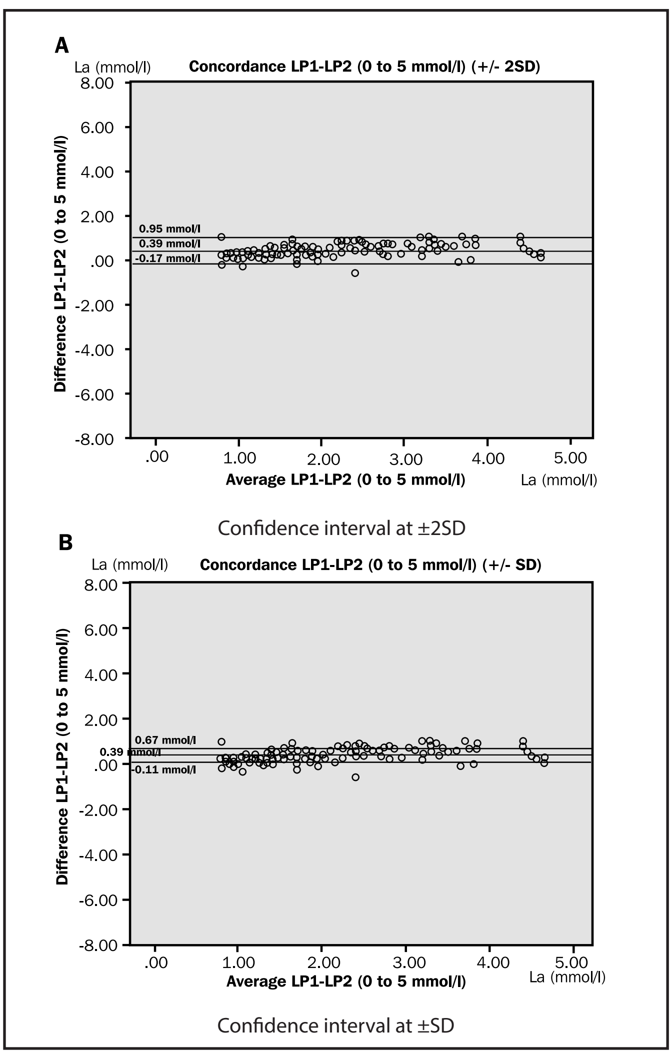
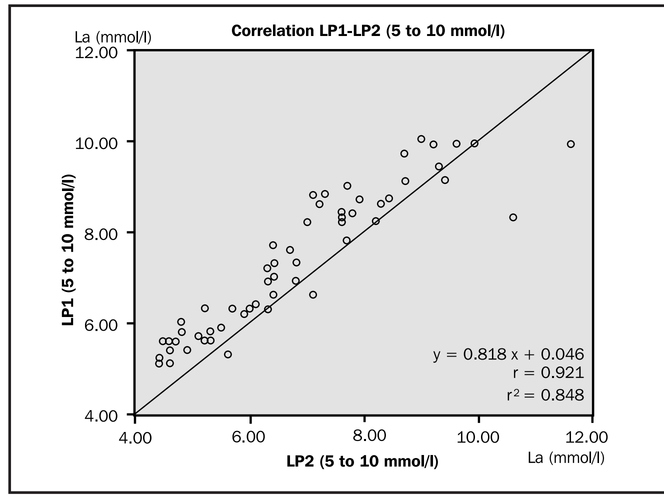


Figure 5. Correlation between LactatePro LT-1710 and LactatePro LT-1730 for the values between 5.1 and 10.0 mmol/l.



Values between 5 and 10 mmol/l

The section of medium lactate values (5.1 – 10.0 mmol/l) reveals a high correlation between both apparatus (r = 0.921 and $r^2 = 0.848$; $p<0.001$), but it is even less than in that observed for the section of low values and logically less than in the collection of data as a whole. The regression equation between both methods in this range was LP2 = 0.818LP1 + 0.046 (Figure 5).

The analysis of the concordance for this group reveals that it is high for the average of the results (0.554 mmol/l), though somewhat less than in the low group and in the data overall, in any case the highest being the measurements with the previous model (LactatePro LT-1710). The margin for the values to 95%, limited by the double Standard Deviation (±2SD), is positioned between +1.87 and -0.81 mmol/l which entails a difference of 2.68 mmol/l (Figure 6a). With reliability margins of ±SD, they are positioned between +1.21 and -0.13 mmol/l, which is a difference of 1.34 mmol/l (Figure 6b). In both cases it is exactly the same in the collection of data as a whole.

Values between 10 and 20 mmol/l

In this section of high lactate values (10.1 – 20.0 mmol/l) the correlation is high, similar to the section of medium values (r = 0.926 and $r^2 = 0.858$), less than in the section of low values and logically less than in the total of the data. The regression equation between both methods in this range was LP2 = 0.761LP1 + 0.480 (Figure 7).

The concordance in this group reveals that this is high for the result average (0.40 mmol/l), but in this case the measurements with the previous model (LactatePro LT-1710) are lower than those of the new model (LactatePro LT-1730). When the margin for 95% is calculated with ±2SD, it is positioned between +1.68 and -2.48 mmol/l, which involves a difference of 4.16 mmol/l (Figure 8a), much higher than that obtained in all the previous analyses. Using the ±SD, the margins are positioned between +0.64 and -1.44 mmol/l, which is a difference of 2.08 mmol/l (Figure 8b). Also above the previously analysed sections.

Figure 6. Concordance between LactatePro LT-1710 and LactatePro LT-1730 for the values between 5.1 and 10.0 mmol/l.

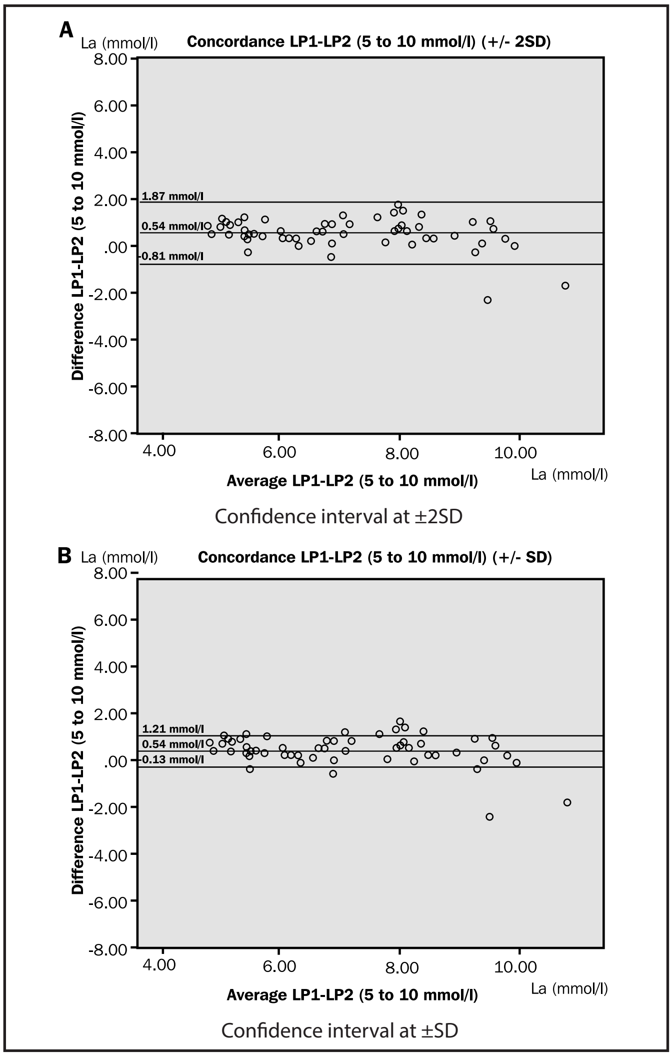


Figure 8. Concordance between LactatePro LT-1710 and LactatePro LT-1730 for the values between 10.1 and 20.0 mmol/l.

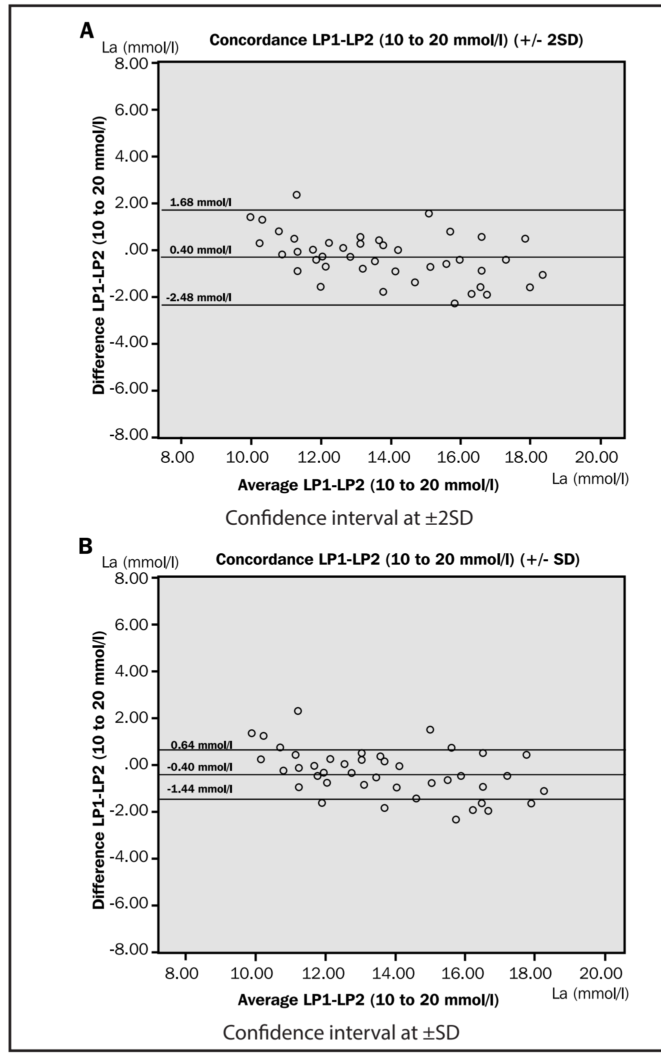
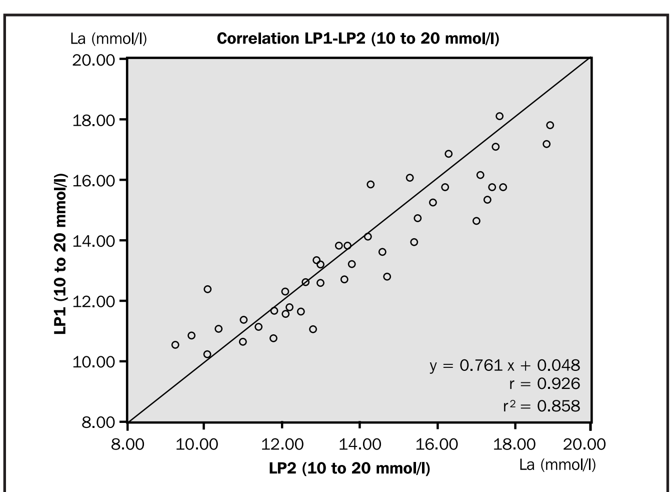


Figure 7. Correlation between LactatePro LT-1710 and LactatePro LT-1730 for the values between 10.1 and 20.0 mmol/l.



Discussion

To the best of our knowledge, this is the first study to analyse the concordance in the measurement of blood lactate values just between the two models studied, and only between them, based on the lactate analyser LactatePro. The results of this study indicate that the change in the measurement of the [La-] values carried out with the former LactatePro LT-1710 model, with those performed using the new LactatePro LT 1730 model by the same manufacturer (Akray Factory Inc. KDK Corporation, Siga, Japan) is possible, given that a high correlation and concordance was observed, both for the entire collection of data as well as for the groups of low (0 – 5.0) and medium (5.1 – 10.0) [La-]. For the high [La-] data (>10 mmol/l) both the correlation and concordance remain high, but in lesser measure than in the previous groups.

These results align with those obtained by Bonaventura *et al.*[9], who observed similar results for the two analysers compared in this study, though in their case, the comparison between the two LactatePro models is included in a comparison with more portable lactate analysers. Just as in this study, in the high concentrations there is a greater dispersion of the results, which could be explained by the high LA in a low blood volume[9], which in the case of the LT-1730 model is very low (0,3 µl) compared to the 5.0 µl of the previous model, with an increased possible difference in the measurements carried out

Our results indicate that the change in the previous model (LT-1710) for the new one (LT-1730) should not generate differences in the calculation of the different lactate thresholds: Aerobic Threshold (LT), Individual Anaerobic Threshold (IAT) or Fixed Threshold of 4 mmol/l (OBLA), as the high concordance of the measurements in the low or medium [La-] groups is high. This aligns with the results of Bonaventura *et al.* who did not find significant differences in the calculation of the thresholds for both analysers[9].

For a precise transfer of the results, the regression equations will be:

For all the measurement margins: LP2 = 0.936LP1 + 0.080

For values between 0 and 5 mmol/l: LP2 = 1.093LP1 + 0.023

For values between 5 and 10 mmol/l: LP2 = 0.818LP1 + 0.046

For values between 5 and 10 mmol/l: LP2 = 0.761LP1 + 0.480

Conclusions

Considering that there is a vast biological variability in the lactate concentrations, the results of our study suggest that the results in the calculation of the training intensities and in the interpretation of the results of an ergometer, obtained with the measurements performed with the new LactatePro model (LT-1730), are interchangeable with those performed using the previous model (LT-1710).

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Review

Sleep improvement in athletes: use of nutritional supplements

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Summary

Sleep is the physical and mental resting state which is fundamental for recovery of the biological system, regulating key mechanisms and metabolic homeostasis. It is recommended to sleep around 8 hours/night, and sleep restriction is considered when a person sleeps less than 6 hours during 4 or more consecutive nights. Some environmental factors adversely affecting sleep will reduce quality of life and may increase mortality risk. Sports performance is obviously a key factor that needs to be successful in a competition period. It is well known that insufficient rest reduces physical fitness and favors the onset of mood disorders. For that reason, multiple lines of research are focused on finding the best way to improve the quality and quantity of sleep in athletes. It has been found that both nutrition and good training periodization are important to improve the rest and sleep of athletes. To get to sleep and its disruption in the previous days to competition, hour of training, athletes' lifestyle and its impact, nutrition and supplementation, are the key topics addressed in this review about sleep in athletes. There is an urgent need of more research to understand and use different strategies, including nutritional supplements, in improving sleep in athletes.

Key words:
Sleep. Performance. Nutrition. Training. Supplement.

Mejora del sueño en deportistas: uso de suplementos nutricionales

Resumen

El sueño es el estado de reposo físico y mental fundamental en la recuperación del sistema biológico, regulando mecanismos claves y ejerciendo su papel en la homeostasis metabólica. Las recomendaciones lo sitúan en torno a las 8 horas/noche, considerándose que una persona sufre restricción del mismo con tiempos inferiores a 6 horas durante 4 o más noches consecutivas. Éste se ve afectado por diferentes factores ambientales de forma negativa lo que conlleva efectos perjudiciales para la esperanza y la calidad de vida. En el ámbito deportivo, el rendimiento es el factor clave para el éxito en la competición. El sueño es pieza clave en el entrenamiento invisible, jugando un papel fundamental en el rendimiento. Está comprobado que la falta de descanso es desencadenante de una menor capacidad física y de la aparición de trastornos anímicos que dificultan la toma de decisiones. Por ello existen un gran número de investigaciones centradas en estudiar cómo mejorar la calidad y la cantidad del sueño de los atletas a partir de una correcta programación de los entrenamientos y/o una nutrición adecuada, y así minimizar la interferencia o mejorar la fase de conciliación del sueño. La conciliación del sueño, la alteraciones de este los días previos a la competición, el horario de entrenamiento, el estilo de vida del deportista y su influencia en el mismo, la alimentación y la suplementación son los principales temas tratados en esta revisión sobre el sueño en deportistas. Es necesario un mayor número de estudios y un mayor nivel de evidencia para poder conocer y usar las diferentes estrategias que mejoren la calidad del sueño en deportistas.

Palabras clave:
Sueño. Rendimiento. Nutrición. Entrenamiento. Suplemento.

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Introduction

Sleep is a state of physical and mental rest in which a person passes into a relatively inactive and unconscious state[1] that is associated with recovery processes, for which numerous biological functions will intervene. Sleep recommendations are set at 8 hours a night, considering that a person suffers from restricted sleep when the amount of hours spent sleeping is reduced to periods of time below 6 hours for 4 or more consecutive nights[2].

Recent studies have revealed that sleep is fundamental in the regulation of key molecular mechanisms, as well as in metabolic homeostasis[3]. However, in the duration or quality of sleep, various factors such as light, jet-lag[4], nutrition[5] and genetics[6] come into play. Despite the complexities surrounding sleep, it must serve a major purpose for human beings, as it has survived thousands of years of evolution[6]. As such, restricting sleep or reducing its quality are factors that can entail damaging effects on life expectancy and quality (Table 1).

Different dietary precursors influence the synthesis and function of diverse neurotransmitters related to sleep, such as serotonin. As such, some substances such as coffee are associated with sleep alterations[7], whilst others, such as tart cherries or kiwis reduce the time needed to fall asleep[8], or reduce awakenings, increasing the sleep time[9].

In the field of sport, on-going sleep restriction can result in overtraining, which can result in mood disorders and affect decision making[10], cognitive performance, the immune system and appetite regulation[11]. Due to the important role that sleep may play in sporting performance, as well as the possible effect of nutritional factors on its modulation, the main aim of this literary review has been to analyse the controllable factors that may directly or indirectly affect the hours of sleep of the athlete, and to assess the nutritional supplements that may improve the quality of sleep, as well as their correct dosage.

Table 1. Effects of restricting sleep on different physiological processes.

Parameter	Physiological effect
Immune Function	Hyperactivity of the T cells and increase of the levels of leukocytes, neutrophils, monocytes and the natural killer cells7, flattening of the circadian rhythms[8]
Inflammation	Stimulation of TNF and IL-6 levels[9]
Metabolic	Less sensitivity to the action of insulin and the capacity to regulate blood sugar[10]
	Reduction of levels of leptin and increase of those of ghrelin[11] Increased feeling of hunger[12]
Neuro-endocrines	Inverse relationship between the duration of sleep and the levels of cortisol[13] and catecholamines[14]
	Reduction in IGF-1, GH and testosterone levels[3]
Psychological factors	Increase of the effects of psychological stress[15] Increase in the risk of suffering from anxiety and developing depression[16]

GH: growth hormone; IGF: insulin-like growth factor; IL-6: interleukin-6; TNF: tumour necrosis factor

Method

This literary review was performed based on scientific works indexed in the Pubmed and Web of Science databases. The search strategy, using key words, included the terms *sleep, insomnia* and *"sleep loss"* in combination with *sport, exercise, "physical activity"* and *"nutrition"*. Later, only the intervention works that were published in English or Spanish were selected, that directly studied sleep or the restriction of sleep on the athlete population and/or with guidelines that may modulate sleep alterations.

Results

Prevalence in sleep disorders among the athlete population

In a study performed on Olympic athletes, it has been proven that despite them spending longer in bed compared to the non-athlete population, the total sleep time is not different, as athletes require more time to fall asleep[12]. However, various research studies have not confirmed these results. As such, the athlete population may present difficulties in covering the daily sleep requirements (8 hours), even with naps[13], especially when going through states of over-training[14] and on days leading up to a competition[15,16].

In a study with 632 high-performance athletes, it was observed that 65.8% of them presented sleep alterations the day before a competition[17], though other works found even higher rates, reaching 80%[16]. Some research studies that assessed the duration of sleep the day before a competition discovered average values of 6.5 hours in cyclists[14] and 5.4 hours in swimmers[16], whilst the time taken to fall asleep may reach 50 and 41 minutes respectively.

Training schedules may have a direct influence on sleep restriction. Here, despite athletes that train first thing in the morning aim to combat the deficit by going to bed earlier, they present a higher rate of sleep restriction[13,18]. Furthermore, the sporting modalities that cause the most subjective pressure on the athlete (individual modalities) present a higher rate of sleep alteration[15], as opposed to sex, which does not appear to be a determining factor in the quality or quantity of sleep in the athlete population[5].

Exercise factors that interact in sleep regulation

The duration of sleep and the time it takes to fall asleep both improve after performing exercise, when it is carried out at least 4 hours before going to bed[4]. In the non-athlete population it has been demonstrated that 12-month exercise interventions improve the quality and duration of sleep[4], whilst shorter programmes (16 weeks) may improve the subjective perception of sleep[18]. However, exercise performed in the 4-hour period leading up to bed time may reveal an inverse relationship with the quantity and quality of sleep[4]. To gain a better understanding of these results, the responses occurring in the phases after exercise that may interfere with sleep should be studied.

As well as increasing the body temperature, once the intensity at which the aerobic-anaerobic transition occurs is exceeded, exercise is accompanied by an increase of the activity of the sympathetic nervous system, characterised by an increase in catecholamine levels[19]. This increase in sympathetic activity may last for hours after exercise.

Body temperature reveals a direct relationship with sleep, in that increases of 1.5-2ºC impede sleep, whilst reductions of around 0.5ºC promote its appearance[20]. In the same way, it has been shown that heart rate (HR) increases (20 beats a minute) are one of the main factors that intervene in sleep interruption[21].

Given that exercise, once the early recovery phase has been overcome, leads to greater activation of vagal tone, it may explain why performing exercise before the 4-hour period could improve the quantity and quality of sleep. On the contrary, hyperactivity of the sympathetic tone that occurs on the days prior to a competition, as well as the first stages of over-training, could explain the sleep alterations experienced by athletes before competing[12,13], or in states of over-training.

Performance

In a study carried out on swimmers, it has been shown that a restriction of 2.5 hours of sleep for 4 consecutive nights does not reduce strength performance, respiratory function or swimming-specific performance, though it is accompanied by increases in symptoms related to depression, confusion, anger, fatigue and reduced vigour[22]. Other later studies, on the other hand, did observe that long-term sleep restriction entails a progressive reduction in the levels of maximum and sub-maximum strength in different exercises[23]. Furthermore, unlike the previous study performed on swimmers[22], in a study with a larger sample, it was proven that restricting sleep may also reduce the respiratory rate and the time to exhaustion in a maximum incremental test in both runners and volley ball players[24].

Sleep restriction is accompanied by alterations on a proprioceptive level and of neuro-muscular control[6], which may be the source of the greatest rate of injuries in athletes that sleep for less than 8 hours each day[25]. Therefore, sleep restriction may become an injury risk factor[20]. Moreover, sleep restriction is associated with an increase of the secretion of pro-inflammatory cytokines[26], possibly affecting the immune function and explaining the greater rate of upper airway infections in athletes with sleep restriction[27]. It should also be considered that sleep restriction is accompanied by an increase of catabolic hormones such as cortisol[28] and a reduction of anabolic hormones such as GH, IGF-1 and testosterone[3], possibly directly affecting the body composition, reducing levels of lean muscle[3]. Therefore, as displayed in Table 2, the quantity and quality of sleep seems to directly affect athletic performance.

The effect of napping on sporting performance

Following sleep restriction, it has been proven that a 30 minute nap improves athletes' performance in speed trials[29]. It has also been shown that naps may improve the cognitive processes affected by sleep restriction[30], which hypothetically may have a positive effect on the technical-tactical performance, when it comes to learning new motor skills or carrying out highly complex motor skills, as well as preventing the appearance of injuries. For this reason, it could be considered that athletes that suffer from sleep restrictions may benefit from a nap, thus turning it into a way of combating accumulated sleep loss.

Lifestyle factors that influence sleep

Lifestyle factors that most influence sleep and that are most represented in the literature are the consumption of caffeine, smoking, exposure to electronic devices, exposure to bright light during the night, and the time dedicated to sleeping[31]. Caffeine increases the state of alertness, antagonising adenosine receptors, which also leads to a reduction in the inclination to sleep. A review of the effects of caffeine on sleep reached the conclusion that there is a strong association between the intake of caffeine and difficulties sleeping[7]. Current evidence does not establish a specific time in which caffeine can be consumed with the aim of avoiding sleep interruption[31].

Table 2. Effects of restricting sleep on different performance indicators.

Performance indicators	Effects of restricting sleep
Performance	Reduction in cardio-respiratory capacity and possible negative effect on maximum and sub-maximum strength levels
Over-training	Interference of the recovery processes that take place during sleep Increase in symptoms such as depression, confusion, anger, fatigue and reduced vigour Increase in levels of catabolic hormones, such as cortisol, in rest and reduction of anabolic hormones, like GH, IGF-1 and testosterone
Predisposition to acquiring an injury	Increased probability of acquiring an injury due to a reduced cognitive performance and proprioceptive and neuromuscular alterations
Predisposition to suffering from infections	The decrease in the immune function may make the athlete more vulnerable to the possibility of suffering from infections, especially of the upper airways
Unfavourable alterations in the body composition	Reduction of lean muscle mass due to an unfavourable anabolic setting

Nutritional supplementing and improvements of sleep indicators

Serotonin and melatonin are the two main molecules responsible for sleep regulation. Given that diverse nutrients can have a direct or indirect influence on the synthesis of melatonin, and especially, on serotonin, nutritional supplementing has been turned to in order to improve the quantity and quality of sleep (Table 3).

Tryptophan

The attempt to increase levels of free tryptophan in the blood is founded on the basis that these levels are closely regulated by the tryptophan/branched-chain amino acids relationship. When an increase occurs in the levels of free tryptophan, whether due to a reduction of the branched-chain amino acids or to an increase of the availability of tryptophan, this amino acid crosses the blood-brain barrier and is transformed into a precursor of serotonin or 5-hydroxytryptamine (5-HT)[32]. In fact, it is considered that the velocity of the tryptophan on a brain level is the limiting factor in the synthesis of 5-HT. Among the functions of 5-HT are those related to lethargy and drowsiness, due to the fact that it acts as a precursor to melatonin in the pineal gland[33].

The modification of tryptophan levels has been performed based on dietary modifications. Thus, the intake of proteins rich in tryptophan such as α-lactalbumin present in whey increases the tryptophan/branched-chain amino acids relationship by up to 130%, increasing the levels of serotonin in the brain. On the contrary, a diet with a nigh content of branched-chain amino acids or with a supplement of them - a very common practice among athletes in both strength and in aerobic resistance - could reduce the levels of tryptophan that cross the blood-brain barrier.

In terms of the intake of carbohydrates, it has been shown that it increases the plasma concentration of tryptophan, which, as we have already mentioned, is a precursor to serotonin and a sleep-inducing agent. Various studies have proven that a large availability of this nutrient may favour the brain's capture of tryptophan through the action of the insulin, due to the fact that it will produce an increase in the capture of branched-chain amino acids in the skeletal muscle, which will increase the levels of free tryptophan[1].

In terms of the necessary dose of tryptophan, it has been revealed that 1g is sufficient to improve both the quantity and the quality of sleep[33].

B-complex vitamins

Sleep is influenced by the action of certain components, such as certain vitamins and minerals, on the synthesis of melatonin, with an association between deficient nutritional circumstances with sleep alterations.

Vitamin B3 or niacin can be produced endogenously from tryptophan. A sufficient amount of this vitamin, through diet or supplements, will mean a smaller amount of tryptophan will be destined to synthesising niacin, by inhibiting the activity of the 2,3-dioxygenase, with a greater amount of tryptophan available to synthesise serotonin[1].

Folate and pyridoxine (vitamin B6) play a crucial role in the conversion of tryptophan into serotonin. The reduced form of the folate 5-Methyltetrahydrofolate increases the tetrahydrobiopterin, which is a co-factor of the Tryptophan-5-Hydroxylase enzyme. This enzyme converts the Tryptophan into 5-hydroxytryptamine (5-HT). The role of Vitamin B6 is related to the aromatic amino acid decarboxylase, which speeds up the transformation of 5-HT into serotonin[1].

For the other part, cobalamin (vitamin B12) also contributes to the synthesis of melatonin, with a possible positive effect on the quantity of sleep in supplement form, proving fundamental for vegetarian athletes, due to the fact that they may present a deficient situation given that this vitamin is found in food sources of animal origin.

It should not be forgotten that supplementing with these nutrients will only have an effect in cases of deficiency or insufficiency. This means that individuals with sufficient levels of them will not need this supplement.

Magnesium

Magnesium is important for the 5-Hydroxytryptamine enzyme N-acetyltransferase to convert 5-HT into N-Acetyl-5-Hydroxytryptamine and which is then transformed into N-Acetyl-5-methoxy tryptamine (Melatonin)[34]. Magnesium is therefore established as a mineral to consider for future research studies to determine its effect on sleep and its dosage.

Zinc

Various studies suggest a relationship between zinc and melatonin[35]. Bediz *et al.*[35] observed the effects of zinc deficiency and the administering of supplements in melatonin levels in rat plasma. The results of this study suggest that the zinc deficiency reduces the levels of melatonin and that supplementing zinc may increase melatonin levels in rats. These results may be cross-checked in humans in order to arrive at more solid conclusions.

Melatonin

Melatonin is a hormone secreted by the pineal gland, which gives information about the lightness-darkness cycle, with its synthesis suppressed by the exposure of the retina to light[29]. From a phylogenetic perspective, it has been linked to the anti-oxidant protection against ionizing radiation and a very oxygen-rich atmosphere, slowing down cellular functions during the hours of greatest exposure to those radiations during the day, to be activated during darkness hours when there is a lower risk[36].

This hormone, associated with the circadian rhythm, will have sedating or hypnotic effects, which is why nutritional supplementing has been carried out as an alternative to sleep disorder treatment[28]. If the nocturnal production of melatonin is not necessary for the appearance of sleep, the presence of darkness during the night is an absolute must[37].

The increase of melatonin concentration in the blood stream induces drowsiness and coincides with a reduction of the body temperature[36].

Effective doses of melatonin seem to be those comprising between 3-12 mg[38], though the possible side effects of this supplement should be taken into account, such as headaches, nausea, drowsiness during the day or nightmares[39], thus affecting performance. We should consider that interventions aiming to manipulate levels of tryptophan ultimately aim to directly influence melatonin levels[29].

Furthermore, melatonin is a lipophilic hormone for which it is capable of crossing cellular, placental and blood-brain membranes in which it performs antioxidant functions[30].

Despite there being no conclusive data regarding the effectiveness of the use of this hormone in increasing hours of sleep, it could improve the capacity of falling asleep[38], particularly among athletes that are continuously travelling to countries with different time zones, as it can reduce symptoms of jet lag[4].

Valerian

Valerian is a herb whose components, valeric acid and its derivatives, target GABA type A receptors, possibly inducing a general calming effect on the body[40] by regulating the degree of excitability of the nervous system.

Although valerian could improve rates related to the quality of sleep, just as with melatonin, no positive effect has been proven of its supplementing on the quality of sleep[6].

The side effects of valerian include dizziness, drowsiness during the day, as well as the appearance of allergies[37].

L-Theanine

L-theanine is an amino acid that is found in green tea leaves, related to a reduction in stress and with relaxing effects without causing drowsiness[41]. It is the most important amino acid in tea, with some 25-60 mg in every 200 ml. and it has been proven in healthy, young subjects, to cause a state of mental relaxation yet alertness through a direct influence on the central nervous system[42]. It crosses the blood-brain barrier in 30 minutes and strengthens the 1-alpha frequency band of the electroencephalogram approximately 40 minutes after ingestion[41]. It acts by blocking the joining of the L-glutamic acid to its receptor (glutamate receptor). Studies of L-theanine reveal an attenuation in the activation of the sympathetic nervous system, improvements of subjective post-stress relaxation, attenuation in the increase of cortisol levels, a reduction in anxiety and a mitigated increase in high blood pressure in response to stress among adults[40], and in terms of sleep, in rats it was observed that it partially counteracted the reduction of slow sleep waves induced by caffeine[17].

Food as a fundamental element in sleep

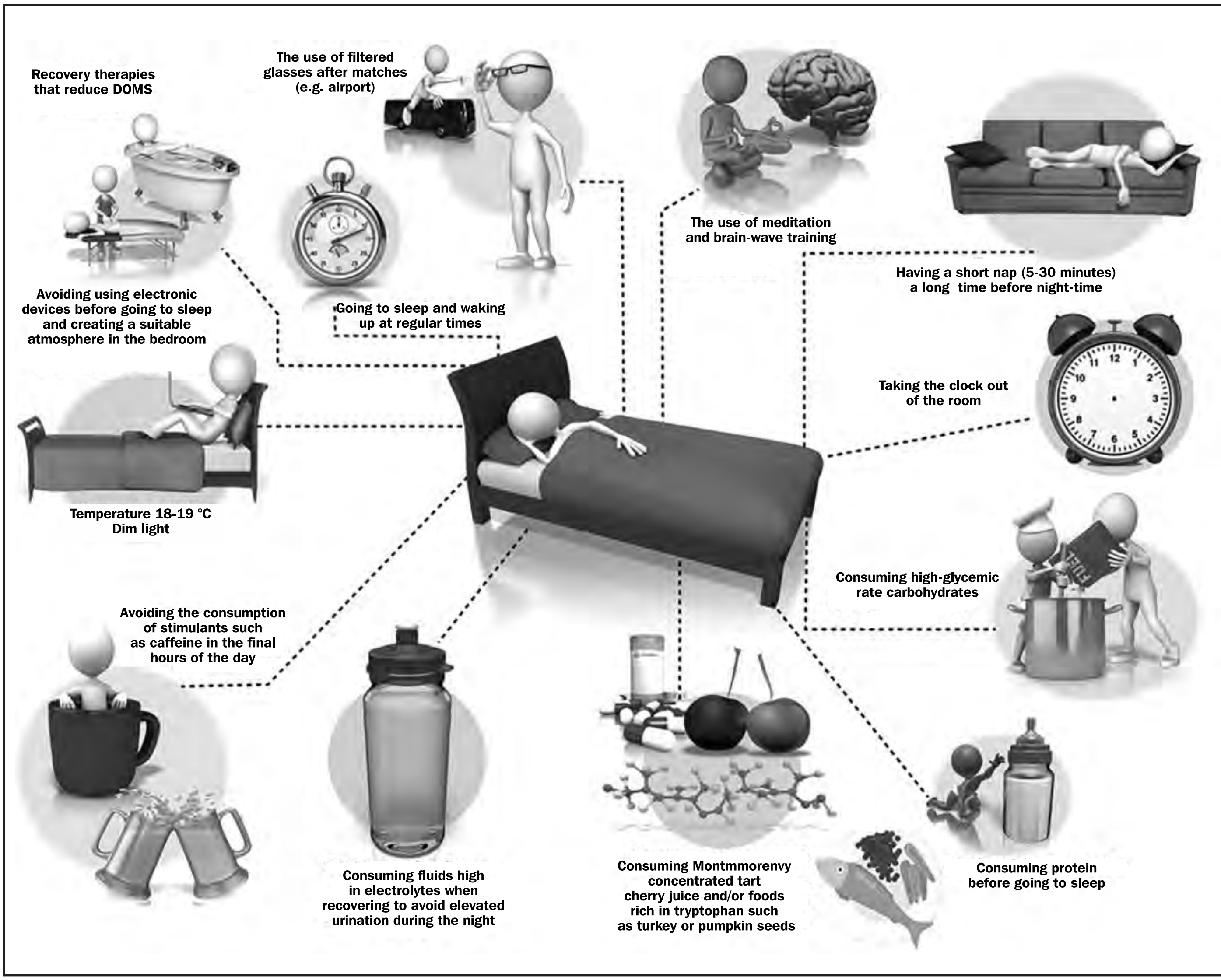
During the review, it became clear how nutritional manipulation via different supplements can influence the improvement of sleep in athletes. It is important to highlight how foods such as fish (>5% fat) constitute a good source of vitamin D and omega-3, important nutrients in regulating serotonin and therefore in regulating sleep[43]. On the other hand, other studies have observed the consumption of fruit in the promotion of sleep[43-45]. As such, consuming two kiwis 1 hour before going to sleep for 4 weeks increased the efficiency of sleep and the total time sleeping measured via actigraphy in adults with sleep disorders[44]. Other fruits such as tart cherries have demonstrated improvements to sleep in different studies, due to its melatonin content[45,46]. Therefore, improved sleep quality seems to be related to a greater consumption of fruit, vegetables and fish, and is inversely related to the consumption of processed foods[47]. A key first step would be to address sleep improvement in athletes by analysing and improving their eating habits.

Table 3. Physiological effect and dosage of the main dietary supplements used to improve the quantity and quality of sleep.

Supplement	Physiological effect	Dosage
Tryptophan	Precursor to serotonin on a cerebral level, hormone responsible for causing sensations like lethargy and drowsiness	1 g•day^{-1}
B-complex vitamins	Vitamin B_3 reduces the activity of the 2-3-dioxygenase, reducing the quantity of tryptophan designated to synthesise this vitamin, leaving a greater amount of tryptophan available to synthesise serotonin	DRI in cases of deficiency
	Vitamine B_6 is involved in serotonin synthesis processes, from tryptophan	
	Vitamina B_{12} is involved in the synthesis of melatonin	
Minerals	Magnesium and zinc intervene in the synthesis of melatonin	DRI in cases of deficiency
Melatonin	Hormone that induces sleep and lethargy	5- 8 mg
Valerian	Reducer of the sympathetic nervous system activity	No positive effect has been demonstrated
L-Theanine	Reducer of the sympathetic nervous system activity	No positive effect has been demonstrated

DRI: dietary reference intakes.

Figure 1. Hygiene measures that may contribute to improving the quantity and quality of sleep in athletes.



Conclusions

Physical exercise, especially that of moderate intensity and performed at least 4 hours before going to bed, may have a therapeutic effect on treating sleep restriction in sedentary people. Athletes with a high level of training, however, may see their sleep disturbed, especially on days leading up to a competition, due to a hyper-activation of the sympathetic nervous system activity or due to time limits when training first thing in the morning or just before going to bed. On the other hand, some nutritional aids, such as melatonin, tryptophan and some vitamins and minerals (in the case of insufficient levels of them through the diet alone), have demonstrated some effects on improving sleep in athletes, with greater levels of evidence required in terms of their effectiveness and the recommended dosage.

Based on everything included in this review, and founding our conclusions on various current reviews about sleep and sport, by means of a summary (Figure 1), some hygienic measures have been displayed that may contribute to improving the quantity and quality of sleep among athletes[48-52].

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Review of generic aspects about Adapted Physical Activity in the Person with Spinal Cord Injuryar

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Summary

Nowadays the Spinal Cord Injury (SCI) implies disability and dependency. The SCI causes changes in sensorial functions, motor functions and/or autonomic functions below the level of injury. The improvement of quality of life as well as the care, among other factors, have contributed to increase life expectancy. This fact allows the person with spinal cord injury to have a lengthy quality life. The person with spinal cord injury requires to follow a long-term program of Adapted Physical Activity (APA) to maintain his / her health. The benefits of APA and its modalities can enhance this activity. Likewise, political-social situation of each country can influence the design and the possibility of development of the APA. This article has been based on the following databases: SPORTDiscus, PubMed, Embase, Science Direct, PEDro and Cochrane Library, including review of the last ten years. 108 articles were found and 24 of them met all the criteria and they were included in this review. The selection criteria were the publication date during the mentioned period, articles with level of evidence A, B or C, and articles which highlight the APA in the person with spinal cord injury during the chronic phase. This research concludes with the following 1) We must continue promoting policies which support the inclusion of the APA. We must make them accessible to all people with disabilities and / or dependency, and in particular the person with spinal cord injury 2) The sport choices of the person with spinal cord injury depends on external factors and especially internal factors 3) The increase of the quality of life related to health and the improvement of self-esteem stand out as benefits of APA.

Key words:
Spinal cord injuries.
Sport for persons with disabilities.
Adapted physical activity.
Health promotion.

Revisión sobre aspectos genéricos acerca de la actividad física adaptada en la persona con lesión medular

Resumen

Actualmente la lesión medular ocasiona discapacidad y dependencia, y provoca alteraciones de las funciones sensitivas, motoras y/o autonómicas por debajo del nivel de lesión. La mejora de la calidad de vida junto a la de los cuidados entre otros factores, han contribuido al incremento de la expectativa de vida, permitiendo que un mayor número de personas con lesión medular (PLM) lleguen más cualitativamente a edades más longevas. La PLM requiere seguir un programa de Actividad Física Adaptada (AFA) para mantener su estado de salud. El conocimiento de los beneficios de la AFA y sus modalidades permite potenciar esta actividad. Asimismo, la situación política-social de cada país puede influir en la concepción y la posibilidad de desarrollo de la AFA. En este artículo se realizó una búsqueda en las bases de SPORTDiscus, PubMed, Embase, Science Direct, PEDro y Cochrane Library, incluyendo revisión de los últimos diez años. Se obtuvieron 108 artículos y 24 de ellos cumplieron todos los criterios, que fueron: la temporalidad señalada, artículos con grado de evidencia de A, B o C y los artículos que destacasen la AFA en la PLM como tratamiento en fase crónica. Tras la revisión se puede concluir que 1) Hay que seguir promoviendo políticas favorecedoras de la inclusión de la AFA con el fin de hacerlas accesibles a toda la población con discapacidad y/o dependencia, y en particular a la PLM 2) La elección de la práctica deportiva de la PLM dependerá de factores externos o ambientales y especialmente de internos o personales 3) Los beneficios que más se señalan sobre la AFA son: el aumento de la calidad de vida relacionada con la salud y la mejora de la autoestima e imagen corporal de la PLM respecto a la sociedad.

Palabras clave:
Lesiones de la médula espinal.
Deportes para personas con discapacidad.
Actividad física adaptada.
Promoción de la salud.

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Introduction

Spinal injury (SI) leads to disability and dependency[1], and provokes alterations to sensitive, motor and/or autonomic functions below the injury level[2]. The improvement in quality of life along with that of the care received, among other factors, have contributed to the increase of life expectancy, enabling a greater number of people with spinal injuries (PSI) to reach older ages[3,4].

Health-related quality of life (HRQL) is defined as that resulting from physician interventions[5]. These interventions enable individuals to understand the evaluation of their state of health from their own perspective[6], likewise, Adapted Physical Activity (APA) offers objectifiable health benefits for PSI.

The first uses of sports in PSI date back to 1944 in the Stoke Mandeville Hospital (United Kingdom), when Dr Ludwig Guttman[7] was already using sports as a rehabilitation method. Furthermore, Guttman founded the Paralympic Games with the aim of making handisport or APA not just a rehabilitation method, but also a way of achieving greater integration, inclusion and participation within society.

People with physical disabilities should carry out APA, in some cases requiring supervision. The PSI will require short-term physiotherapy treatment (strategies against algias, strategies against cardio-respiratory, digestive and urinary complications, and strategies for keeping tone) and long-term physiotherapy strategies, educational-therapeutic measures and APA modalities to improve mood, HRQL, self-esteem and well-being levels[8].

Some countries favour innovation, research and development policies in Paralympic sport, without a doubt, the world popularity of APA arose from the competition. Currently, the three most well-known sporting events are: the Paralympic Games, the World Special Olympics and the Deaflympics. PSI have been able to compete in the Paralympic Games since 1960, the year in which 23 countries participated in the event held in the city of Rome. In the recent Games in the city of Rio de Janeiro, 175 countries participated, with 4,350 athletes in 22 sports: athletics, wheelchair (WC) basketball, *boccia,* cycling, WC fencing, 5-aside football, 7-aside football, goal-ball, judo,weightlifting, horse riding, swimming, rowing, table tennis, WC tennis, archery, Olympic shooting, WC rugby, sitting sailing and volleyball, canoeing and triathlon[9]. This fact is a clear example of how the Paralympic Games manage to develop programmes that facilitate the integration process within our society[10].

As such, the main objective of this article is to review the APA that PSI may carry out, the factors that depend on this choice, and the consequences or effects of the APA and its link to the promotion of health and HRQL.

Development

A review was carried out of the SPORTDiscus, PubMed, Embase, Science Direct, PEDro and Cochrane Library databases of the articles published in the last ten years with the key words *"Spinal Cord Injuries, Sport for Persons with Disabilities, Adapted Physical Activity, Health promotion".* From these potential articles found, a selection was made considering their appropriateness within the topic, excluding articles that did not meet the inclusion criteria. The inclusion criteria were: articles with a degree of evidence of A, B or C that included the development of any APA carried out by PSI. As exclusion criteria, the following were indicated: those articles that did not match the study topic and articles in which the PSI was in the acute/recent phase of the SI and therefore required other kinds of care. Of the 108 articles initially obtained from the search, 24 of them met all the criteria and were included in this review. Other relevant articles in the field were also considered.

Adapted physical activity: political-social situation

The term APA first appeared in 1973 with the foundation of the "International Federation for Adapted Physical Activity". APA, as defined by DePaw and Doll-Tepper[11] in 1989, is conceived as a sporting activity that pays attention to the capacities of people with limitations. APA is a wide conception that includes therapeutic, recreational and sporting activities without adaptation, with adaptation or newly created.

In the study by Martin *et al*[12], in which 695 PSI were interviewed over the telephone, daily practices poor in APA were revealed of 27.14 ± 49.36, with 50% of interviewees not performing any activity at all. This study, carried out in Sweden, indicated the need for specific interventions to stimulate physical activity in specific subgroups of PSI (women, older adults, more serious injuries, etc.).

Today, environmental barriers continue to pose a handicap across all levels, and are still very present in many countries. Serrano *et al*[13] indicated the difficulties in the practice of physical and recreational activity in Colombia, and the importance of generating political and social strategies to encourage the inclusion of people with physical disabilities. The study by Perrier *et al*[14], with a sample of 201 Canadians, highlighted the need for sporting organisations to adapt their programmes to promote sports among people with acquired physical disabilities. Currently, PSI report serious difficulties in accessing spaces where they can perform sport. Despite this, living close to a centre where APA can be carried out does not imply greater participation, as indicated by Arbour *et al*[15] in their study, in which this fact was analysed in 50 PSI. in in t.

Inclusion-favouring policies require a state implementation of an APA project for people with disabilities and dependency, which includes a specific action for each age range and need. Pereda and Calero[16] proposed an 11-phase methodology with this objective in Ecuador. Other simpler and less expensive alternatives could be effective, such as the one indicated by Arbour *et al*[15] regarding the effectiveness of an individualised telephonic programme with sporting guidance to promote APA in a sample of 65 PSI over six months.

In any case, some studies such as the one carried out by the North American Blawet and Lezzoni[18] indicated that public policies and governmental regulations are expanding and improving sporting opportunities among users with disabilities, promoting inclusion opportunities for participation in APA. Therefore, although adapted sport has made great progress, inclusion-favouring policies of APA should still be promoted in all countries with the aim of making it accessible to all the population that requires it.

Modalities of adapted physical activity

APA for athletes in WC is a healthy habit among PSI both physically and mentally[19]. Diverse entities develop sporting programmes with the aim of including APA as a fundamental part of daily life and promoting health. As such, the Spinal Cord Injury Foundation (FLM)[20] offers four different modalities within the Sporting Action Section: table tennis, quad-rugby, *boccia* and stacking. Along the same line, Handisport Mallorca[21] offers navigation activities, blokart, water skiing, kayaking, golf, trailing, diving and superfour 4x4. The Aspaym association[22], with headquarters across the whole of Spain, along with other organisations (foundations, sports clubs, non-profit making entities, etc.) participate and facilitate these APA, offering facilities and guidance. The APA that PSI can carry out are, among others: basketball, football, golf, *boccia,* athletics, hand cycling, fencing, weightlifting, horse riding, swimming, rowing, rugby, tennis, table tennis, archery, sailing, volleyball, Olympic shooting, motor racing, badminton, skiing, underwater activities, slalom, paddle tennis, etc.

Any APA can be carried out recreationally and/or competitively and preferably in a group with the aim of boosting and promoting healthy behaviour within the community. The conditioning factors when it comes to PSI choosing a sporting activity will depend on: external factors (weather conditions, geographical living location, normal place of residence, accessibility, socio-political strategies, etc.) and internal factors (interests and personal tastes, level of injury and the capacities of PSI, socio-economic situation, etc.).

On the other hand, classification and categorisation are important to consider in some competitive sports. Current functional classification focuses enable a wider vision of the athlete's reality. The aim of classification is the equity leading to individual competency development, an objective that is achieved through four stages and is led by the classifier. Classification is not a simple activity, and proof of that is the difficulty in developing valid measures for deterioration[23]. In some studies such as that by Gil *et al*[24], the relevance of classification was indicated, in this case, in WC basketball players. As such, some of the sports that PSI can carry out and that on a competitive level include adaptations in their classification depending on injuries are mainly: track and field athletics, basketball, rugby, Nordic skiing and swimming.

On the other hand, Saebu and Sorensen[25] indicated that personal factors have more influence on the practice of APA than environmental factors, or factors linked to functioning and the disability. Malone *et al*[26], in their study of 152 people with physical disabilities, indicated weaknesses referring to physical effort through the Exercise Benefits and Barriers Scale (EBBS)[27], achieving high response percentages in the following items: "Exercise tires me out", "Exercise is hard work for me" and "Exercise fatigues me".

Recent pioneering studies in our country, with cell therapy, have achieved improvements in the sensitivity, spasticity and motor function in over fifty percent of patients[28]. Furthermore, technical advances enable the offer of more alternatives to adapted sport compared to twenty years ago[29], thanks to the improvement and creation of new devices. Recent implantations of exoskeletons that are used for rehabilitation could offer standing sporting activities. Recent studies with these exoskeletons or Advanced Reciprocating Gait Orthosis (ARGO) already work with the aim of improving, among other functions, kinematics, speed and gait length[30].

As such, internal factors, for various reasons, may entail a more determining weight in the choice of an APA, also conceiving a new paradigm that will enable the expansion of the current offer.

Effects of adapted physical activity

Despite activity being conceived as a clear benefit regarding immobility, it should not fall in the mythification of the benefit *"per se"*. A critical attitude should always be upheld when promoting the APA[31], always considering a suitable control and follow-up.

Jacobs[32] indicated significant improvement in the muscle capacity of the upper limbs through participation in a 12-week resistance training programme. Ochoa *et al*[33] remarked upon the importance of physical activity as a tool against osteoporosis in the PSI. Davis *et al*[34] indicated cardio-respiratory, metabolic and bio-mechanical advantages as a response to the leg exercise with functional electrical stimulation. Some of the advantages were: an improvement of the blood circulation to the leg, an increase in enzymatic and metabolic activity, an increase in the capacity of functional exercise, an alteration of the bone mineral density, and the improvement of strength and muscle resistance.

Martin *et al*[35] revealed benefits of the APA such as psychological and physical well-being (prevention of chronic illnesses and the promotion of the physical condition). Furthermore, the importance of using the APA to promote health was highlighted. In the study by Gernigon *et al*[36] some differences were indicated in the PSI that did not practise APA compared to those that did, notably the first being low physical and overall esteem. Moreover, Day and Wadey[37] indicated how participating in sports is a central element in the recovery from a trauma in patients with acquired disabilities, and this participation enables improvements in the bodily and philosophical understanding of life.

Perrier *et al*[38], with the aim of highlighting the importance of sport in promoting health, revealed the effectiveness of the Health Action Process Approach (HAPA) in 101 people with acquired physical disabilities. Along these same lines, Wilhite and Shank[39] in their study with 12 people with disabilities that performed APA, indicated the benefits of sport on a physical, emotional and social level.

Despite some interventions promoting health such as APA lacking specific descriptions as to whether they help to reduce or prevent secondary conditions of the disability, long-term maintenance programmes should be promoted, which include participation in a community[40]. For this reason, these activities should be encouraged and guided with the aim of promoting autonomy to increase the level of health, well-being, quality of life and self-esteem of PSI.

Final considerations

With over 70 years gone by since the start of this change in the paradigm of rehabilitating to enable, we are still working on this objective to approach and improve APA for PSI. Educational-therapeutic measures are essential in any programme in which physiotherapists participate[41], as such PSI will be ergonomically assessed in the sporting practice. The collaboration of other professionals in the field of Adapted Physical Activity and Sport will also be essential throughout this work, based on cross-disciplinary models.

Ferrante[42] reflected on the concept of disability and how sporting practice could transform the vision of the person with the disability. APA in PSI should be conceived as just another activity, standardised within everyday life, and not as a far-off activity that is impossible to achieve, worthy of admiration and contemplation.

Some of the limitations found in the undertaking of this review have been:

- The majority of studies do not explicitly describe the APA that is being performed.
- Some studies include other disabilities aside from SI in the same study group.
- The policies and social interests of people with disabilities are different depending on the country where the study is being carried out.

After this review it can be concluded:

- There must be an on-going promotion of policies that favour the inclusion of APA with the aim of making them more accessible to the entire population with disabilities and/or dependency, in particular to PSI.
- The PSI's choice of sport will depend on external or environmental factors, and in particular internal or personal factors.
- The most indicated benefits of APA are: an increase in HRQL and the improvement of self-esteem and body image of PSI in terms of society.

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Vichy Catalán y sus beneficios para la hidratación en general y en el deporte

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El hombre necesita mantenerse hidratado correctamente en su vida habitual pero donde es imprescindible un adecuado estado de hidratación es en el deporte. Sólo con una correcta hidratación se puede, por una parte, garantizar que no existirán problemas para la salud, y por otra, que el deportista no se expondrá a dos graves circunstancias. La primera, que no sufra enfermedades o lesiones relacionadas con la deshidratación, como agotamiento por calor, golpe de calor o lesiones musculares incluso más allá de los calambres musculares. La segunda, y no menos importante, evitar la disminución del rendimiento deportivo, consecuencia de un déficit hidroelectrolítico.

Las necesidades de hidratación, en relación con la actividad física y deportiva, se presentan en tres situaciones: antes, durante y después del esfuerzo. En cada una de las circunstancias se debe conseguir una correcta hidratación. Preparar el organismo para la actividad, en la primera; proporcionar el agua y electrolitos necesarios, en la segunda; y, reponer las pérdidas provocadas por el esfuerzo, en la última. En cada uno de estos momentos hay que proporcionar el agua y electrolitos que se precisan para asumir sus necesidades y evitar problemas.

Es bien sabido que existen muchos líquidos que el hombre toma en su alimentación: agua y sus diversas modalidades, zumos, leche, refrescos, infusiones, bebidas deportivas, entre otras. Una de las aguas más conocidas es el Vichy Catalán, que ofrece esta empresa en agua carbónica embotellada. Fue el médico Modest Furest quien en 1880 adquirió los manantiales de agua termal del *Puig de les Ànimes* e inició el proceso que conduciría a este producto a ser un referente actual. El compromiso de esta empresa con la hidratación en la salud y en el deporte lo demuestran varios hechos, pero el más notorio es el de la elección de Vichy Catalán y Font d'Or como las aguas de los XXV Juegos Olímpicos, celebrados en Barcelona en 1992.

Vichy Catalán es un agua mineral natural con gas carbónico y con un contenido de sales muy adecuado, especialmente en lo que supone el sodio, y que favorece los procesos digestivos. El papel de una bebida de estas características en el contexto de la actividad física, como puede ser en el ámbito laboral y doméstico, y deportivo, se centra en la hidratación en la alimentación habitual y en la que se realiza antes y después del ejercicio, y es consecuencia de sus propiedades. En primer lugar porque se trata de agua mineral de calidad como lo constata el hecho de sus certificaciones. En segundo lugar, por su contenido de electrolitos (bicarbonatos, sulfatos, cloruros, sodio, potasio y litio). En tercer lugar, por sus propiedades de palatabilidad que la convierten en una bebida muy agradable de tomar y por su digestibilidad por lo que es muy bien tolerada.

Antes de la actividad física es necesario hidratarse convenientemente para poder afrontar el esfuerzo en las mejores condiciones. Vichy Catalán proporciona la cantidad de agua y de electrolitos adecuados para los ejercicios de larga duración. Pero después de la actividad, especialmente si se ha realizado en un ambiente muy caluroso y ha sido de larga duración, es imprescindible reponer las pérdidas hidro-electrolíticas y este agua proporciona estos elementos de una forma muy adecuada. Esto es especialmente importante, si la actividad deportiva se va a repetir en breve, como puede suceder en los deportes por etapas.

En definitiva, un agua como Vichy Catalán es una opción muy útil para la hidratación y el aporte de electrolitos en la dieta habitual de cualquier persona, y de las que realizan actividad físico-deportiva, así como en la hidratación de después de la actividad física.

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MANUAL DE MEDICINA DE MONTAÑA Y DEL MEDIO NATURAL

Por: Enric Subirats Bayego
Edita: Editorial Médica Panamericana
Calle Sauceda 10,5ª planta. 28050 Madrid.
Telf.: 911 317 800 - Fax: 914 570 919
E-mail: info@medicapanamericana.com Web: www.medicapanamericana.com
Madrid 2017. 430 páginas. P.V.P.: 38 euros

En los últimos años se ha experimentado un aumento de las actividades ligadas al disfrute del medio natural. Esta tendencia, no ha sido, en muchas ocasiones, paralela al grado de preparación necesario para minimizar los potenciales riesgos para la salud que conllevan este tipo de actividades. La medicina del medio natural responde a la necesidad de ofrecer atención sanitaria en casos de emergencia en medio hostiles y sin recursos. Esta obra, es un manual práctico que cubre las circunstancias que pueden darse al realizar actividades recreativas en zonas de montaña, desde las medidas preventivas que deben seguir los montañeros, y el material de primeros auxilios necesario, hasta las técnicas que pueden ser de utilidad para los profesionales sanitarios en caso de accidente.

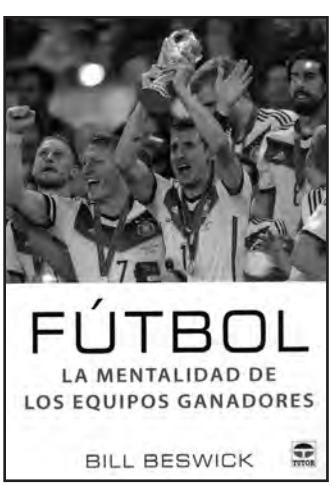
Las novedades que aporta este libro son: a) Actualización de los temas, mediante la metodología de la Medicina Basada en la Evidencia, y una presentación práctica para facilitar la consulta; b) Describe las afecciones específicas relacionadas con el medio natural e incluye pistas que indican la utilidad de la exploración física; c) Especial atención a las lesiones más frecuentes y enfermedades que pueden presentarse en zonas de montaña.

ENTRENAMIENTO PARA MEDIO MARATÓN

Por: Hal Higdon
Edita: Ediciones Tutor-Editorial El Drac
Impresores 20. P.E. Prado del Espino. 28660 Boadilla del Monte. Madrid
Telf.: 915 599 832 - Fax: 915 410 235
E-mail: info@edicionestutor.com Web: www.edicionestutor.com
Madrid 2017. 208 páginas. P.V.P.: 19,95 euros

Este libro contiene todo lo que se debe saber sobre esta prueba, incluyendo dónde empezar, en qué centrarse, cómo establecer el propio ritmo, cómo evitar las lesiones, cómo hacer un seguimiento de los progresos, cómo terminar la carrera y cómo mejorar. Ya sea este para el lector el primer medio maratón… o el 50º, hay un plan para él. Incluye 16 programas personalizables, que van desde principiante hasta avanzado, así como estrategias de probada eficacia, consejos para el día de la prueba y motivación de medio-maratonianos de todo el mundo.

El autor, ha ayudado a innumerables corredores a completar sus objetivos en diversas distancias. Ahora con esta obra ha intentado creado la guía definitiva sobre la distancia más popular hoy en día, el medio maratón.



FÚTBOL. LA MENTALIDAD DE LOS EQUIPOS GANADORES

Por: Bill Beswick
Edita: Ediciones Tutor-Editorial El Drac
Impresores 20. P.E. Prado del Espino. 28660 Boadilla del Monte. Madrid.
Telf: 915 599 832 - Fax: 915 410 235
E-mail: info@edicionestutor.com Web: www.edicionestutor.com
Madrid 2017. 240 páginas. P.V.P.: 19,95 euros

En el fútbol, tal vez más que en ningún otro deporte, el éxito depende más del rendimiento del equipo que del juego individual. Como bien saben los entrenadores, inspirar a un grupo de deportistas para que jueguen como una unidad perfectamente coordinada y mejor avenida es un reto inacabable. Aunque son varios los factores que interfieren en la cohesión y juego fluido de un equipo de fútbol, ningún libro publicado, hasta ahora, ha abordado específicamente el modo de prevenir y solventar tales problemas.

La obra está organizada siguiendo una secuencia en que da a conocer desde dentro los principales retos a los que se enfrentan los entrenadores cuando quieren inculcar en sus equipos una mentalidad ganadora. Se muestran técnicas, herramientas y sugerencias para enfrentarse a los retos habituales y particulares de la temporada. También se presentan ejemplos descritos en contextos específicos como finales y diversos torneos. Además de poner de manifiesto que la mentalidad de equipo es un factor que marca la diferencia entre el éxito y el fracaso, se aportan estrategias probadas por uno de los más prestigiosos psicólogos del rendimiento deportivo en el mundo del fútbol.

VII JORNADAS NACIONALES DE MEDICINA DEL DEPORTE

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24-25 de noviembre de 2017

Zaragoza

Aula Luis Giménez - Pedro Asirón

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SOCIEDAD ESPAÑOLA DE MEDICINA DEL DEPORTE (SEMED)

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- El papel de la prueba de esfuerzo

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- El sodio
- Los carbohidratos

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XXVI International Conference on Sports Rehabilitation and Traumatology: The Future of Football Medicine	13-15 Mayo Barcelona	web: www.isokinetic.com www.footballmedicinestrategies.com
55 Congreso de la Sdad. Española de Rehabilitación y Medicina Física	17-20 Mayo Pamplona	web: www.sermef.es
18th World Congress of the International Association of Physical Education and Sport for Girls and Women (IAPESGW)	17-21 Mayo Miami (EEUU)	web: www.barry.edu/iapesgw
12º Congreso Bienal SETRADE	18-19 Mayo Pontevedra	E-mail: secretaria@setrade.org web: www.setrade.org/congresos/12setrade/
XV Jornadas da Sociedade Portuguesa de Medicina Desportiva	20 Mayo Lisboa (Portugal)	web: www.spmd.pt/
Curso Nacional de Rehabilitación en Deformidades del Raquis	25-26 Mayo Barcelona	web: www.aulavhebron.net/aula/index.php?go=info_cursos&curso=68&idioma=es
XXI Congreso Anual AEMEF	26-27 Mayo Valladolid	E-mail: comunicación@aemef.org web: www.aemef.org
VI Congreso Internacional Actividad Física Adaptada Deporte y Salud	26-28 Mayo Asunción (Paraguay)	E-mail: congresosasociacion@gmail.com
International Multidisciplinary Scientific Congress	26-28 Mayo Craiova (Rumania)	E-mail: firicajean@gmail.com web: http://asociatiadidactica.ro/
ACSM Annual Meeting, World Congress on Exercise is Medicine® and World Congress on The Basic Science of Energy Balance	30 Mayo-3 Junio Denver, Colorado (EE.UU.)	web: www.acsm.org/
Vth World Conference on Science and Soccer (WCSS)	31 Mayo-2 Junio Rennes (Francia)	web: https://wcss-rennes2017.sciencesconf.org/
11th Biennial ISAKOS	4-8 Junio Shanghai (China)	web: www.isakos.com/2017Congress
Movement 2017	9-11 Junio Oxford (Reino Unido)	web: www.movementis.com
5th CSIT World Sports Games	11-18 Junio Riga (Letonia)	web: www.csit.tv/en/world-sports-games
8th Asia-Pacific Conference on Exercise and Sports Science (APCESS 2017)	14-16 Junio Bangkok (Tailandia)	web: http://apcess2017.kasetsart.org/index.php
V Simposium Internacional de Biomecánica y Podología Deportiva	16-17 Junio Málaga	web: www.aepode.org web: simposiumpodologia.com / sepod.es

XXV Congreso Internacional SLAOT	28-30 Junio Buenos Aires (Argentina)	web: www.congreso-slaot.com
XXVIII Jornadas AEMB (Asoc. Esp. Médicos Bcesto)	29 Junio-1 Julio Cádiz	web: http://aemeb.es/cadiz2017/
Congreso Mundial de Fisioterapia (WCPT)	2-4 Julio Cape Town (Rep. Sudáfrica)	web: www.wcpt.org/congress
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22nd annual Congress of the European College of Sport Science	5-8 Julio Ruhr Bochum (Alemania)	E-mail: congress@ecss.de web: www.ecss-congress.eu/2017
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54º Congreso Nacional de la Sociedad Española de Cirugía Ortopédica y Traumatología (SECOT)	27-29 Septiembre Barcelona	web: www.secot.es
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14th International Congress of shoulder and elbow surgery (ICSES)	17-20 Septiembre Buenos Aires (Argentina)	web: www.icses2019.org
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